POSITIVE TECHNOLOGY: DESIGNING E-EXPERIENCES FOR POSITIVE CHANGE

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POSITIVE TECHNOLOGY: DESIGNING E-EXPERIENCES FOR POSITIVE CHANGE

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The potential of virtual reality for mental wellbeing.
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In recent years, there has been a growing interest in the potential role that digital technologies can play in promoting well-being. Smartphones, wearable devices, virtual/augmented reality, social media, and the internet provide a wealth of useful tools and resources to support psychological interventions that facilitate positive emotions, resilience, personal growth, creativity, and social connectedness. Understanding the full extent of this potential, however, requires an interdisciplinary approach that integrates the scientific principles of well-being into the design of e-experiences that foster positive change. This book provides an overview of recent advances and future challenges in Positive Technology, an emergent field within human-computer interaction that seeks to understand how interactive technologies can be used in evidence-based well-being interventions. Its focus of analysis is two-fold: at the theoretical level, Positive Technology aims to develop conceptual frameworks and models for understanding how computers can be effectively used to help individuals achieve greater well-being. At the methodological and applied level, Positive Technology is concerned with the design, development, and validation of digital experiences that promote positive change through pleasure, flow, meaning, competence, and positive relationships.

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Editorial: Positive Technology: Designing E-experiences for Positive Change

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Editorial on the Research Topic

Positive Technology: Designing E-experiences for Positive Change

While there is little doubt that our lives are becoming increasingly digital, whether this change is for the better or for the worse is far from being settled. Rather, over the past years concerns about the personal and social impacts of technologies have been growing, fueled by dystopian Orwellian scenarios that almost on daily basis are generously dispensed by major Western media outlets. According to a recent poll involving some 1,150 experts, 47% of respondents predict that individuals' well-being will be more helped than harmed by digital life in the next decade, while 32% say people's well-being will be more harmed than helped. Only 21% of those surveyed indicated that the impact of technologies on people well-being will be negligible compared to now (Pew Research Center, 2018).

Although many scientific efforts have been devoted to acknowledging the risks of digital technologies, the question of how computers could be used to improve people's well-being has been much less explored. This was the main motivation for the development of a novel research area—Positive Technology—which aims at investigating how ICT-based applications and services can be used to foster positive growth of individuals, groups and institutions (Botella et al., 2012; Riva et al., 2012; Gaggioli et al., 2017). This area resulted from the convergence of two main trends. First, the emerging interest in the scientific understanding of conditions and processes that contribute to people happiness and well-being, chiefly represented by the fast-growing movement of Positive Psychology. The second trend was the increasing recognition, in the field of Human-Computer Interaction, of the central importance that human experience, values, and ethical concerns have in the design, development and use of interactive systems. The integration of these two perspectives has led to new questions and possibilities concerning how digital technologies could help shaping positive human functioning, strengths, personal empowerment at the individual level, and of groups and organizations, from a social/interpersonal point of view (Botella et al., 2012).

In the last 10 years, research in Positive Technology has attracted increasing attention from an interdisciplinary community of scholars, leading to many conference papers, dedicated symposia and workshops, special issues in journals, and edited books. As an emerging area of research, considerable efforts have been spent on developing conceptual pillars and levels of analysis (Villani et al., 2016; Gaggioli et al., 2017), as well as on the definition of frameworks for bringing well-being principles into the design of interactive systems (Calvo and Peters, 2014; Fleming et al., 2016).

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At the methodological and applied level, research on Positive Technology has focused on the design, development, and validation of novel digital experiences that aims at promoting positive change through pleasure, flow, meaning, competence, and positive relationships. These two main facets—theoretical and methodological—of Positive Technology are well reflected by the papers published in this Research Topic, which this editorial aims to briefly summarize.

CONCEPTUAL FRAMEWORKS FOR USING INTERACTIVE TECHNOLOGIES FOR POSITIVE CHANGE

Yaden et al. review the technologies that mental health professionals may use to intervene on and measure well-being, such as predictive algorithms, brain stimulation and virtual reality, and discuss the potential promise and pitfalls of these technologies. While the range of tools that can be used to empower well-being is broad and continues to extend, the authors suggest that safety, effectiveness, and ethical aims are core criteria to be met for the introduction of any technology in people's lives.

Kitson et al. address the important question of how immersive technologies—including virtual, augmented, and mixed realities—can mediate for positive change in users, and which design elements and interaction strategies are best suited to support this process.From this review, these authors provide a set of prescriptive design considerations to serve as tools for designers and developers interested in creating immersive interactive systems and experiences, with the goal of eliciting positive states and supporting positive change.

Filling the gap between existing well-being theories and immediately actionable design practices is a key challenge in Positive Technology. To address this issue, Peters et al. provide a psychological framework grounded in Self-determination Theory (Ryan and Deci, 2017) called Motivation, Engagement & Thriving in User Experience (METUX), which allows HCI researchers and practitioners to design technologies that support psychological well-being and human potential. The model holds that in order to address well-being, psychological needs must be considered within five different spheres of analysis: at the point of technology adoption, during interaction with the interface, as a result of engagement with technology-specific tasks, as part of the technology-supported behavior, and as part of an individual's life overall. These five spheres of experience sit within a sixth, society, which encompasses both direct and collateral effects of technology use as well as non-user experiences.

Diefenbach addresses the question of how psychological knowledge can be translated into technology design, creating synergies between various disciplines. According to Diefenbach, in order to examine this issue, it is important to consider the "bitter-sweet ambivalence of change," including potential relapses and risks of self-threat, so that technology-mediated interventions adapted from (positive) psychology can have a positive impact to full effect.

POSITIVE TECHNOLOGY APPLICATIONS IN MENTAL HEALTH

Positive Technology aims at designing and validating digital well-being interventions that can be effectively used in the prevention and treatment of mental disorders. Enrique et al. describe a pilot randomized clinical trial that evaluated a positive technology application in patients with eating disorders. The experimental application integrated the "Best Possible Self" exercise, a positive psychology intervention that consists in writing and envisioning a future where everything has turned out in the best possible way. The trial involved 54 outpatients who were receiving ongoing specialized treatment in eating disorder services, randomly allocated to either the BPS intervention or to a control condition. Findings showed that both conditions improved over time, but no statistically significant difference was found between the BPS, and control groups.

Villani et al. report results of a controlled study, which tested the efficacy of a 2-weeks e-health Stress Inoculation Training (SIT) intervention on emotion regulation and cancer-related well-being, by comparing it with a control group without such intervention. The experiment involved 29 women with a diagnosis of breast cancer, who had received radical surgery, and who were suitable candidates for adjuvant chemotherapy. Findings showed that patients in the experimental condition did not achieve significant changes related to emotion regulation strategies, but they significantly reduced emotional suppression by 3 months after the end of the intervention. Furthermore, patients in the e-health SIT condition reported a good level of acceptance of the intervention.

Mira et al. describe results of a secondary analysis derived from a randomized controlled trial that tested the efficacy of an internet-based positive psychology intervention designed for patients with depressive symptoms. The intervention consisted of an 8-module Internet-based program, which combined 4 modules based on cognitive-behavioral strategies and 4 modules based on positive-psychology strategies. The clinical study involved 108 patients having minimal, mild, or moderate depressive symptoms. Results showed that patients' negative affect and anxiety decreased significantly during the implementation of the cognitive-behavioral therapy and positive psychology modules. However, depression and positive affect improved only after the introduction of the positive psychology modules.

An interesting development of the use of technology for promoting mental health concerns so-called "serious games," which are games designed to teach knowledge, skills or behavior change. A key challenge in this domain is how to effectively promote therapeutic games to ensure wide adoption and scalability of this strategy. Poppelaars et al. carried out a study comparing two alternatives in promoting mental health games, one including explicit mental health messaging, and the other not mentioning mental health but highlighting the entertainment value. The experiment involved 129 young adults with mild to mental health symptoms. Participants were shown two distinct trailer designs, but they were unaware that both trailers promoted the same commercial video game. Results showed that young adults with mild to severe mental health symptoms were almost four times more likely to select a game when it was explicitly promoted as beneficial for mental health, compared to when it was promoted as entertaining. Brivio et al. review the concept of technostress—that is, the psychological distress associated with the inability to cope with the use of new technologies—and discuss how Positive Technologies could help preventing this issue, by promoting positive work experiences through an effective organizational safety culture.

Emotion regulation—a person's ability to effectively manage and respond to an emotional experience—is a key aspect of psycho-social functioning and well-being. How could digital tools be used to support this process? Colombo et al. address this question in a perspective article, which discusses the potential of integrating technologies such as virtual reality, wearable biosensors, smartphones, and biofeedback for improving understanding, assessment, and intervention of emotion regulation.

POSITIVE TECHNOLOGIES FOR COGNITIVE ENHANCEMENT AND NEUROREHABILITATION

While abundant literature exists regarding the negative psychological implications of videogames, less attention has been dedicated to the potential positive impacts of these technologies on cognitive processes. Milani et al. report results of an experimental study, which investigated the effects of the videogame Tetris in the visuospatial domain both for adolescents and preadolescents, comparing two visualization styles (i.e., 2D vs. 3D). Results showed that playing the Tetris videogame had a positive effect on visuospatial skills—at least in the short term—and that the two visualization formats had a differential influence on these competences.

Interactive technologies such as virtual and augmented reality are increasingly being integrated in treatments aimed at restoring cognitive and motor functions following a neurological damage. In this area, Positive Technology can offer several contributions, e.g., by inspiring the design of ICT-based rehabilitation strategies that support patient's empowerment, engagement and motivation. Perez-Marcos et al. identify four key aspects to consider when designing long-lasting effective treatments for neurorehabilitation: (i) motor-cognitive training; (ii) evidence-based neuroscience principles, in particular those related to body perception; (iii) motivational games; and (iv) empowerment techniques. According to these authors, virtual reality is an effective tool to deliver neurorehabilitation programs because it offers the opportunity to integrate these four assets into a unique training environment. In a similar vein, La Corte et al. describe the significant potential offered by virtual reality to develop applications for the assessment and training of episodic memory in normal and pathological aging, thanks to the possibility of creating personalized and adaptive virtual environments that can simulate naturalistic situations and contexts.

POSITIVE TECHNOLOGY FOR FOSTERING EMPATHY AND PROSOCIAL BEHAVIORS

In the last few years, scientific interest toward the use of advanced simulation technologies, such as virtual, augmented and mixed reality, for promoting prosocial abilities, and behaviors has been increasing. Schoeller et al. discuss the potential of virtual reality, biofeedback, and brain-control interfaces to foster empathic abilities in humans. In particular, they suggest that virtual reality can empower empathy training by allowing users to "embody another self"—i.e., by providing access to sensorial data concerning the body of another person, its immediate context, and peri-personal space. Halton and Cartwright report results of a study, which tested the efficacy of an immersive training intervention to replicate the experience of living with a chronic condition (Inflammatory Bowel Disease). The training intervention, called "In Their Shoes," draws on the biopsychosocial model of illness and consists of constructed narrative that contains individual challenges typically faced by someone living with Inflammatory Bowel Disease. The digital simulation was delivered via a smartphone application. The study involved 155 employees of a pharmaceutical company and consisted in a pre-post intervention assessment without control condition. Findings showed that the immersive training program led to increased understanding of and empathy for the lived experience of patients with Inflammatory Bowel Disease.

Recupero et al. discuss how mixed reality could be used in combination with storytelling to design experiences that promote cross-cultural integration of immigrants. The authors focus on homesickness (i.e., a state of distress associated to being located in a new and unfamiliar environment) and need of cultural integration as two key dimensions of immigrants' experience. They argue that mixed reality may help addressing these challenges by providing new digitally-augmented tools to improve immigrants' intercultural communication with people in the receiving culture. For example, the use of mixed reality could offer new ways of disclosing cultural meanings, practices, memories, and personal representations of the hosting community, reducing immigrants' feeling of distance and isolation from their countries of origin, and integrating digital storytelling as a practice to make meaning and share experiences of places, events, and people of the new culture.

Żuromski et al. investigate the potential of virtual reality technology to foster empathetic, altruistic, and understanding abilities. In particular, they describe embodied experiences and virtual reality technologies as a form of socially-extended mind and in turn as "mental institutions" that may be used as a model to further our understanding of social phenomena.

POSITIVE TECHNOLOGY FOR PROMOTING SELF-TRANSCENDENCE

A recent development of Positive Technology concerns how interactive technologies may be used to promote self-transcendent emotional experiences, that is, out-of-the-ordinary life moments that allow individuals experiencing something greater of themselves, reflecting on deeper dimensions of their existence, shape lasting spiritual beliefs, and enhance feelings of connectedness (Gaggioli, 2016; Kitson et al., 2019).

Two papers investigated how virtual reality can be used to promote and assess awe, a complex emotion with a significant transformative potential. Chirico et al. describe results of a study, which tested the efficacy of virtual environments designed to elicit awe experiences. In this experiment, which involved 36 participants, three virtual environments were designed to induce awe, whereas the fourth was targeted as an emotionally-neutral stimulus. Results showed that virtual environments designed for enhancing perception of vastness and need for accommodation—two key dimensions of awe—induced higher awe and sense of presence compared to the neutral virtual environment. Quesnel and Riecke investigated how virtual reality may elicit awe, and how features of aesthetic beauty/scale, familiarity, and personalization (i.e., self-selection of travel destinations) may elicit this complex emotion. In their study, 16 participants were presented with a virtual environment that allows for the appraisal of the Earth's landscapes, cityscapes, and a view of the planet from Earth's orbit. To test participants' awe intensity, the authors used frequency of goose bumps for each participant using a custom-made "goosecam" as well as self-report questionnaires to collect participants' emotion ratings of the virtual experience; in addition to these quantitative measures, qualitative methods of open-ended interviews and observations of the participants were used. Results of the experiment showed that immersive virtual reality can elicit subjective experiences of awe and physiological goose bumps were observed in several participants. Furthermore, findings revealed that aesthetic beauty/scale and familiarity/personalization of the environment positively influenced awe.

Stepanova et al. provide a design framework to create virtual reality experiences of the "Overview Effect," a profound cognitive shift reported by many space-travelers triggered by the sight of the earth from beyond its atmosphere. Common outcomes of the experience are a feeling of awe for the planet, an enhanced feeling of interconnectedness and a renewed sense of responsibility for taking care of the environment. After reviewing key psychological studies on the Overview Effect and awe, authors propose guidelines for creating virtual reality experiences to elicit this experience and evaluation methods for assessing it.

CONCLUSIONS

The papers published on this Research Topic provide a broad overview of Positive Technology and indicate directions for its future developments. The diversity of frameworks, applications areas, intervention protocols and technological solutions covered by these studies suggest that this emerging field offers exciting new avenues for research and innovation in the domain of digital well-being. Furthermore, the analysis of these contributions allows identifying some key challenges for the future evolution of this area.

First, the variety of conceptual analyses published in this Research Topic confirms the inherently interdisciplinary nature of Positive Technology, emphasizing the plurality of perspectives (i.e., psychological, neuroscientific, technological, design, artistic) that play a role in the design of digital well-being tools. On the one side, the richness of these diverse views offers the unique opportunity to create new synergies between different research communities, with the common goal of improving the relationship between people and technology and human functioning in general.

On the other, renewed efforts are required to create common theoretical and methodological approaches, also in terms of developing interdisciplinary education programs to train core skills and competences to psychologists, designers, and practitioners interested in this topic. Furthermore, as emphasized by Peters et al. achieving a stronger connection between frameworks and actionable design practices is a key research objective.

A further important trend highlighted by the contributions included in this Research Topic is that applications of Positive Technology are growing and wide-ranging, encompassing mental health, neurorehabilitation/cognitive enhancement, multicultural integration, socio-cognitive skills, and education. However, several of these applications are still conceptual and little or no empirical work exists on benefits, thus an important future challenge is to translate these scenarios into testable tools, protocols, and services.

A third and final consideration that can be drawn from the present Research Topic is that more emphasis should be placed on experiences, rather than on technologies, when designing for positive change. In this regard, the definition "Positive Technology" could be misleading, as a technology is neither positive nor negative: its valence is ultimately determined by the experience that a person has when interacting with a digital tool or content, to which extent this experience is meaningful and relevant and can contribute to a positive change for that person. Thus, a future goal for Positive Technology researchers is to better understand which dimensions of digital tools can promote positive change through pleasure, effort, challenges, flow, meaning, competence, endeavor, and positive relationships.

In conclusion, this Research Topic provides an overview about the state of the art of research in technology for mental well-being and offers possible directions to guide the design of future applications and services in this area. Although these contributions have highlighted several tools—such as virtual/augmented reality, biosensors, smartphones, videogames—which can be used for promoting positive change, the range of technologies that can be used for this purpose is steadily growing and potentially extends to robotics, artificial intelligence, and neurotechnologies. In this perspective, we believe that Positive Technology represents not only a scientific, but also a cultural opportunity to promote a more human-centered view on the development of our digital future.

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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The Future of Technology in Positive Psychology: Methodological Advances in the Science of Well-Being

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Advances in biotechnology and information technology are poised to transform well-being research. This article reviews the technologies that we predict will have the most impact on both measurement and intervention in the field of positive psychology over the next decade. These technologies include: psychopharmacology, non-invasive brain stimulation, virtual reality environments, and big-data methods for large-scale multivariate analysis. Some particularly relevant potential costs and benefits to individual and collective well-being are considered for each technology as well as ethical considerations. As these technologies may substantially enhance the capacity of psychologists to intervene on and measure well-being, now is the time to discuss the potential promise and pitfalls of these technologies.

Keywords: positive psychology, psychopharmacology, non-invasive brain stimulation, computational linguistics, virtual reality, technology

INTRODUCTION

In *Homo Deus*, historian Harari (2016) extrapolates from current trends to predict how technology might influence humanity's future. As society continues to succeed in reducing disease, poverty, and violence (e.g., Pinker, 2011, 2018), Harari argues that more resources will likely be devoted to extending the human life span and fostering well-being. In terms of well-being, Harari points specifically to the increasing capacity of technologies to modulate mental states and for algorithms to help guide decision making in ways highly relevant to well-being. According to Harari, these advances in biological and information technology may exert such a substantial influence on the well-being of those who use them that these individuals could have a fundamentally different experience of life. In other words, enhanced individuals may differ from the non-enhanced not only in degree – but also in kind.

We are still far from any such fundamental alterations to human experience, but there are several technologies poised to profoundly influence the scientific study of well-being, even within the next decade. While Harari provides fascinating far-future speculations about psychopharmacology, non-invasive brain stimulation, virtual reality environments, and big-data methods, there is a need to review and discuss *current and emerging* manifestations of these technologies. In this perspective article, we predict that the technologies we review will become commonplace in psychological research on well-being in this decade, yet many well-being researchers are relatively unaware of them or ill-informed about their potential. In this review, we use Harari's work as an inspiration to describe some of these technologies and call for further ethical and safety discourse due to the increased capacity for intervention and measurement that these technologies make possible.

The most well-known umbrella term for the scientific study of well-being is Positive Psychology (Satterfield, 2000; Seligman, 2018). While Seligman's (1998) address to the APA on balancing an overemphasis on psychopathology to include more research on well-being marks an important moment for the field of Positive Psychology, quantitative well-being research (e.g., Diener, 1984) and positive psychology theory (e.g., Maslow, 1964) stretch back decades earlier. In recent years, some progress has been made toward understanding the major contributors to, and other outcomes associated with, well-being. Some reliable factors associated with well-being include; income, physical health, marriage, optimism, and social support (e.g., Diener et al., 2002). Technological advances will likely support, advance, and in some cases provide entirely new tools for well-being measurement and intervention.

In terms of current measurement tools, well-being research typically uses self-report surveys distributed through digital platforms. While this was once a paper-and-pencil process, survey data are now typically gathered through digital surveys hosted on platforms like Qualtrics and Amazon's Mechanical Turk or posted on websites (Buhrmester et al., 2011). Unlike in previous decades, most psychometric scales distributed in contemporary research have been tested for their factor structure, validity, and reliability – and are used only after having demonstrated adequacy across several metrics (Furr, 2011). The most well known scales in positive psychology can be generally divided into affective measures and satisfaction measures. An example of an affective measure is *Positive and Negative Affect Scale* (*PANAS*; Watson et al., 1988) which asks participants to indicate the emotions that they have recently experienced (Watson et al., 1988) and an example of a satisfaction measure is *Satisfaction With Life Scale* (SWLS; Diener et al., 1985) which asks participants to indicate their overall assessment of their life. While other measures of well-being exist, such as measuring facial expressions like Duchenne smiles (Ekman et al., 2013) and some physiological and neurological markers (Davidson and Irwin, 1999), self-report scales distrusted through online survey platforms is the most common measurement strategy among contemporary psychological researchers.

In terms of current well-being interventions, sometimes called "positive interventions" (Rashid, 2009), most consist of psychosocial activities. Like cognitive behavioral therapy (CBT; Beck, 1979), many of these interventions presume that a change in attention, engagement, and beliefs can foster both a change in behavior and emotional experience. One example of a positive intervention is "Three Good Things," in which one keeps track of three good things that happened to them and why (Seligman et al., 2005). Structured well-being-oriented curricula have been developed, including the Penn Resiliency Program, which teaches children psychological skills that have been demonstrated to reduce the incidence of mental health problems (Gillham et al., 2007), Comprehensive Soldier Fitness (Cornum et al., 2011), which is aimed at increasing the resilience of the U.S. armed forces, as well as various positive education initiatives, which aim to increase psychosocial skills, mindfulness, and aspects of character development, have shown success in improving academic performance and well-being in some countries (e.g., Adler, 2017). Positive interventions have generally been demonstrated to be reliably effective yet small in effect size (Seligman et al., 2005; Bolier et al., 2013). Notably, our interest in positive interventions in this article is descriptive rather than prescriptive; we see positive interventions primarily as tools with which to scientifically study well-being.

Measurement and intervention paradigms in well-being research are on the verge of shifting, however, and the current measurement and intervention tools described in the previous two paragraphs will likely look quite different a decade from the time of this writing. These changes are largely due to several technologies that will likely exert a strong influence on positive psychology research in the coming decades. Some have referred to research at the interface of positive psychology and technology, "positive technology" (Calvo and Peters, 2012; Riva et al., 2012; Villani, 2016; Baños et al., 2017; Gaggioli et al., 2017).

In this review, we do not include technologies related to genetic manipulations or so-called 'strong' artificial intelligence (which exhibits general intelligence across domains) because, while, if created, they will be undoubtedly massively influential in well-being research, we believe that their development and effects will be felt most acutely in longer than a decade from the time of this writing (Russell and Norvig, 2016). Similarly, we do not discuss social robotics, the internet of things, or nanotechnology (e.g., Bhushan, 2017) for this reason. On the other hand, we also do not discuss mobile device applications (apps) or wearables (Piwek et al., 2016) because they are already widely used for measurement and intervention, and have been discussed elsewhere (e.g., Kay et al., 2011), nor do we discuss gaming, which has also already been explored for well-being research and interventions (e.g., McGonigal, 2011).

Here, we limit the scope of our focus on emerging technologies that are not yet widespread but which we predict will have a large impact on well-being intervention and measurement within a decade from this writing. In terms of measurement, machine-learning algorithms applied to large data sets ("big data") are becoming viable, allowing for scalable, unobtrusive measurement of well-being and other psychological constructs at the population level. In terms of interventions, non-invasive brain stimulation, psychopharmacology, and virtual reality are improving rapidly and proliferating in research and consumer contexts, allowing for the modulation of mental states in ways relevant to well-being. This article reviews predictive algorithms, psychopharmacology, non-invasive brain stimulation, and virtual reality, in terms of how each pertain to the near future of well-being research.

BIG DATA MACHINE LEARNING PREDICTIVE ALGORITHMS

"Algorithms... will be so good at making decisions for us that it would be madness not to follow their advice"

– Yuval Noah Harari

Predictive algorithms are perhaps most frequently encountered as continuously improving decision and suggestion systems that decode patterns from millions of user interactions—from Google Now alerting us that a flight is delayed the moment we step out of the door to race to the airport, to the movie suggestions on Netflix. These systems have come into our lives in a manner similar to how GPS did – at first most people tend not to entirely trust the device's advice, taking its directions more as suggestions. Eventually, though, most people end up trusting and following its directions without much hesitation. Beyond entertainment, marketing, and minor administrative duties, it may soon become the case that predictive algorithms will provide more general insights that resemble those of coaches – and perhaps even make highly accurate predictions about which life decisions will maximize well-being, even in highly personal domains like work and love, both of which have a tremendous influence on well-being.

Algorithms have some learning advantages over human cognition—when an algorithm detects and learns to avoid a mistake based on a few occurrences, an update will push this algorithmic insight to its entire user base. Once a self-driving car learns a new trick, all cars share in the trick—unlike human drivers, who have been trained individually. Algorithm-informed decisions, in short, are on a different cumulative learning curve than human decisions. The quality of their predictions is likely to diverge further and further from those of human cognition with every additional example that is added to its database to digest. In general, algorithms are different from human decision-making in terms of (1) ease of learning, (2) sensitivity and specificity of decision making (typically measured against objective ground-truth), and (3) generalizability of the learning. Humans tend still to have advantages in (3) but machine/algorithmic approaches may soon surpass humans at (1) and (2).

At present, algorithms have not yet entered the highest-stakes domains in the decision-making processes of most people – they are not even close to making career or marriage decisions. However, the data that feeds predictive algorithms in these domains is being collected from most of the population at unprecedented rates, and with all big data algorithms, the strongest predictor of the quality of a prediction system is the availability of data sets of sufficient quality. Mobile phones, owned now by the majority of the global population, are routinely loaded with tens of sensors that span the detection of motion, light, and environmental conditions, and capture health data, like heart rate and step counts. Beyond these sensors, in our use of digital spaces we leave behavioral residues, or "digital footprints," from sources such as our text message histories, geographic location, and social media posts. With relatively few steps in some cases, these data can be accessed through application programming interfaces (APIs)—well-defined interfaces between algorithms, allowing for the exchange and integration of data into large data ecosystems. In addition, the Quantified Self movement spans many apps and dedicated sensor systems, tracking everything from weight to fluid intake to sleep quality, and pushes the integration of digital quantification forward and into the mainstream (Swan, 2013).

Algorithms can predict various psychological traits of users on the basis of digital footprints with a high degree of accuracy. Kosinski et al. (2013) have shown that "likes" on Facebook can predict sexual orientation, ethnicity, and political orientation – and these algorithm-based personality predictions can exceed in accuracy those made by acquaintances (Youyou et al., 2015). Kosinski and Wang (2017) showed that face-detection algorithms (like those used to unlock smartphones) can distinguish between hetero- and homosexual orientation with 71–81% accuracy, exceeding those of human raters. Beyond these examples using "likes" and images, the vast majority of our digital traces are textual. The linguistic content shared in Facebook posts can be used to predict Big Five personality traits (Park et al., 2015), gender (Park et al., 2016), and the linguistic features used for prediction can reveal interesting features of constructs, such as for religious affiliation (Yaden et al., 2017a). Importantly, a variety of papers have documented the possibility of detecting mental health states from social media (see Guntuku et al., 2017, for a review) as well as physical health issues of communities such as heart disease (Eichstaedt et al., 2015). Across these examples, the predictive power of algorithms often exceeds those of friend ratings or other meaningful baselines currently employed.

So far in psychology, these algorithms primarily constitute an advance in ways to collect data and—using machine learning algorithms-combine distributions of observed features into measurements and estimates. While the accuracy in many of the early studies remains constrained by the self-report scale it is trained on, measurement can proceed at much larger scales unobtrusively. By using machine learning, researchers can train models to associate certain features (i.e., certain words, phrases, or "likes") with scores on a given psychometric scale or task that as been administered to the same users – but and then the model can predict a score based on the features alone, without the need for traditional measurement (Kern et al., 2016). For example, given sufficient language from Facebook posts from users who have also taken a psychometric self-report scale like a life satisfaction measure, the model can then predict a score on the life satisfaction measure based only on the social media language collected from a sample. In other words, while the training of such a prediction model may require costly survey administration in a sample of users for which social media language is also available, such a model can be applied at much larger scale. For example, a life satisfaction model can be trained on samples of about 2,000 Facebook users, and then applied to the geo-located Tweets of tens millions of Twitter users to generate estimates of average life satisfaction levels across entire geographic regions. As a proof of concept, using this approach, the World Well-Being Project at the University of Pennsylvania has created a map of the well-being of U.S. counties in the United States (see **Figure 1**[1]; see also Schwartz et al., 2013).

In the near future, this increased capability for psychological measurement of individuals and populations will begin to inform and tailor interventions. When algorithms ingesting text messages and social media messages are able to detect, for example, depression relapse or the onset of manic episodes, therapeutic interventions may be initiated immediately. This linguistic approach will likely be combined with other big data streams from genomic and neural network research (e.g., Baker et al., 2014) to increase the accuracy of risk profiles to improve early intervention and may help to guide decisions about which interventions to utilize in a given instance. Health coaching algorithms will be able to give tailored advice on how to increase one's well-being (e.g., apps might send messages to users like: "sleep more!" "Your correspondence with Alice increases your stress levels!" "Bob calms you down and lifts your mood"). And finally, at the community level, the fine-grained measurement of the psychological health of populations may mean that a number of different policy interventions can be tested in different communities, and the one shown to be most efficacious rolled out on a larger scale—pushing the idea of *evidence-based policy* into the age of big data.

Thus, this technological advance in measurement and algorithm-derived models is progressively identifying possible opportunities for targeted and measurable intervention. We now consider three technologies as candidates to advance the frontier of well-being interventions.

[1] map.wwbp.org

PSYCHOPHARMACOLOGY

". . . in order to raise global happiness levels we need to manipulate human biochemistry."

– Yuval Noah Harari

Psychopharmacology is already commonplace in US society and medications for mental disorders are among the most prevalent prescriptions (Kantor et al., 2015). Some research shows that about 70% of Americans are on at least one prescription drug (Zhong et al., 2013) and at least 10% use a psychopharmaceutical (Paulose-Ram et al., 2007). That is to say, psychopharmacology is already quite common in contemporary culture. Because of this proliferation, psychopharmaceutical research is a well-funded and technologically sophisticated domain of modern research. Most of this research has been devoted to treating physical and mental illness, but, increasingly, people are taking medications for less serious mental disorders, which in some cases may come closer to a lifestyle choice than a treatment for a mental disorder. Little is known about the effects of most common pharmaceuticals on well-being, including whether or not there are detrimental side-effects or benefits to well-being.

At some points in US history, taking prescription pharmaceuticals for well-being was popular. Milltown (Meprobamate), for example, was a substance marketed for its capacity to increase happiness. It was found, however, that the substance is addictive and approval for its prescription was withdrawn (Pieters and Snelders, 2009). Psychopharmacology is a well-resourced research field out of which advances in mental health treatment can be expected, and, likely, advances in enhancement. However, the questions of addiction looms

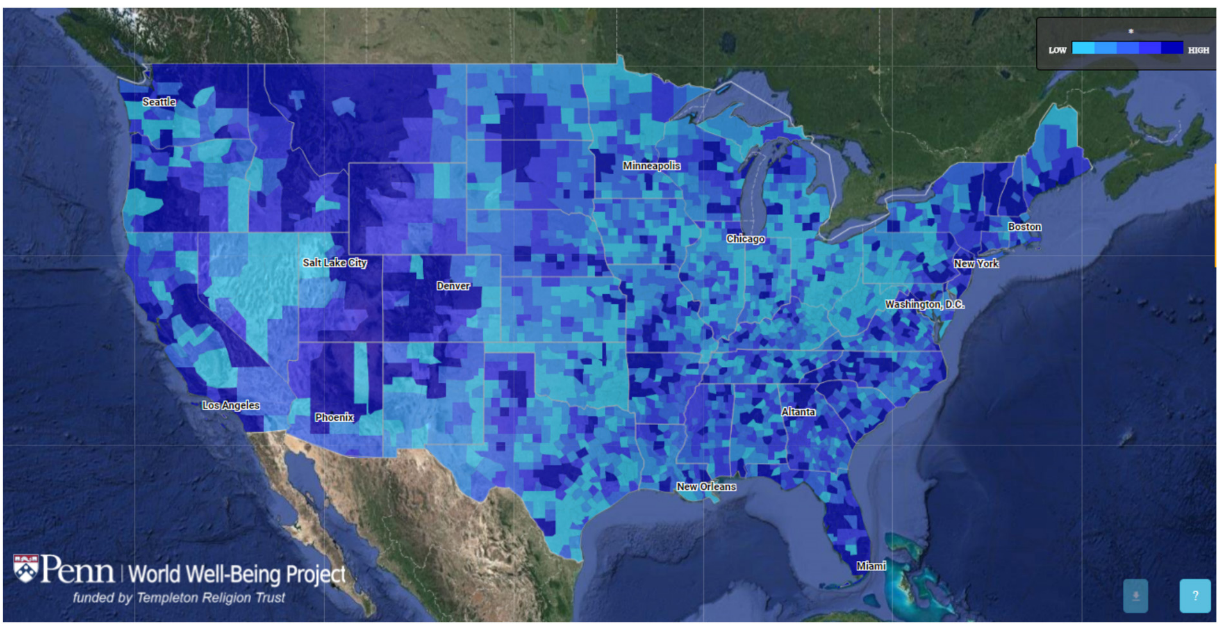

FIGURE 1 | County-level well-being map of U.S. counties generated using a big data analysis of geo-located Tweets (adapted from footnote 1). The low-high dimension represents county level scores of well-being.

large in this area, and it may be the case that, in general, long-term chronic use of many psychopharmaceuticals tends to diminish well-being. Future research in this area will need to play close attention to the difference between addictive "highs" and non-addictive enhancements to overall well-being.

It may also be the case that enhanced well-being is a hitherto understudied mediator of the therapeutic effects of some medications for mental disorders. The most common medications for mental disorders include medications for depression: selective serotonin reuptake inhibitors (SSRIs) and selective serotonin norepinephrine reuptake inhibitors (SSNRIs); anxiety: Benzodiazepines (e.g., Alprazolam and Clonazepam); pain: cyclooxygenase-2 (COX-2) inhibitors and opioids; attention: amphetamine, dextroamphetamine, and methylphenidate. Pain medications have played a central role in an epidemic of opioid addiction (Nelson et al., 2015). Attention deficit medication has been used as an enhancing substance by many college students and has been shown to increase motivation to study though there are health risks to this practice (Smith and Farah, 2011). The question of psychopharmaceuticals for enhancement is a relevant topic in the field of bioethics, and, more specifically, neuroethics (Farah et al., 2004). Again, the relationship between these widely prescribed psychopharmaceuticals and well-being (potential benefits and detriments) is largely unknown.

Chronic versus acute use of psychoactive substances may be an important distinction in terms of well-being outcomes. Several substances currently undergoing clinical trials have demonstrated well-being effects from administrations in single sessions. The first of these is the single session use of Ketamine for the treatment of depression (Murrough et al., 2013), which tends to result in an enhanced sense of well-being (Dillon et al., 2003). MDMA, sometimes referred to as an "empathogen" due to its tendency to increase positive emotions and feelings of warmth toward other people, is currently being tested for its efficacy in treating PTSD (Oehen et al., 2013). MDMA is also reportedly associated with enhanced feelings of well-being (Liechti et al., 2000). Lastly, psilocybin is being tested for its capacity to reduce symptoms of depression and anxiety (Ross et al., 2016). Psilocybin has also been associated with marked increases in aspects of well-being in clinical trials (Griffiths et al., 2006) and correlational studies (Yaden et al., 2016). These substances raise the potential for episodic interventions to treat mental disorders and/or increase well-being. Similar to the self-quantification movement, in the United States there exists a vibrant "biohacking" community that is actively exploring the use of small or below-threshold doses of psychopharmaceuticals to improve daily well-being, attention and creativity (for a discussion, see d'Angelo et al., 2017).

The use of psychopharmaceuticals for enhancement and well-being beyond psychopathology remains relatively uncharted terrain about which further ethical discourse and research is required. This includes research into the potential well-being benefits and detriments of recreational uses of psychoactive substances, which has been rarely explored despite the legality and widespread normative use of various substances (e.g., alcohol, marijuana). With modern efforts to develop "designer drugs" that maximize the effectiveness of psychopharmacology to treat specific problems within specific persons (Belmaker et al., 2012; Oquendo et al., 2014), it is also critical to evaluate under what circumstances these approaches can enhance or diminish well-being.

NON-INVASIVE BRAIN STIMULATION

"In research labs experts are already working on more sophisticated ways of manipulating human biochemistry, such as sending electrical stimuli to appropriate spots in the brain. . ."

– Yuval Noah Harari

Whereas psychopharmacology generally influences many synapses distributed throughout the brain, brain stimulation offers the ability to be more spatially precise. Directly modulating the brain has long been a topic of science fiction, but is now a scientific reality. In *Do Androids Dream of Electric Sheep* (Dick, 1996), Philip K. Dick describes a device called a "Penfield Mood Organ." This device allows its users to dial up whatever mood or mental state that they desire. It is named for Wilder Penfield, the neuroscientist who demonstrated that running low amplitude electrical current through regions of a patient's brain during surgery could produce certain reliable effects on one's subjective experience and bodily functions (Penfield and Boldrey, 1937). By stimulating the motor strip, for example, Penfield could move the patient's arms or legs; by stimulating temporal lobe he could produce vivid recall of memories. Since the 1980s, brain stimulation technology has been moving Penfield's pioneering findings closer to the fictional mood-modulating device.

There are several widely used forms of brain stimulation technology, some invasive and some non-invasive. Invasive forms of brain stimulation include deep brain stimulation (DBS; Perlmutter and Mink, 2006) and electroconvulsive therapy (ECT). DBS involves surgically implanting a lead into brain tissue, which can then be activated. DBS has shown breakthrough success in treating Parkinson's (Moreau et al., 2008) and is being tested as a depression treatment (Mayberg et al., 2005). ECT involves introducing a stronger electrical current that is capable of generating a seizure in patients. It is a widely misunderstood treatment in that many laypeople have a negative impression of it despite its considerable effectiveness in treating major depression (Sackeim, 2017). ECT will remain a standard of care and DBS will likely be shown to demonstrate further efficacy in mental and physical illnesses, but the application of these technologies in well-being research will likely remain limited due to the medical risks involved with these procedures. Closed-loom stimulation may be the most near-term candidate for major advances in invasive brain stimulation (Klein et al., 2016). Furthermore, while Elon Musk's neuroscience start-up Neuralink may use

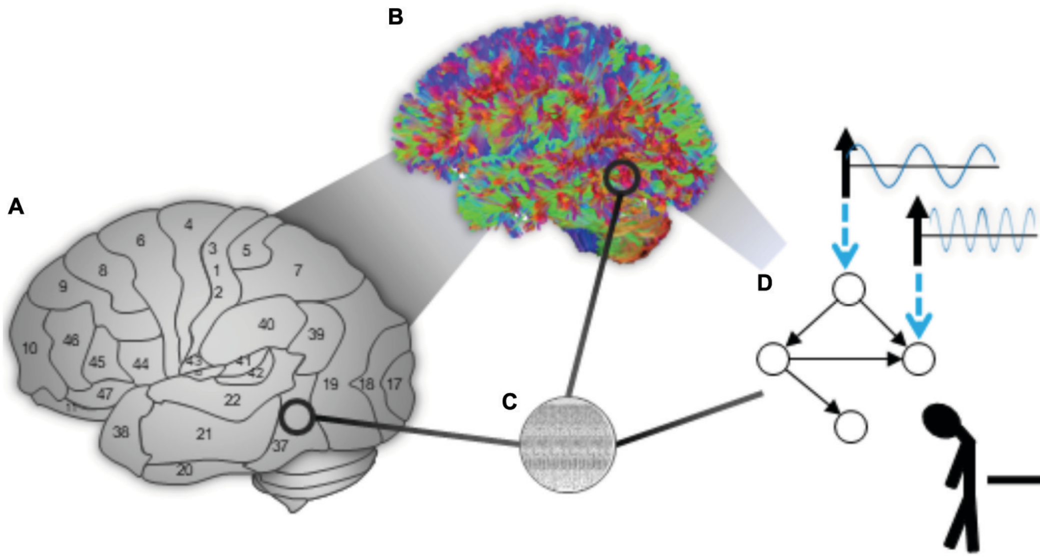

FIGURE 2 | (A) The brain includes major neural subdivisions that serve distinct roles in computation, here represented by labeling Brodmann (1909). **(B)** Techniques such as diffusion weighted imaging can provide information about the major connections among brain regions (the "connectome"). **(C)** Low level neural organization supports information processing and is embedded within the macro-scale connectome. **(D)** The brain can be represented by networks at multiple scales that can putatively be guided using control input targeted to specific neurons, regions, and circuits to promote states of better wellbeing. Figure and caption adapted with permission from Medaglia et al. (2017).

minimally invasive means in order to create sophisticated brain–computer interfaces (BCI), this possibility may be more than a decade away from immediate relevance to most psychological researchers.

Non-invasive forms of brain stimulation are the kinds of brain stimulation technology that are already beginning to exert an influence in the field of well-being research. Historically, bio- and neurofeedback – the use of operant conditioning in combination with physiological measurement – have shown some efficacy, which is now being enhanced by more precise forms of measurement (Watanabe et al., 2017). Transcranial magnetic stimulation (TMS) involves passing magnetic pulses through the skull and into the cortex, which can then hypo- or hyper-polarize neurons, thereby allowing for some control over the activation or inhibition of particular cortical regions (Hallett, 2000). Transcranial direct current stimulation (tDCS), another form of non-invasive brain stimulation, works by passing a low voltage current between anodal and cathodal electrodes on the scalp, allowing the brain tissue between the electrodes to complete the circuit between them (Fregni and Pascual-Leone, 2007). This electrical charge can raise or lower the action potential threshold in the neurons across particular cortical regions, making them more or less likely to fire, thus altering brain activity across a brain region. TMS and tDCS have both been demonstrated to successfully modulate a number of mental processes, including creativity, morality, learning, attention, and depression (Hamilton et al., 2011).

Most psychological research on TMS has been focused on its application as a depression treatment, for which it has been found effective (O'Reardon et al., 2007), and its application to boosting well-being is only just beginning. Future brain stimulation studies on well-being will build on findings from neuroimaging and optogenetic research. For example, several "hedonic hotspots" have been identified that brain stimulation researchers might target to enhance well-being (Smith et al., 2010). These regions relate to well-being in different ways. For example, "liking" and "wanting" circuits have been differentiated from one another (Kringelbach and Berridge, 2009, 2017).

In addition to identifying specific targets to influence well-being, brain stimulation is being combined with modern approaches from complex systems to seek personalized approaches to brain stimulation. For example, approaches from modern "connectomics" are identifying ways to control brain dynamics in complex networks (Muldoon et al., 2016). More broadly, control theoretic approaches applied to neuromodulation might lead to energy efficient, adaptable technology that can more precisely guide dynamics to desired neural and cognitive states (see **Figure 2**; Medaglia et al., 2017).

VIRTUAL REALITY

> *". . . it should therefore be theoretically feasible to simulate an entire virtual world that I could not possibly distinguish from the 'real' world."*
>
> – Yuval Noah Harari

Virtual reality (VR) involves hardware and software capable of generating realistic sensory simulations (Parsons et al., 2017). While using VR, people experience differing degrees of presence, or the feeling of really being 'there' in both mind and body (Riva et al., 2007). During these immersive VR experiences, it is common for virtual stimuli to elicit reflexive responses beyond that which can typically be elicited using 2-D screens and can even evoke responses similar to those produced by equivalent situations in real life (Meehan et al., 2002).

Virtual reality is likely on the verge of becoming a ubiquitous consumer device in economically developed nations. This is primarily due to its capacity to enhance the experience of communication by bringing in a more embodied component, combined with the increasing quality and lowering cost of the necessary hardware. With VR, users can inhabit the same virtual space as their communication partner(s), making the experience more like a face-to-face conversation than current social media platforms allow. The popular social media company Facebook bought one of the most advanced consumer VR companies, Oculus Rift, providing research and development funding to make the widespread use of VR more likely. VR may become a common form of digital interaction, but the effects of spending substantial periods of time in virtual environments for communication or recreation remains unknown, particularly in terms of well-being. Here again, the distinction between addiction, other detrimental effects, and/or benefits to well-being will need to be carefully disambiguated through research.

Positive emotions and other experiences related to well-being can be induced in VR environments. That is, transient VR environments can effectively simulate various specific scenarios, often occasioning visceral subjective responses in users, even in highly controlled laboratory settings. A variety of more general health-related VR applications are currently available (Baños et al., 2013; Freeman et al., 2017) and have been for some time (Riva, 2005; Gregg and Tarrier, 2007). VR is a particularly ideal tool to further create feelings of awe, because most awe stimuli (such as the view from the top of a mountain) are difficult to create in laboratory settings, but are relatively easy to simulate using VR (Chirico et al., 2016). Preliminary studies have indeed found that VR can indeed effectively induce awe in laboratory settings (Chirico et al., 2017). We note that VR is not only a useful well-being research tool for intervention, but also for measurement, as newer equipment will be capable of tracking eye movements and scanning facial expressions. Additionally, physiological measurements can be easily taken in VR laboratory settings and behavior in the virtual environment can be recorded.

Virtual reality technology may have the capacity to democratize certain positive experiences. For example, a hospitalized or otherwise housebound individual could put on a VR headset and walk the streets of Paris, climb Mount Everest, or orbit the planet Earth. Research using VR as a tool for inducing certain emotional states, perceptual illusions, and standardized social interactions will likely become quite common in laboratory contexts. VR can help us understand the specific manipulations that influence well-being with unprecedented control and possibilities. Additionally, the large-scale experiment of VR-mediated communication in social media platforms will become an important topic of well-being research. The well-being of VR users will likely be impacted both by how long they spend in VR and the kinds of experiences they engage in while in virtual contexts.

ETHICAL CONSIDERATIONS

> *"Through trial and error we are learning how to engineer mental states, but we seldom comprehend the full implications of such manipulations."*
>
> – Yuval Noah Harari

The opportunities for well-being measurement and intervention research raised by the emerging technologies reviewed above also raise a number of risks and ethical concerns. These technologies open avenues to an increased degree of control over human experience, both in terms of modifying mental states and traits. This possibility raises concerns about changing personal identity and autonomy as well as issues related to the equitable distribution of technology – issues that are discussed in more detail below. We lack the space to cover the unique issues with each technology, but will make some general observations about issues specifically related to enhancing well-being. As always, safety is paramount, as are protections around informed consent (Iwry et al., 2017). People participants should understand the kind of experience that they are embarking upon in every given instance of enhancement – the risks and the potential benefits. We recommend that research ethics guidelines be developed for each of the technologies reviewed in this article, signed by members of the relevant professional communities (e.g., Madary and Metzinger, 2016).

One perspective on this increased capacity to manipulate human experience has been called 'Mind Control' (Medaglia et al., 2017). Neural manipulations combined with modern systems engineering could eventually produce very specific control over mental experience and behavior. While many uses of brain stimulation are in some ways analogous to "nudges" (Thaler and Sunstein, 2008) – altruistic efforts to minimally but effortfully influence individuals to make better choices – it is in principle possible to evoke more potent and specific control over an individual. In the most optimistic cases, we could greatly improve our capacity to enhance well-being in persons. However, the opposite ability to do great harm may also prove possible. Thus, if these techniques become available, we must rigorously evaluate uses of technologies in terms of safety, beneficence, respect for persons, justice, and preservation of human autonomy (Shamoo and Resnik, 2009).

Regardless of the mechanism and potency of an intervention, the possibility of enhancing traits raises the question of which traits might be targeted. A number of traits are highly valued by society, such as intelligence and self-regulation, for the aim of professional and financial success. Some traits have been shown to be highly associated with well-being. The traits related to professional success and well-being form a partially overlapping set. People could be enhanced to have their thresholds for experiencing positive emotions and negative emotions independently adjusted, for example, to alter their overall ratio of emotional experiences (Fredrickson, 2013). These kinds of adjustments, it should be noted, carry the danger of de-coupling one from their assessments of life circumstances. In some cases, one may become more in touch with reality (if they tend to be overly pessimistic) whereas in other cases, there may be a trade-off between realism and well-being, which most people would likely not prefer (see Lavazza, 2016). Specifically, most people desire to have the most accurate possible view of themselves and the world, even at the expense of well-being, as described by Nozick (1974) in his experience machine thought experiment. Therefore, well-being enhancements should also consider and potentially aim to enhance both accuracy and the capacity to pursue one's goals in the world. Certain personality traits have been associated with well-being, and recent research has shown that personality traits, while usually stable, are changeable (e.g., from a course of CBT; Roberts et al., 2017). Could these interventions change our very identities? If so, how can this possibility be adequately communicated in a robust informed consent process?

In regard to well-being and achievement in particular, one should be concerned with equitable distribution. There are, of course, many resources that are not distributed equitably (e.g., education, healthcare, and the "digital divide" between the haves and have-nots of digital technologies), which is also the case with psychology. ECT, for example, while one of the most effective severe depression treatments, is less available in low SES areas (Sackeim, 2017). More generally, novel technologies developed at great cost are usually more accessible to the affluent. Even if equitable distribution does eventually occur, as it is unlikely to in the early stages of technological development, an enhanced class could emerge that would amplify existing class differences along socio-economic lines. We suggest that researchers and policymakers should not treat technologies for enhancing well-being differently than other resources known to enhance well-being, such as access to educational, vocational, and recreational opportunities. If the approaches to enhancing well-being described above are validated, safe, and become widely available, the principle of equity would dictate that efforts should be made for such interventions to be equitably available to all persons under reasonable safety guidelines.

In addition to trait enhancements, these technologies will increase access to certain kinds of mental states, or experiences. Various intensely altered and meaningful states of consciousness may be amenable to manipulation using these emerging technologies. To illustrate with one kind of mental state that has been shown to be highly associated with well-being, self-transcendent experiences (STEs) are associated with increased connectedness and decreased self-salience (Yaden et al., 2017b). A number of mental states described in common psychological constructs contain a self-transcendent aspect (though they are otherwise more dissimilar than alike), including: flow (Csikszentmihalyi, 1996), mindfulness (Davidson and Kabat-Zinn, 2004), awe (Keltner and Haidt, 2003), and mystical experiences (Hood et al., 2001). There is variability in our culture in terms of who has had these experiences and who has the time and resources to seek them out. Several studies have shown that about 30% of the population completely agrees that they have felt at one with all things (Hood et al., 2009). Some of these experiences are counted among life's most meaningful moments and psychopharmacology and non-invasive brain stimulation may make these experiences increasingly available. This possibility raises a host of ethical concerns, especially in cases where direct technological causation is incompatible with one's metaphysical commitments and given the possibility that easy access to such experiences might diminish their value or positive effects. Such mental states, which impact well-being as well as identity and interact strongly with belief and value systems, will likely be amenable to manipulation by emerging technologies, so ethical discussion regarding this possibility is warranted and needed. Describing a vision that seems equal parts inspirational and worrying, Harari writes:

> *In the future, however, powerful drugs, genetic engineering, electronic helmets and direct brain-computer interfaces may open passages to these places. Just as Columbus and Magellan sailed beyond the horizon to explore new islands and unknown continents, so we may one day embark for the antipodes of the mind.*

In the case of measurement issues and the increasing power of algorithms, it should be acknowledged that business ecosystems exist to generate economic value from these datasets. Many companies already collect, integrate, and trade such data as a core part of their business model, and micro-targeted advertisement on the basis of such data sets was at work in the last few US elections (Grassegger and Krogerus, 2017) with unclear effect. The need for ethical discourse and education about these existing technologically driven changes to social processes is urgently necessary. Furthermore, well-being research more generally could be leveraged by business ecosystems: if well-being is an in-demand product of some technologies, these technologies are likely to become commercialized and subject to general market principles. This is already the case for numerous non-invasive brain stimulation technologies well in advance of scientific consensus about the efficacy (or lack thereof) of these products. While there may not currently be a regulatory gap for these early technologies (Wexler, 2016), new developments should be closely monitored to ensure that business practices conform to federal guidelines, and consumers should be educated about the evidential basis for specific technologies. Researchers as well as the public ought to be vigilant against false claims in the media or even in popular fiction (Wurzman et al., 2017) regarding the efficacy of well-being enhancement. Consideration of the concerns and risks raised in this section such as consent, safety, beneficence, respect for persons, justice, autonomy, and equitable distribution, as well as other ethical considerations that we cannot yet anticipate is imperative. We also note, however, that failing to take the potential utilities of such technologies into account raises a set of ethical concerns (e.g., Danaher et al., 2018).

CONCLUSION

New technologies capable of enhancing measurement and intervention will likely have a sizable impact on the science of well-being. To reiterate, we are not advocating for the increased utilization of technology for the purpose of enhancing well-being, nor are we implying the naïve view that a positive correlation between technology use and well-being exists. In fact, it may well be the case that well-being research finds that in many cases less frequent use of certain technologies increases well-being, as has been found in the area of some kinds of social media use, for example (Seabrook et al., 2016). A careful empirical evaluation of each intervention is warranted in terms of its capacity to increase or decrease well-being – an effort that requires larger and richer datasets than have been available to field. The extent to which biotechnology and information technologies achieve safety, effectiveness, and, especially, ethical aims, must form the core criteria for the introduction of any technology into our lives for the purpose of increasing well-being.

AUTHOR CONTRIBUTIONS

DY conceived of and wrote the manuscript. JM and JE contributed writing, figures, and edits.

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Designing for Motivation, Engagement and Wellbeing in Digital Experience

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Research in psychology has shown that both motivation and wellbeing are contingent on the satisfaction of certain psychological needs. Yet, despite a long-standing pursuit in human-computer interaction (HCI) for design strategies that foster sustained engagement, behavior change and wellbeing, the basic psychological needs shown to mediate these outcomes are rarely taken into account. This is possibly due to the lack of a clear model to explain these needs in the context of HCI. Herein we introduce such a model: Motivation, Engagement and Thriving in User Experience (METUX). The model provides a framework grounded in psychological research that can allow HCI researchers and practitioners to form actionable insights with respect to how technology designs support or undermine basic psychological needs, thereby increasing motivation and engagement, and ultimately, improving user wellbeing. We propose that in order to address wellbeing, psychological needs must be considered within five different spheres of analysis including: at the point of technology *adoption*, during interaction with the *interface*, as a result of engagement with technology-specific *tasks*, as part of the technology-supported *behavior*, and as part of an individual's *life* overall. These five spheres of experience sit within a sixth, *society*, which encompasses both direct and collateral effects of technology use as well as *non*-user experiences. We build this model based on existing evidence for basic psychological need satisfaction, including evidence within the context of the workplace, computer games, and health. We extend and hone these ideas to provide practical advice for designers along with real world examples of how to apply the model to design practice.

Keywords: HCI, user experience, wellbeing, self-determination theory, design, motivation, engagement

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INTRODUCTION

The Impact of Technologies on Psychological Wellbeing

Every technology can deliberately or inadvertently impact psychological wellbeing. As a simple example, consider the nuanced impacts emerging from the instant connectivity made possible by smartphones. Kushlev and Dunn (2015) demonstrated that the number of times a day people could check email increased stress levels, while other studies show that the mere presence of a mobile phone diminishes the quality of face-to-face interaction (Przybylski and Weinstein, 2013; Misra et al., 2016).

Beyond these unintended effects, technologies can also be consciously designed to enhance or regulate people's emotions (Norman, 2005) and over the last 15 years interaction designers have shifted their focus from mere usability to also making products enjoyable and engaging, generally with the goal of increasing usage. However, factors such as engagement and enjoyment do not necessarily contribute to sustainable wellbeing. Indeed, as studies in video games (Rigby and Ryan, 2011) and media consumption (Hefner and Vorderer, 2017) confirm, too much engagement can crowd-out healthy activities to the detriment of overall wellbeing. Thus a larger question remains: How can technology be designed to support wellbeing that encompasses more than just immediate hedonic experience, but also its longer-term *eudaimonia*, or true flourishing? (Ryan and Deci, 2001, 2017; Sirgy, 2012).

Design for Wellbeing in HCI

A desire to design for deeper meaning, happiness, and human flourishing has gained momentum in HCI over the past 5 years, and both researchers and practitioners have struggled to bridge this new impetus to clear actionable practice.

Among the contributions to this area is work on Positive Technologies (Riva et al., 2012), Experience Design (Hassenzahl, 2010), Positive Design (Desmet and Pohlmeyer, 2013), and Positive Computing (Calvo and Peters, 2014). At the broadest level, Positive Technologies takes from positive psychology and argues for the benefits of using technology to influence the (1) affective quality, (2) engagement/actualization, and (3) connectedness of experience. Examples of positive technologies have generally been virtual reality environments and other forms of software design as interventions for mental health and wellbeing. Positive Design on the other hand has focused on how the design of any artifact, built environment or service might foster flourishing. Desmet and Pohlmeyer's framework for wellbeing requires that a product be designed for virtue, pleasure and/or meaning, where none of these components interferes with the others (Desmet and Pohlmeyer, 2013). Hassenzhal has proposed an experience-focused approach centered on "fulfilling psychological needs" (including autonomy, popularity, stimulation and others) as a method for inscribing meaning and happiness into products (Hassenzahl, 2010). He proposes doing so by uncovering "experience patterns" in human activities that distil the essence of certain need-fulfilling practices. Finally, as part of Positive Computing, Calvo and Peters (2014) have focused on wellbeing-supportive design for all technology by targeting wellbeing determinants (i.e., self-awareness, compassion, gratitude, motivation, etc.) and by leveraging the research and measures for these constructs for design and evaluation.

The four approaches described above (Riva et al., Desmet and Pohlmeyer, Hassenzhal, and Calvo and Peters) provide pathways to inspiring design based on psychological factors shown to contribute to wellbeing. In addition, other combined editorial works such as (Calvo et al., 2016; Villani et al., 2016) help bring together frameworks and empirical evidence helpful to advancing the field.

However, there remains a substantial gap between existing frameworks and immediately actionable design practices. For example, a library of validated "experience patterns" as Hassenzhal's work points to, has yet to be developed. Clear design features relating to wellbeing determinants, pleasures, virtues or meaning (as Positive Computing and Positive Design recommend) have yet to be identified. Most importantly, perhaps, in light of urgent concerns with technology addiction, none of the frameworks provides help or guidance on how design can disentangle engaging experiences that are *healthy* from engaging experiences that are *addictive*. In other words, the design community has made important headway in shaping what we believe to be the next era in human-centered technologies, but more bridge-building is necessary before the practice of wellbeing-supportive design can be robustly deployed across the industry.

The field requires a model based on methodologically sound approaches that can support hypotheses which can be tested experimentally. This model, and the studies it would support, would allow for experience patterns to be developed, design strategies to be identified and unhealthy positive experiences to be differentiated from healthy ones. In this paper we propose a candidate for such a model of wellbeing-supportive design along with practical methods for working with that model.

The Three Keys to Engagement, Motivation and Wellbeing

The core elements in our solution to designing for wellbeing leverage *Self-Determination Theory* (SDT; Ryan and Deci, 2000b, 2017) which provides a mature and empirically-validated approach to examining factors that promote sustained motivation and wellbeing. Although a nuanced theory, in its broadest strokes, SDT identifies a small set of basic psychological needs deemed *essential* to people's self-motivation and psychological wellbeing (Ryan et al., 2013), and whose neglect or frustration is associated with ill-being and distress. These basic needs are:

- **Autonomy** (feeling agency, acting in accordance with one's goals and values),
- **Competence** (feeling able and effective),
- **Relatedness** (feeling connected to others, a sense of belonging).

These three factors are a sort of minimum common denominator, which come with the widest research evidence available (see Ryan and Deci, 2017 for a review) to explain causal relationships between independent variables (design features) and dependent variables (wellbeing, motivation and engagement measures).

This differs from the approach taken by other authors. For example, Hassenzhal and colleagues incorporate "popularity" as a psychological need (Hassenzahl et al., 2010) however, we argue that popularity is sometimes a desired *outcome* mediated by the basic psychological needs for relatedness and competence and not a universal core need in and of itself. Likewise, the wellbeing determinant, "compassion" which we've elaborated on in previous work (Peters and Calvo, 2014), is also a wellbeing-supportive *outcome* which is itself mediated by the three basic needs (largely relatedness, but also autonomy and competence which differentiate compassion from empathic distress (Peters and Calvo, 2014).

We are certainly not suggesting there is no value in using constructs such as popularity or compassion to inform design. Nor are we attempting to reduce the totality of human psychological experience to three constructs. We are simply highlighting that these three are the most rigorously shown to be essential and predictive of wellbeing and other desired HCI outcomes, and therefore most critically important to assess within HCI contexts. Specifically, SDT defines the term "basic psychological need" very strictly as those satisfactions that:

- are inherently rewarding/motivational.
- when satisfied lead to flourishing.
- when frustrated lead to negative experience.
- function across diverse cultures and developmental stages.

At first blush this may seem like a lot to attribute to three constructs, but a more thorough exploration of them reveals a depth and clear link to more commonly articulated concepts like meaning or happiness. More importantly, this claim is based, not on opinion, but on four decades of empirical research systematically demonstrating these specific three factors to be the most predictive and reliable mediators of motivation, engagement and wellbeing. A survey of the literature is out of scope for this paper, but Ryan and Deci (2017) and Vansteenkiste and Ryan (2013) provide comprehensive reviews.

In addition, several meta-analyses aggregate the results of multiple studies to provide robust evidence for these needs within various domains. For example, Ng et al. (2012) aggregated data from 184 studies exploring SDT constructs for behavior change in health. A meta-analysis by Hagger and Chatzisarantis (2009) combined the results of 34 studies of the Theory of Planned Behavior (TPB) and SDT and provide cumulative empirical evidence of how SDT predicts intentions and behavior in the TPB. A meta-analysis by Chatzisarantis et al. (2003) used 21 studies to explain motivation and SDT constructs in the context of exercise, sport, and physical education. Gagné and Deci (2005) analyzed the literature on how SDT explains the interaction of intrinsic and extrinsic motivation in the workplace.

It is also important that the basic needs defined by SDT are: measurable, intrinsically rewarding, and always safe targets for design because there is no point at which you "overfill" on them (as opposed to, for example, stimulation as posited by Hassenzahl et al., 2010). For example, with regard to autonomy, people cannot have too much volition—feel "too willing" to act (they want to feel as autonomous as possible). People cannot feel *too* competent (yes, one can be bored, but not too effective as in "I wish I were less competent at this"). Finally, one cannot feel too much relatedness—even if one can get too much meaningless or unwanted social stimulation. Understanding these basic needs is important for design because it represents a path in which experiences of inherent import to users can be addressed and without great risk of overdoing it.

Basic Psychological Needs as Effective Proxies for Wellbeing-Supportive Design

There are many constructs that describe the positive elements of human psychological experience (serendipity, fun, praise, gratitude, etc.) and any of these can be very useful to design for ideation and insight. However, by distilling our focus to just the three basic psychological needs that have been consistently and cross-culturally shown to mediate wellbeing, we are handed the controllers, so to speak, of wellbeing-supportive experience.

While the secrets to engagement, motivation and wellbeing have often appeared to reside inside a black box, what research shows is that it is the basic needs that are in that box. In other words, if you increase autonomy then engagement will improve, if you increase competence then motivation will increase, and if you increase relatedness then wellbeing will be enhanced–these needs become the controllers we tweak and adjust to iterate on and improve experience. In other words, basic needs are the mediating variables between product and well-being, and thus can be used as proximal criteria for adjusting design (making possible the "usable evidence" called for by Klasnja et al., 2017).

For example, SDT has been used to develop "personas" of digital coaches (Jansen et al., 2017). It can also be used during testing, for example, to evaluate feedback from a wearable device in order to optimize product satisfaction. Does the device provide feedback that increases feelings of mastery (enhancing competence) or does the feedback provided feel like empty praise or meaningless numbers? Does the device offer meaningful choices (enhancing autonomy)? Do features that connect users actually increase relatedness? In this way, the specific features of an interface can be measured against psychological need satisfaction and adjusted accordingly with resulting improvements to user experience, engagement and wellbeing.

Links to Behavior Change

Basic psychological needs are not new to HCI. They have already been applied, but almost exclusively as a model of motivation to enable behavior change (i.e., Hekler et al., 2013). In contrast, the literature linking psychological needs to *wellbeing* or sustained *engagement* is less well-known within the HCI community and therefore fewer links have been made.

This paper answers a call extended by Hekler et al. (2013) for "behavioral scientists and HCI researchers to work together on the design of behavior change technologies." Specifically they advocate drawing on theory to "make decisions about *which* functionality to support and *how* to implement such functionality." In their paper, which provides guidance to HCI researchers on the use of behavioral theories, they discuss behavior change models such as TPB (Ajzen, 1991), Self-Efficacy Theory (Bandura, 1996; Schunk and Usher, 2012), and SDT (Ryan and Deci, 2000b, 2017). These are all large-scale theories that generalize to multiple contexts (i.e., meta-models), but which can often be hard to apply in HCI with much resolution. Herein, we provide tools to make this application, regarding self-determination theory (SDT), far more straightforward. Our SDT-based model *Motivation, Engagement, and Thriving in User Experience (METUX)* is described below.

Background Summary and Walkthrough

In summary, SDT identifies three basic needs, the satisfaction of which are known to increase three primary desired outcomes of user experience: motivation, engagement and wellbeing. Therefore, through conscious design and testing, designers can focus on supporting these basic needs through the functions, features and contents of their technologies in order to improve user experience and wellbeing. Evidence for this impact and the practical links to design decisions are included in this paper.

We first introduce relevant SDT constructs and how they can be adapted holistically to the technology design context. Then we present METUX, a model that can be used for the evaluation and iterative design of technologies in order to optimize engagement, motivation and wellbeing. We elaborate on motivational design in a technology context and provide measures that can be used to evaluate designs for psychological needs in practice.

CRITICAL CONCEPTS FOR A MODEL OF WELLBEING-SUPPORTIVE DESIGN

The Importance of Differentiating Spheres of Impact

Calvo et al. (2014) explored ways in which autonomy can be influenced by technology within various spheres of experience. This work highlighted the necessity for specificity about the levels at which need satisfaction can take place. For example, "autonomy-support" could equally refer to the addition of customization to software, or to the extent a self-driving car increases autonomy in the daily life of someone who is vision-impaired. We posit that it is helpful to think about how a technology influences wellbeing within at least four different spheres of experience: (1) As part of interacting with the technology via its *interface*, (2) As part of engaging with technology-enabled *tasks* (e.g., self-tracking) (3) In relation to the overarching technology-supported *behavior* (e.g., exercise) 4. As part of a user's overall *life* (See **Figure 1**).

Acknowledgment of these differing spheres of experience is essential if we are to avoid creating technologies that are need-satisfying at one level but need-frustrating at another (i.e., addictive). Nevertheless, this acknowledgment has been largely missing from the literature on design for human factors. The conceptions about HCI as a discipline (Long and Dowell, 1989) have often limited research to what goes on at the interface level, even arguing that some spheres are beyond the bounds of HCI (Siek et al., 2014). Others like Smith et al. (2014) have instead valued the importance of considering impact on a "value-chain" of proximal intermediate and distal effects. No matter how wide the purview of HCI *per se*, design for wellbeing is an interdisciplinary endeavor and can therefore not be bound by disciplinary limits if we are to design holistically for thriving. Our

FIGURE 1 | User Experience of wellbeing – Spheres of Experience within which technology can influence wellbeing.

model, therefore includes consideration of the different spheres of experience within which psychological needs can be influenced and we describe these in greater detail in relation to the model in section A model for Motivation, Engagement, and Thriving in the User Experience (METUX).

Basic Psychological Needs in Context

Before discussing the METUX model it is worth taking a brief look at more complete definitions of the three basic psychological needs and how they have already been used in service of HCI research. The first and most widely studied within technology domains is autonomy.

Autonomy

The term autonomy literally means to be governed by the self and refers to a sense of willingness, endorsement or volition in acting (Ryan and Deci, 2017). Autonomy should not be confused with merely doing things independently or being in control; rather when people act with autonomy, they act with high willingness and in accordance with their personal goals and values, connecting autonomy to meaning & purpose. An individual can very willingly relinquish control or embrace interdependence. As a result of autonomous experience, an individual's quality of behavior and performance is higher and they experience greater wellness. A growing understanding of the importance of autonomy has lead to a radical shift within healthcare and a parallel change on the horizon in engineering. Where in the past, doctor-patient relationships left little room for patient agency, biomedical ethicists (Beauchamp and Childress, 2001) now consider deference to patient autonomy as a guiding principle.

Within engineering, the vast majority of research has focused on the design of autonomous *systems*, particularly robots and vehicles, rather than on supporting autonomous *humans* (Baldassarre et al., 2014). More recently however, the Institute of Electrical and Electronics Engineers (IEEE) has developed a charter of ethical guidelines for the design of autonomous systems that places *human* autonomy and wellbeing center-stage (Chatila et al., 2017). One of our aims within this paper is to assist technology creators in this quest to respect and support human autonomy as part of overall psychological need satisfaction in future technology design.

Friedman (1996) identified four aspects of software systems than can support or hinder user autonomy (i.e., system capability and complexity, misrepresentation, and fluidity) but focused on the direct impact of the system's use (what we would refer to as the interface sphere) and not the broader impact on other aspects of a person's life.

Design for autonomy is very familiar to game designers (Ford et al., 2012) and has been shown to predict measures of presence and intuitive controls (Ryan et al., 2006). Devices that offer options and choices over use, and do not in turn demand actions from users without their assent, enhance feelings of autonomy. Personalization also creates a sense of ownership and choice beneficial to autonomy (Ryan and Rigby, 2018). Ryan et al. (2006) showed how perceived autonomy in video games can lead to game enjoyment, preferences, and short-term wellbeing. Furthermore, Peng et al. (2012) tested an interactive exercise game in which an autonomy-enhancement feature was turned "on" and compared to an "off" condition. The feature inclusion significantly affected game enjoyment, motivation for future play and overall game ratings. Most relevant is that the relationship between the design feature and engagement was mediated specifically by autonomy in expected ways, consistent with SDT.

Beyond the sphere of the user interface, technologies can also facilitate greater autonomy within daily life by removing obstacles or augmenting capabilities, allowing people to pursue self-determined goals more fluently. For example, assistive technologies, productivity tools or health management apps, can all increase autonomy in relation to daily behaviors.

Finally, there is the potential for technologies to foster autonomy as an overarching characteristic of psychological development and flourishing. For examples, some technologies such as educational, health or behavior change tools, might help users develop a greater sense of autonomy in their lives generally and to more effectively realize their personally held values. In sum, there are many opportunities within various spheres for technologies to be autonomy-supportive and research shows that making them so, will foster engagement, motivation and wellbeing.

Competence

Competence, or feeling capable and effective, is the second psychological need identified by SDT. There are certain factors that have been shown to enhance a sense of competence including optimal challenge, positive feedback and opportunities for learning. These will be familiar to usability engineers as all usability heuristics can be explained by the needs for competence and autonomy. In the sphere of video games, for example, Rigby and Ryan (2011) detail how the intuitive design of controls, and the density and clarity of feedback all impact engagement via increased competence. In fact, controversies over the importance of difficulty and novelty in games (Lomas et al., 2017) can be better understood as competence issues. Both "difficulty" and "novelty" are only important to engagement to the extent to which they provide competence satisfactions. A game that is too easy stops providing them, as does one that is too hard. Novelty (such as new level designs or new rewards) is also engaging to the extent that it provides new opportunities for competence satisfactions (new designs and features promise new opportunities for learning and mastery).

Illustratively, Peng et al. (2012) in the exergame experiment mentioned above, manipulated a competence-enhancement condition based on dynamic difficulty. Specifically, the program featured an automated system to create optimal challenges based on player performance, whereas in the "off" condition challenge levels remained relatively constant. Decreased game enjoyment was mediated by a shift in competence satisfactions. This work demonstrates how design features might be iterated with respect to their impacts on need satisfactions toward improving the user experience.

Relatedness

Relatedness is described as a sense of belonging and connectedness to others and it is core to most, if not all, theories of wellbeing (Baumeister and Leary, 1995). Research has even linked positive relationships to greater longevity more powerfully than diet and exercise (Kasser and Ryan, 1996). Yet not all social interactions help people feel a greater sense of belonging or connectedness. Many app features and communication devices can even frustrate relatedness with subsequent impacts on engagement and wellbeing. Moreover, such affects can occur as a result of apparently small details and in ways that are surprising (e.g., Hudson et al., 2015 found that emoticons influence Facebook jealousy).

Considering the explosion of new social media technologies, support for relatedness arguably defines a category of digital experience that shapes our generation. What SDT provides us with are assessments of relatedness against which specific features of devices (e.g., video chats, cooperative features, emoticons, nudges, etc.) can be tested to ensure that they are meaningful, satisfying, and lead to genuine relatedness, rather than the mere semblance of connection, hurtful interactions or social isolation (e.g., Sheldon et al., 2011).

Significant qualitative differences between different types of technology-enabled social connection have already been suggested by a number of studies, most notably, observational studies on Facebook use. For example, (Burke et al., 2010) found that directed communication between pairs (i.e., wall posts, comments, and "likes") is associated with greater feelings of bonding social capital and lower loneliness, whereas, users who engage in mere browsing of friends' content (i.e., status updates, photos, and friends' conversations with other friends) report reduced social capital and increased loneliness. Furthermore, they point to how these findings could inform design decisions, specifically "enhancements for fostering communication over passive engagement." Furthermore

Grieve and Watkinson (2016) showed that in Facebook, only authentic self-representation was associated to wellbeing, while lack of authenticity was related to stress and lower wellbeing which suggests that a design promoting authentic self-representation may have better wellbeing outcomes within these technologies.

There has also been suggestion as to how design might be directed to support constructs such as empathy and compassion (Belman and Flanagan, 2009; Peters and Calvo, 2014). Principles posited in both of these works suggest that the satisfaction of psychological needs mediate these constructs as well. In these, as well as in the Facebook experiments, if we were applying the model described herein, established measures of relatedness would be used to determine the impact of various designs and to help pre-empt inadvertent harm.

In short, because our relationships are increasingly mediated by technology, and because technology experience is increasingly social, models and measures of relatedness stand to contribute to both the literature on wellbeing and to the future of technology design.

The Importance of Motivation Type (Autonomous vs. Controlled)

An additional contribution of SDT to technology design is the insight that the value of motivation (in terms of its ability to contribute to wellbeing) depends strongly on how *autonomous* (v. extrinsically-controlled) it is. In other words, someone can be highly motivated in ways that are highly controlled and that don't foster wellbeing (e.g., by threat of punishment.) In contrast, extrinsic motivation that is highly *autonomous* is highly effective and does contribute to wellbeing (with outcomes similar to those of intrinsic motivation (Ryan and Deci, 2000a, 2017).

Deci et al. (1999) in a meta-analysis of 128 studies, confirmed that rewards contingent to engagement, completion, and performance undermined intrinsic motivation. Positive feedback instead enhanced free-choice behavior and interest. A meta-analysis by Ng et al. (2012) within the healthcare context, confirmed that autonomous motivation supports more effective and lasting behavior change. Specifically, an autonomy-supportive health care climate positively predicted need satisfaction which, in turn (together with autonomous motivation) predicted better health outcomes.

Figure 2 shows that intrinsic and extrinsic forms of motivation can be placed on a continuum from controlled to autonomous. Here we have redrawn Ryan and Deci's original model (Ryan and Deci, 2000a) adding a "User experience" row in order to show how the model applies within the technology context (see **Figure 2**). Controlled extrinsic motivation involves a sense of pressure or obligation and often includes extrinsic rewards or penalties (Ryan and Deci, 2000a), while highly autonomous extrinsic motivation is close in quality to intrinsic motivation with regard to its ability to foster wellbeing and positive outcomes. In other words, even when something isn't fun (intrinsically motivating), we can be very meaningfully motivated to engage with it when our motivation is highly autonomous.

A plethora of new technologies promise to motivate people to engage in healthy behaviors, but as SDT has shown, the way behaviors are initiated and maintained (autonomously or via controlling methods) will have a significant impact. More recently, researchers have begun exploring how *physical* health apps can also support *psychological* wellbeing. For example, Karapanos et al. (2016) explored how commercial wearable activity trackers mediate meaningful experiences in everyday life. While most commercially available trackers employ competition as the primary mode of social exchange and motivation, their study showed that tracking involves much more nuanced socially motivated experiences, including a sense of belonging, social support, and bonding.

Having specified the various categories of motivations upon which our discussion draws, we can now describe our model for wellbeing-supportive design.

A MODEL FOR MOTIVATION, ENGAGEMENT, AND THRIVING IN THE USER EXPERIENCE (METUX)

A number of existing evidence-based models inform and set a precedent for the need-satisfaction-based model we propose. For example, the SDT model of health behavior change (Ryan et al., 2008) shows how a combination of environmental and individual determinants can support or hinder need satisfaction within the health context. Furthermore, the model predicts how need satisfaction will also have a positive impact on mental and physical health outcomes.

Similarly, the SDT model of video game engagement is focused on what has been called the PENS (*Player Experience of Need Satisfaction*; Ryan et al., 2006). In this model both game contents (e.g., narrative and story) and features (e.g., open world, goal choices, dialogue boxes, etc.) all affect satisfactions of autonomy, competence and relatedness during play, in turn predicting enjoyment and sustained engagement. The PENS framework is readily tested using assessments of need satisfaction such as those employed by Ryan et al. (2006) which can be broadly applied (Przybylski et al., 2010).

Drawing on the evidence and previous work in health, video games and other domains including workplace, education, and sport (see Ryan and Deci, 2017 for a review), our model (**Figure 3** and **Table 1**) applies existing evidence to describe and predict the impact of technologies on motivation, engagement and wellbeing based on psychological needs satisfactions.

The table below lists six separable spheres of experience that can be influenced by technology design. **Figure 3** illustrates the relationship between design for psychological need satisfaction and engagement, motivation and wellbeing within each sphere of experience. The first five spheres of experience identified by the model refer to elements of the *individual* user experience upon which a technology can have an impact.

Adoption is not pictured in the diagram because of its peripheral role preceding actual use, and neither is the broadest sphere, *society* owing to its position beyond the individual user experience. Society is the one sphere that goes beyond the user

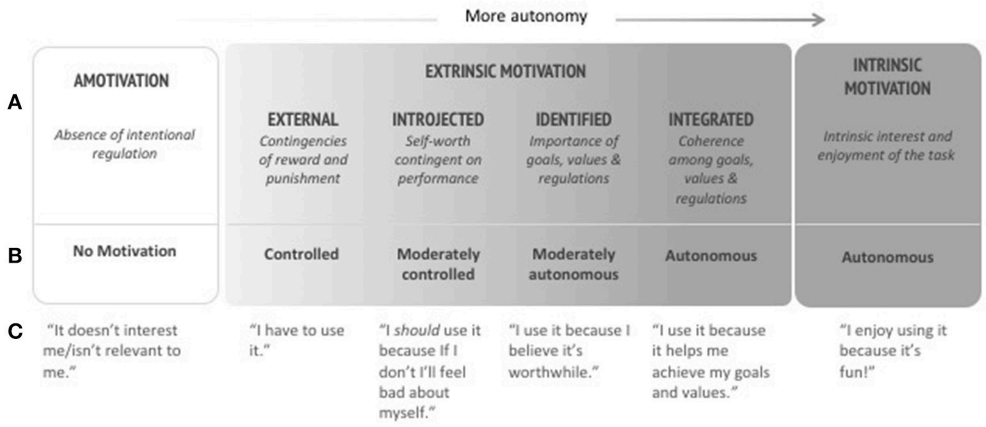

FIGURE 2 | Taxonomy of Human Motivation; **(A)** Type of regulation, **(B)** Type of motivation, and **(C)** Examples translated to the user experience context (Adapted from Ryan and Deci, 2000a).

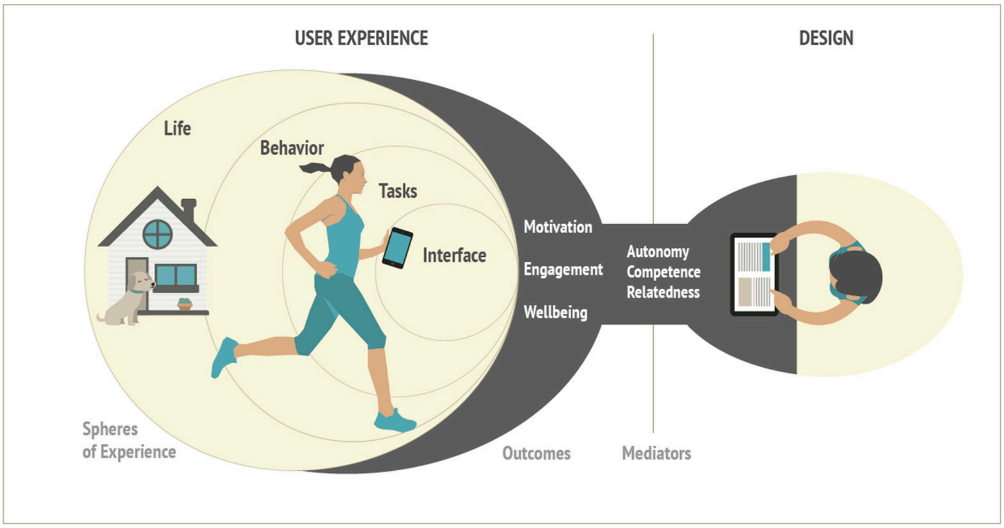

FIGURE 3 | METUX model diagram - The basic psychological needs of autonomy, competence and relatedness mediate positive user experience outcomes such as engagement, motivation and thriving. As such, they constitute specific measurable parameters for which designers can design in order to foster these outcomes within different spheres of experience.

to encompass *non*-user experiences, and collective and collateral effects.

It is worth noting that the boundaries between these spheres is merely conceptual and examples of overlap and interrelation exist. The point is not to overemphasize boundaries but to provide a way of organizing thinking and evaluation in a way that can address contradictory parallel effects (i.e., a technology can support psychological needs at one level while undermining them at another). Each of these spheres is described in greater detail below, while descriptions of evaluation measures follow in the next section. We also provide three examples of how the spheres can provide a valuable framework for the analysis of diverse technologies (**Table 2**).

ADOPTION—Anticipated Need Satisfaction at the Point of Adoption

The first level, adoption, begins when a person first becomes aware of a new digital product and ends when he or she acquires and uses it for the first time. The primary outcome of this phase is uptake of the technology. SDT predicts that users will be likely to adopt a new technology to the extent that they are autonomously motivated to do so. Therefore, the primary question is: to what extent is a user's motivation to adopt a technology *autonomous,* that is, willing and aligned with their values and goals (e.g., "I really want to try that app because I think it will help me engage with exercise more"), versus perceived as externally controlled ("my boss is forcing me to download this app")?

TABLE 1 | METUX model in detail, including measures.

Sphere of experience	Psychological needs (mediators) in context	Evaluation measures	Desirable outcomes
Adoption The decision-making experience between becoming aware of a new technology and acquiring it.	• To what extent is technology adoption autonomously motivated? • To what extent does a potential user anticipate they will be competent at using it?	• ACTA[i]	• Adoption (i.e., purchase, download)
Interface The experience of interacting with a technology via its interface during use.	• To what extent does direct interaction with the technology (i.e., via the user interface) support psychological need satisfaction?	• TENS-Interface[i]	• Engagement (with technology) • Usability • User satisfaction
Task The experience of engaging in a technology-specific task.	• To what extent does engagement in technology-specific tasks support psychological need satisfaction? (e.g., step tracking, text chatting)	• TENS-Task[i]	• Engagement (with task) • User satisfaction
Behavior The experience of engaging in a behavior (that a technology is intended to support).	• To what extent does the technology improve psychological need satisfaction with respect to the behavior that the technology is intended to support? (e.g., exercise, managing a chronic disease, communicating with friends, speaking a second language.)	• Assessments of psychological need satisfaction in relation to behavior (e.g., PNSES[ii] for exercise) • Assessments of behavior-specific outcomes (e.g., BMI measure for exercise)	• Engagement (with behavior) • Satisfaction (with behavior) • Behavior-specific outcomes (e.g., weight-loss, symptom control) • Experience of wellbeing during behavior.
Life An individual's overall experience of life including all that is outside or beyond the technology.	• To what extent does the technology influence the user's experience of psychological need satisfaction in their life overall?	• TENS-Life[i] • BPNS[iii] • Other validated measures of flourishing	• Increased life satisfaction, wellbeing, thriving/flourishing.
Society The experiences of all members of a society beyond the users of a technology.	• To what extent does the introduction of the technology impact on societal wellbeing?	• Population measures such as the FS[iv]	• Increased measures of societal wellbeing.

[i]ACTA, TENS-Interface, TENS-Task and TENS-Life are introduced in section 4. [ii]PNSES, Psychological Need Satisfaction in Exercise Scales (Wilson et al., 2006). [iii]BPNS, Basic Psychological Need Satisfaction scale (Deci and Ryan, 2000; Gagné, 2003). [iv]FS, Flourishing Scale (Diener et al., 2009)

Drawing on the Intrinsic Motivation Inventory (Ryan, 1982), we devised a measure of intrinsic motivation specific to technology adoption (described below). To this measure, we added two perceived competence items, as we hypothesized that a person's willingness to adopt a technology would be influenced by anticipated competence to use it (which can also be framed as perceived ease-of-use). This can be influenced by aesthetics (see "aesthetics-usability effect" Norman, 2004), marketing, a user's prior experience, and their general attitude toward technology adoption.

There seems little scope for any actual increase in relatedness during the adoption phase, therefore, although *anticipated relatedness* can have an influence (e.g., "I will be able to connect with my family better if I use this") it functions as an autonomous motivator rather than as relatedness itself (anticipated relatedness contributes to autonomous motivation as it aligns with values and goals).

Of course there are a number of existing technology adoption models approaching the problem from various angles, including the Technology Acceptance Model (Davis et al., 1989), based on the Theory of Planned Behavior (Ajzen, 1991), which is used to understand behavior change and persuasion based on "perceived use." Within the information systems literature "perceived use" has been described as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989). By viewing adoption through the lens of SDT, we can broaden this definition by rephrasing it as "the degree to which a person believes that using a particular system would enhance his or her sense of autonomy, competence or relatedness in any facet of life."

In our model, we address "perceived use" within the context of motivation which has the added benefit that it allows for compulsory use to be taken into account (people may adopt a technology even if they don't perceive usefulness). For example, someone may autonomously elect to use a video chat app because they anticipate it will increase their productivity (enhance competence) or allow them to connect to their grandchildren (enhance relatedness), both of which are

TABLE 2 | Examples of three diverse technologies through the lens of the METUX model.

Sphere of experience	Wearable fitness device	Chronic illness support App	Language learning online course
Adoption	Purchasing the device. *[ACTA]*	Downloading the app *[ACTA]*	Enrolling in the course *[ACTA]*
Interface	Controls, navigation, information display and aesthetics of the device. *[TENS-Interface]*	Controls, navigation, information display and aesthetics within the app *[TENS-Interface]*	Controls, navigation, information display and aesthetics on the site *[TENS-Interface]*
Tasks	Step counting, heart-rate monitoring & session timing *[TENS-Task]*	Symptom tracking, mood tracking & goal-setting *[TENS-Task]*	Vocabulary repetition, text translation, sentence generation *[TENS-Task; SRQ-Learning]*
Behavior	Exercising *[TSRQ-Exercise]*	Managing asthma *[TSRQ* (adaptation for asthma management)*]*	Learning Spanish *[TSRQ* (adaptation for language learning)*]*
Life	Overall wellbeing (influenced by Increased engagement in regular exercise) *[TENS-Life]*	overall wellbeing (influenced by improved asthma control) *[TENS-Life, BPNS]*	overall wellbeing (influenced by ability to communicate in a new language) *[TENS-Life]*
Society	Societal wellbeing (Increase in regular exercise across a population could improve overall societal wellbeing via increased levels of physical and mental health.) *[FS Scale]*	Societal wellbeing (Improved management of asthma could improve overall societal wellbeing via decreased fatalities and increased population health.) *[FS Scale]*	Societal wellbeing (Fluency in an additional language across a population could improve overall societal wellbeing via increased cross-cultural relatedness.) *[FS Scale]*

Possible measures for evaluation are listed in brackets.

autonomous motivations. On the other hand, someone may be required by their workplace to use it, in which case, they may not perceive any use for it at all but adopt the technology anyway for fear of penalty (externally regulated extrinsic motivation). In other words, an SDT-based approach shifts the focus from the content of perceived use to how autonomously motivated it is.

INTERFACE—Need Satisfaction From Interaction With the Interface

SDT predicts that users will engage with a technology to the extent that interaction with the system satisfies their psychological needs and the primary outcome from need-satisfaction is sustained engagement. One way this manifests is through usability. Poor usability will cause need frustration (to autonomy and competence). Studies by Rigby and Ryan (2011) provide some examples of interface-based need satisfaction that show how variations in video game feature design impact a user's sense of autonomy and competence during play which in turn determine to what extent users engage with and enjoy a technology.

In contrast, relatedness has been less studied with regard to interface interaction, probably because it is not essential to technology engagement (even a digital game of solitaire can be engaging). Relatedness is essential to *wellbeing* but does not have to be served by every technological experience. As such, simply tacking on social features in an attempt to reap the benefits of relatedness is not necessarily advisable, on the one hand because social features don't guarantee relatedness, but also because there are situations in which the quality of the user experience may be diminished if it is shifted from being private to being social at the interface level.

For example, a personal journal or mindfulness app may be far more effective at achieving intended outcomes (honest self-reflection, reduced self-criticism) without the incorporation of social features such as a "share" button. Calvo and Peters (2014) consider how social features applied to mindfulness technologies may make users more likely to compare themselves to others which is antithetical to the goals of mindfulness practice. Interestingly, in this case it could be said that a lack of social features would better contribute to relatedness as it better supports the behavior itself which itself increases relatedness. This increase in relatedness could only be detected *beyond* the level of the interface but is an example of the far-reaching impacts of interface-level choices. These distinctions further demonstrate why unpacking various spheres of experience is helpful for evaluating a design's affect on human psychological needs.

TASK—Need Satisfaction From Engagement With a Technology-Enabled Task

Every technology has features and functionalities that enable various tasks. For example, a fitness app may allow you to track steps, count calories or read athlete stories. Each of these tasks may be more or less fulfilling of psychological needs; for example, reading athlete stories might make you feel worse or better about yourself depending upon the content of the stories. Likewise, you may find the task of step tracking valuable or frustrating. The step tracking features can be designed in many different ways at the interface level, but the task of step tracking itself is an identifiable activity enabled by the technology.

Finally, a particular task is generally intended to support an overall behavior (e.g., exercise) which brings us to the next sphere.

BEHAVIOR—Need Satisfaction Related To a Technology-Supported Behavior

With the notable exception of games, most technologies are designed to enable, augment, or enhance some separable overarching behavior. Health apps, for example, may be intended to influence behaviors like exercise, healthy eating, or meditation. Calendaring apps support time-management or event planning while email supports professional or social communication. In other words, you use the technology because it helps you to succeed at something else. You might engage with these behaviors for intrinsic reasons (I exercise because it feels good) or because you're aiming for a separable outcome (I exercise to lose weight). In relation to the tasks sphere described above, the behavior is the overarching activity that a task is intended to support.

The difference between these spheres is important because a technology might support need-satisfying interaction at the interface level (be satisfying to use), and at the task level (completing tasks is satisfying) but may still not necessarily impact need satisfaction in relation to the behavior it's designed to support. For example, a user who adopts a new exercise app may find the app itself engaging but not feel more willingness to exercise as a result of it. Likewise, a user may become very proficient with their calendaring software but it may not make them feel any more autonomous with regard to managing their time. In fact, seeing all events presented in color on one screen may cause them to feel overwhelmed and less in control. Clearly, to truly understand the impact of a technology holistically, measuring need-satisfaction at the interface is not sufficient.

Life—The Link Between Technology and Overall Wellbeing

The SDT literature indicates that psychological need satisfaction increases mental and physical health. However, momentary need satisfaction relating to the use of a technology may not be sufficient to affect measurable improvements to individual flourishing. For example, a superbly designed egg timer may improve the cooking experience (allowing the user to feel more autonomous and competent as a cook) and yet this device on its own would not be expected to measurably change a user's overall satisfaction with life. However, one might expect that an effective mindfulness tool would. Therefore, whether a technology goes beyond need satisfaction at the interface, task and behavior spheres, and has a large enough impact to increase overall wellbeing in life, will often depend on what is intended.

The notion of the life sphere is especially useful when assessing technologies that consciously aim to impact overall wellbeing. For example, consider rehabilitation technologies. A platform that delivers videos for teaching rehabilitation exercises (e.g., for chronic pain patients) may be successful at the interface level (being easy to use and providing helpful options), and even at the behavioral level (the person effectively performs the exercises regularly). But if the person does not "transfer" what is learned as part of rehabilitation to other aspects of their life (e.g., driving, sleeping), then it cannot be argued that the rehabilitation was successful, and improvement to overall wellbeing in life is unlikely to occur.

This sphere is also critical for identifying addiction. Most of us can recall someone who "had to delete an app because it was just taking up too much of their time." They experienced over-engagement (ie. addiction). A casual game, for example, can be so need satisfying within the first few spheres, that at the life sphere, important activities get crowded out leading to drops in relatedness as human relationships are ignored, drops in autonomy as they feel less able to make decisions aligned with their values. Therefore, any technology wishing to claim it improves wellbeing, or even that it merely doesn't harm it, will need to measure at the life level.

While not all technology projects will aim for changes to long-term wellbeing, aiming to satisfy psychological needs has the potential to benefit all projects. In addition to increasing engagement and activity-specific outcomes, doing so may have positive collateral effects, for example by removing causes of stress, and increasing overall psychological need satisfaction in people's lives. Even if these improvements are not easily measurable or causally attributable to any one technology, they will still be contributing to a cumulative effect that could increase individual or even societal wellbeing measurably over time.

SOCIETY—Beyond the User Experience

The sixth sphere in the model is largest in scope and is the only one to step beyond the *user* experience. Societal wellbeing may be affected by the use of a technology both directly and indirectly. Within this sphere, ethical issues regarding impact of an economic and environmental nature may become relevant. For example, a well-designed self-driving car may promote greater wellbeing and life satisfaction for many users. Yet the collateral impact of such cars on the livelihoods of the millions who survive off of driving taxis, buses and trucks can only be revealed at a societal level of analysis because this impact goes beyond the users of this technology. In fact, as technology penetrates social infrastructures, downstream effects are often multiple and interactive. This level of societal impact requires the consideration of interdependent factors, and therefore, will be, by far, the most difficult to accurately assess and will require multidisciplinary collaboration and new methods.

We now move to a discussion of evaluation measures for implementation of the model in practice.

EVALUATION MEASURES

Introduction to Measures of Psychological Need Satisfaction

In this section we review a number of validated instruments that can be used directly or adapted in order to measure the user experience of autonomy, competence and relatedness within the various spheres described by the METUX model.

The instruments described herein have been used in various contexts, for example to assess to what extent a medical professional (Williams et al., 2009), healthcare intervention (Williams et al., 2011; Teixeira et al., 2012) or a procedure (Ng et al., 2012) supports autonomy. SDT researchers have also used these instruments to evaluate the impact of coaches, teachers, education systems and learning technologies (Chen and Jang, 2010; Bartholomew et al., 2011). Decades of research provide evidence that psychological need-support within these environments has a significant impact on domain-specific (e.g., health, work and education) outcomes.

We show how these measures can be adapted to evaluate technological environments. The intention is to assist designers in measuring need-satisfaction related to their designs such that they can make iterative improvements that result in increased engagement, motivation and wellbeing, as has been done in other domains. This is precisely how SDT researchers have worked with game designers to increase user engagement in digital games (see Rigby and Ryan, 2011; Przybylski et al., 2014). **Figure 4** shows an example of how SDT-based measures might be incorporated along the timeline of a wellbeing-supportive HCI project.

For three of the spheres we propose novel adaptations of existing SDT-based questionnaires adapted for the technology context. These are provided in Appendices 1–4. References to the literature available on the SDT-based measures discussed, along with links to many instruments, are available on the Self-determination theory website (www.selfdeterminationtheory.org).

Measures for Technology Adoption

The Self-Regulation Questionnaire (SRQ) identifies types of motivation (autonomous vs. controlled) via questions concerning the regulation of a particular behavior (e.g., exercising regularly) or class of behaviors (e.g., engaging in religious behaviors) (Ryan and Connell, 1989). Therefore the SRQ can be readily adapted to assess motivation for the adoption of a technology, essentially focusing on the "why" of purchase/usage intentions. The questionnaire results range from amotivated, to controlled, to autonomous, with distinctions between intrinsic and extrinsic motivation as elaborated previously in **Figure 2**.

We have also argued that adoption will be mediated by anticipated competence and for this we recommend an adaptation of the Perceived Competence Scale (PCS). The original PCS includes 4 questions, and, in the context of technology adoption, only two would be relevant. These two can be added to an adapted SRQ to form a basic technology adoption questionnaire based on psychological need satisfaction. We have created such an adaptation, "Autonomy and Competence in Technology Adoption (ACTA)" and included it in Appendix 1. An initial validation of the ACTA is described in Appendix 5.

There has been considerable research into the adoption, intended use, and acceptance of technologies which has focused on other factors including demographic characteristics, traits, or variables to do with a specific domain. The specific research questions relating to a particular technology project will determine which measures are best suited to that project, however, we provide a measure based on psychological need satisfaction in order to provide a complete and theoretically consistent approach to the evaluation of technologies at all levels.

Measures Relating to the Interface

Among the most common measures for evaluating a technology interface are questionnaires like the System Usability Scale (Bangor et al., 2008). While usability measures can be useful in identifying *obstacles* to engagement, high usability does not necessarily predict high engagement or positive experience (Febretti and Garzotto, 2009). In contrast, the PENS (Ryan et al., 2006) is a validated 21-item SDT-based questionnaire that has been shown to predict engagement and enjoyment. The PENS has been used to assess the experience of need satisfaction and user experience in video game contexts and has been refined in its ongoing use (see Rigby and Ryan, 2011). It assesses both the degree to which the user experiences mastery of the interface, need satisfaction during use, and qualities such as immersion and includes a number of questions only relevant to gaming that can be excluded for adaptation to other technologies.

We provide a complete adaptation of the PENS for non-game technologies, which we call the TENS-Interface (Technology-based Experience of Need Satisfaction–Interface) as Appendix 2. Validation data for the TENS-Interface is included in Appendix 5.

Measures Relating to the Task

Because the PENS was developed for use in video games, for which, uniquely, the technology itself provides the activity it supports, the PENS also evaluates need satisfaction within the task sphere. As such, we have been able to adapt a task-based questionnaire from the PENS and provide this Technology-based Experience of Need Satisfaction-Task (TENS-Task) instrument as Appendix 3. The TENS-Task can be used to measure psychological need satisfaction provided by engagement with technology-supported tasks. Validation data for the TENS-Task is included in Appendix 5.

Measures Relating to the Behavior Domain

As discussed earlier, a technology generally mediates or supports a behavior in ways that are more or less satisfying to an individual's psychological needs. The SDT literature provides numerous examples of validated questionnaires for specific behavior domains including exercise, diet improvement, parent-child interaction and learning. For example, the Psychological Need Satisfaction in Exercise Scale (PNSES) (Wilson et al., 2006) measures perceived psychological need satisfaction when doing exercise and would therefore serve as a measure of need satisfaction at the behavior level for an exercise technology.

However, in many cases there will not already be a questionnaire adapted to the specific behavior in question. In this case, we recommend that the general Basic Psychological Needs Satisfaction questionnaire (BPNS; Chen et al., 2014) or General Self-Regulation Questionnaire be adapted to the context (much in the way existing domain-specific questionnaires were developed). For examples, see the development of the above-mentioned PNSES (Vlachopoulos and Michailidou, 2006) or an adaptation for the work domain (Broeck et al., 2010). Separate to measures of need satisfaction, projects are also likely to include domain-specific outcome measures.

Measures Relating to Life

The TENS-Life (Technology Effects on Need Satisfaction in Life) scale (Appendix 4) is introduced as a measure to identify the extent to which users believe a technology has had an impact on need satisfaction in their lives. With items such as "I spend more time on the technology than I feel I should" and "using the technology has made me feel a greater sense of belonging to a community" the TENS-Life provides a direct link between

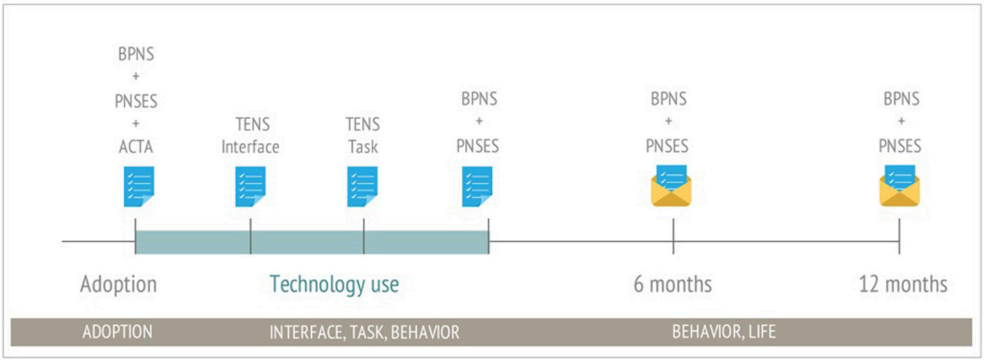

FIGURE 4 | Evaluation timeline example – Example timeline of a wellbeing-supportive technology project highlighting the points at which SDT-based measures might be used for evaluation. METUX spheres are listed along the bottom. The PNSES is specific to exercise but would be replaced by an adaptation to the behavior domain relevant to the project. The PNSES and BPNS are given at baseline, 3, 6, and 12 months to show change over time, a common approach for psychology studies.

a technology and wellbeing in life allowing for the identification of autonomy frustrations that may relate to addictive patterns. Validation data is provided in Appendix 5.

Another approach to measuring changes to overall wellbeing is via standard wellbeing measures run pre- and post-use of a technology. This is particularly useful for technology-based psychology interventions. The Basic Psychological Need Satisfaction (BPNS) scales provide a theoretically consistent measure. However, other validated measures of wellbeing are also available, such as Ryff's Psychological Wellbeing Scales (Ryff, 1989), the MHC-SF (Lamers et al., 2011), the Flourishing Scale (Diener et al., 2009), or frameworks in which wellbeing is conceptualized as lying at the opposite end of a spectrum of mental illness (Huppert and So, 2013).

CONCLUSIONS: TOWARD TECHNOLOGY DESIGN FOR FLOURISHING

In this paper we have argued that the impact of a technology on the psychological experience and wellbeing of an individual can be better understood, empirically evaluated, and designed for, by targeting basic psychological needs as defined by Self-determination Theory. We present a model for bridging SDT theory to technology design practice which we refer to as METUX (Motivation, Engagement & Thriving in User Experience). In order to ensure a sufficiently broad view of wellbeing (i.e., one that includes eudaimonia and accounts for addiction) the model posits that psychological needs be considered at five different separable spheres of analysis, including: at the point of technology *adoption*, during interaction with the *interface*, as a result of engagement with technology-specific *tasks*, as part of the technology-supported *behavior*, and as part of an individual's *life* overall. These five spheres of experience sit within a sixth, *society*, which encompasses both direct and collateral effects of technology use as well as *non*-user experiences.

We present examples of existing SDT-based measures, as well as introduce four new measures that can be used to evaluate need satisfaction at the five levels. According to research, in addition to predicting impact on wellbeing, motivation and sustained engagement with technology, SDT measures also predict the fulfillment of domain-specific outcomes (such as health or educational outcomes) making SDT an ideal basis for understanding and improving other common goals within technology projects.

Of course, a number of limitations should be noted. The measures presented are initial iterations that will require more thorough validation and refinement in response to usage over time. Moreover, the spheres themselves are approximations and other delineations may very well prove more useful overall or within different contexts. Finally, SDT, while a mature theory with robust support, remains a psychological theory open to ongoing interrogation. Further research on all fronts (with regard to the measures, the HCI implementation and the psychological basis in the technology context) is required and it is our hope that the theory and measures provided herein can form a useful starting point.

Our intention is that the model and instruments provided will enable technology designers to evaluate their technologies for wellbeing impact, and allow HCI researchers tools and theory upon which to improve. In this way, as a community we may iterate collectively toward a future in which all technologies are better designed to support psychological wellbeing and human potential.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Australian Code for the Responsible Conduct of Research and the National Statement on Ethical Conduct in Human Research. The protocol was approved by the Human Research Ethics Committee at Australian Catholic University (review number 2017-21516). All subjects gave informed consent in accordance with the Declaration of Helsinki.

AUTHOR CONTRIBUTION

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00797/full#supplementary-material

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Immersive Interactive Technologies for Positive Change: A Scoping Review and Design Considerations

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Practices such as mindfulness, introspection, and self-reflection are known to have positive short and long-term effects on health and well-being. However, in today's modern, fast-paced, technological world tempted by distractions these practices are often hard to access and relate to a broader audience. Consequently, technologies have emerged that mediate personal experiences, which is reflected in the high number of available applications designed to elicit positive changes. These technologies elicit positive changes by bringing users' attention to the self—from technologies that show representation of quantified personal data, to technologies that provide experiences that guide the user closer in understanding the self. However, while many designs available today are either built to support or are informed by these aforementioned practices, the question remains: how can we most effectively employ different design elements and interaction strategies to support positive change? Moreover, what types of input and output modalities contribute to eliciting positive states? To address these questions, we present here a state of the art scoping review of immersive interactive technologies that serve in a role of a mediator for positive change in users. We performed a literature search using ACM Digital Library, Web of Science, IEEE Xplore, and Design and Applied Arts Index (beginning of literature—January 1, 2018). We retrieved English-language articles for review, and we searched for published and unpublished studies. Risk of bias was assessed with Downs and Black 26-item QAT scale. We included 34 articles as relevant to the literature, and the analysis of the articles resulted in 38 instances of 33 immersive, interactive experiences relating to positive human functioning. Our contribution is three-fold: First we provide a scoping review of immersive interactive technologies for positive change; Second, we propose both a framework for future designs of positive interactive technologies and design consideration informed by the comparative analysis of the designs; Third, we provide design considerations for immersive, interactive technologies to elicit positive states and support positive change.

Keywords: scoping review, immersive technology, positive technology, transformative technology, design, virtual reality, augmented reality, mixed reality

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INTRODUCTION

Technology is becoming increasingly more prevalent in our everyday lives. Yet, for all the new hardware and gadgets available, we have only recently seen an increased interest in designers, developers, and researchers deliberately thinking about how these technologies might be used to improve our lives and increase our well-being (Bowman and McMahan, 2007; Roo et al., 2016; Valmaggia et al., 2016; Gaggioli et al., 2017). The Western practice and literature so far has focused primarily on mental health problems and treatments, from a medical or psychiatric lens (Valmaggia et al., 2016) and with a focus on treating symptoms rather prevention. Furthermore, literature focusing on healthy populations and using a preventative medicine point of view is uncommon. Focusing on preventable measures is important because non-communicable diseases cause 70% of deaths globally and about half of all deaths in the US were preventable (Mokdad et al., 2004; WHO, The top 10 causes of death), and the use of preventative healthcare has shown to provide numerous health benefits and increase quality of life dramatically (Cohen et al., 2008; Maciosek et al., 2010). That said, there does appear to be a rise in interest in using technology for positive human functioning and well-being across many different domains. This diversified interest seems to imply promise for future applications of technology for improving positive experiences and health. Yet, a challenge lies in trying to integrate all the existing knowledge across the various domains because, although they are all aiming toward a common goal, they are using different terminology, frameworks, and theoretical lenses to approach the topic. We have created a visualization in an attempt to better understand both the development of these different domains over time and how they interact with each other (see **Figure 1**), and will elaborate on it below. Approaches to technology that supports positive human functioning and well-being appear to be seeded from three different domains: Psychology, HCI, and Computer Science. We will briefly discuss the history of these approaches, although we recognize that this may not be an exhaustive list because of the highly multidisciplinary nature of this research area.

Psychology

In the late 1990s, Psychology was dominated by psycho-analysis and behaviorism that focused on a "mental illness" model of human functioning. Positive Psychology was then introduced as a counter to this way of thinking; instead it emphasized happiness, well-being, and positivity. Positive Psychology originated with Seligman's PERMA theory and Csikszentmihalyi's Flow theory. PERMA consists of five elements that can help people reach a life of fulfillment, happiness, and meaning: Positive emotions, Engagement, Relationships, Meaning, and Achievement. Flow is an activity with goals/progress, feedback, and balancing perceived challenge and skill. Together, these two theories then formed the basis of several positive technology approaches including Persuasive Technology, Positive Computing, and Positive Technology. Fogg (1999) was one of the first researchers to put forth the idea that computers are able to persuade or change the behavior of people. Later, Knowles (2013) expanded upon this idea by placing importance on implicit values of both the user and designer to motivate behavior change. Positive Computing and Positive Technology both arose as ideas around the same time and are highly related (Gaggioli et al., 2017). Both consider ways for bringing well-being considerations into interaction design through positive technology theories. One difference is that Positive Computing (Sander, 2011; Calvo and Peters, 2014) uses an engineering lens for considering well-being in any technology either as preventative or active integration, whereas Positive Technology (Riva et al., 2012) uses a psychological lens for considering technology as a platform for supporting and sustaining well-being and the process of change. TechnoWellness (Kennedy, 2014) emerged in response to Positive Technology, arguing that Positive Technology was missing key factors for holistic wellness based on a counseling perspective that uses the IS-Wel model (Myers and Sweeney, 2005). The IS-Wel model, or Indivisible Self Model of Wellness, integrates both the model of the Indivisible-Self and the five factor Wellness Wheel. Emotional Design emerged with this effort to promote positive emotions or pleasure in users (Norman, 2004), and has since been expanded upon to the design of interactive technologies (Triberti et al., 2017). Directly stemming from Positive Technology came Computer-Mediated Self-Transcendence (Gaggioli et al., 2016), which is a more specific pathway of Positive Technology that focuses on interactive technologies to support self-transcendent emotional experiences. Similar to Computer-Mediated Self-Transcendence, Transcendence Technology (Mossbridge, 2016) seeks to use technology to move beyond the self and connect with others, but was developed more through a noetic sciences, i.e., parapsychological, lens. A specific example of Transcendence Technology is the study of lucid dreaming to inform the design of virtual reality introspective experience (Kitson et al., 2018). Desmet and Pohlmeyer (2013) took cognitive emotion theory and combined it with user experience (UX) design to form the framework of Positive Design, design that promotes human flourishing. A few years later, Buie (2016) formed Techno-Spiritual Design. Seemingly not wanting to use any of the existing theories on designing technology for well-being, Buie used a research through design approach to actively engage the user throughout the design process of creating technological experiences that support going beyond the self.

Human-Computer Interaction (HCI) and Computer Science

The idea of understanding human nature in relation to work has been around for a long time. In 1857, Jastrzebowski (1857) first coined the term ergonomics, referring to worker productivity in labor, entertainment, reasoning, and dedication. More contemporarily, ergonomics was reintroduced in the 1970s by Murrell (Edholm and Murrell, 1973) to mean understanding human-system interactions to optimize human well-being and system performance. Ergonomics then took on many different forms and specialties including cognitive ergonomics that encompasses usability, human-computer interaction (HCI), and user experience (UX) design. Some researchers viewed

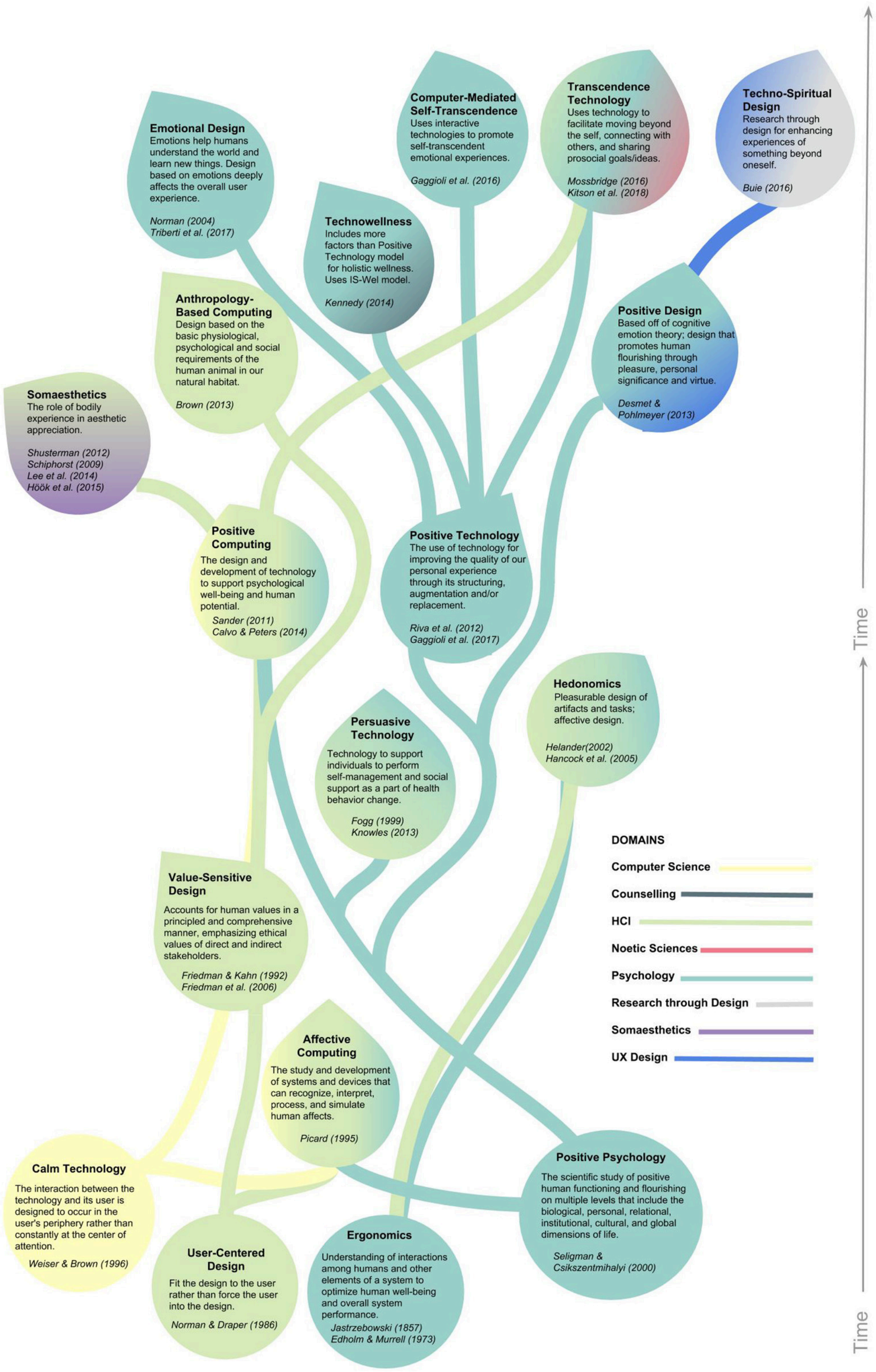

FIGURE 1 | Existing domains of technology for positive functioning and well-being: moving along the y-axis is the passage of time on a non-linear scale that depicts the growth of different fields that stem from the foundational three domains of Computer-Science, HCI, and Psychology. Each color represents a different domain; the stems show the progression of the domain, feeding into the next; and the leaves are colored by the influences from those domains. Leaves represent the first conceptualization of an approach, and do not imply the cessation of progress, e.g., Affective Computing was first introduced in the 1990s and is still relevant today.

Ergonomics as focusing on negatively framed constructs such as pain prevention, particularly in the workplace. In order to look at the same human-technology interaction problem from a different perspective, a group of researchers created Hedonomics, the science and design devoted to the promotion of pleasurable human-technology interaction (Helander, 2002; Hancock et al., 2005). In the mid 1980s, the term User-Centered Design was first coined by Donald A. Norman's work in their lab (Norman and Draper, 1986). This concept focused on putting the user's needs and wants at the forefront of the product rather than trying to force the user to adapt their existing behaviors. User-Centered Design was soon adopted into many fields as a way to incorporate user feedback throughout the design process and not only at the evaluation phase as was originally used. Friedman and Kahn (1992) introduced Value-Sensitive Design—developing technology by making decisions based on implicit and explicit values, and that values of both designers and users should be accounted for. Value-Sensitive Design guidelines were eventually developed with an ethical values framework in mind (Friedman et al., 2006). Meanwhile, in the domain of computer science, Weiser and Brown (1996) were developing a framework for designing the interaction between technology and user that had the technology seamlessly integrated without constantly being at the center of attention—Calm Technology. At the same time, Affective Computing used both physiological and psychological theories and both computer science and HCI lenses to support the design of technology that recognizes, interprets, processes, and simulate human affect (Picard, 2010). The seeds of both Computer Science and HCI contributed to fields of Positive Computing and Persuasive Technology as well (discussed above). Two other fields that emerged from the domain of HCI are Somaesthetics (Schiphorst, 2009; Shusterman, 2012) and Anthropology-Based Computing (Brown, 2013). Somaesthetics grounds itself in human bodily experience and movement to inform design, particularly the aesthetics of interaction. This approach has been adopted by many designers of technologies that support positive human functioning (for example: Lee et al., 2014; Höök et al., 2015). Anthropology-Based Computing uses basic human behavior in our natural habitat as a basis of designing technological systems.

Motivation

Overall, following the emergence and the advances in the field of human-computer interaction, many different research domains have been focusing on designing for human-technology interactions that support positive human functioning and well-being, as discussed above. The foci of HCI research have been greatly concerned with the question: How to aid and mediate the interaction between a user and a system in such a way to allow for more efficient accomplishment of a task, that being retrieving the information, or alleviating states (e.g., stress) that can prevent them from accomplishing a task. Furthermore, early technological developments were focused on performance and production from an Engineering and Computer Science standpoint of usability and information retrieval. With the advent of the informational age, HCI and Psychological theories came together to ground human-technology interactions in genuine human experience, emphasizing the stance of the user over the system. We can see these ideas and framework permeate into the UX and design space, leading to current trends of using immersive, interactive technologies for providing experiential accounts mediated through technologies that support positive human functioning and well-being. However, there is not a clear understanding of what this design space looks like and how we might move forward with all these approaches in mind. In continuing the trajectory laid out in **Figure 1**, we seek to understand how immersive, interactive technologies might elicit positive states and support positive change. We found that there exist a few review articles on interactive technologies for supporting mindfulness (Sliwinski et al., 2017), transcendence (Mossbridge, 2016), and health (Botella et al., 2017). However, there does not seem to be comprehensive reviews looking at immersive, interactive technologies in eliciting positive states and supporting positive change. This motivated us to perform a scoping review in order to explore the extent of the literature in this domain, and potentially inform the scope of a future systematic review. While mindfulness may fit into the idea of positive states and positive change, we differentiate ourselves by expanding and including *immersive, interactive experiences that support people on hedonic, eudaimonic, and social/interpersonal levels*, which are the three positive technology domains as put forth by Riva et al. (2012). Hedonic relates to pleasant sensations, eudaimonic focuses on meaning and self-realization, and social/interpersonal involves relations or communications between people. We emphasize the focus on immersive technologies because they have a high potential of influencing and transforming the user through increased presence, the physical feeling of being in the simulated environment, which then enhances the experience's effectiveness (Riva et al., 2007; Diemer et al., 2015; Cummings and Bailenson, 2016).

Defining Immersive, Interactive, and Well-Being

The term "immersion" has been discussed and used by researchers in the technology field for decades, yet there seems to still be some confusion because the term is so widely used to describe experiences in games (Brown and Cairn's, 2004; Ermi and Mäyrä, 2005), paintings (Grau, 2003), literature (Nell, 1988), and cinema (Bazin, 1967). Defining immersion is critical to our understanding of the relationship between the user and the virtual environment because it addresses the very notion of being in the context of such simulated environments (Grimshaw, 2013). Moreover, without a clear definition of the concept, results can be uninterpretable. Some researchers, particularly in the gaming field, view immersion as different facets: sensory-motoric immersion, cognitive immersion, emotional immersion, and spatial immersion (Bjork and Holopainen, 2005). Ermi and Mäyrä's (2005) SCI model of immersion consists of three components: sensory, challenge-based, and imaginative. These models of immersion seem to suggest that immersion is a psychological process. However, contemporary researchers of immersion (IJsselsteijn and Riva, 2003; Rettie, 2004; van den

Hoogen et al., 2009) roughly follow Slater and Wilbur's definition of system immersion as

> a description of a technology… that describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the sense of a human participant (Slater and Wilbur, 1997, p. 606).

Here, immersion appears to be less of a psychological process and more of a physical process where our bodies and senses are tricked into behaving and reacting like the virtual environment is real. A similar construct, presence, is then the psychological process of believing the virtual environment is real or the feeling of "being there" (IJsselsteijn and Riva, 2003). Following these definitions of immersion and presence, virtual lucidity, a term defined by Quaglia and Holecek (2018) is when a person is immersed (the virtual environment feels real) yet not present (knows the virtual environment is not real). This review is focused on the psychological factors determining presence; we note, however, that there are different theoretical accounts on the definition of presence and which factors influence it (Coelho et al., 2006; Triberti and Riva, 2016). Aligning ourselves with contemporary definitions, we also chose to follow Slater and Wilbur's definition of immersive as an objective property of the technology for the purposes of this review.

Steuer (1992) defines interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" (p. 14). Rubio-Tamayo, Barrio, and García have defined interactivity as

> the potential to receive information from the ensemble of our senses and to construct and configure an alternate reality or to simulate reality. Additionally, it is the potential to influence (in real time) in the digital environments, the objects and the narrative framed in it (Rubio-Tamayo et al., 2017, p. 11).

Non-interactive technological experiences such as web-pages, video instructions, guided mobile apps, 360 videos, and movies were excluded from this review. These applications can provide, from a certain point of view, a two-way flow of information between computer and user. However, they do not meet the definition proposed by Rubio-Tamayo et al. (2017) as having the potential to influence digital environments. Related to interactivity is the construct of embodiment, where cognition is shaped by the body (Varela et al., 1992; Markman and Brendl, 2005). Technologies can be embodied for their abilities to modify the cognitive factors regulating the experience of body and space (Riva et al., 2016).

Well-being refers generally to the interconnected dimensions of physical, mental, and social health of an individual. A few models in psychology attempt to understand and define well-being. First, is the *broaden-and-build hypothesis* that states positive emotions broaden people's momentary thought-action repertoires, and positive emotions build over time enduring psychological, intellectual, physical, and social resources (Fredrickson, 2001). Second, is the *self-determination theory* where autonomy, competence, and relatedness needs must be satisfied in order to foster well-being and health; and self-determined behavior is intrinsically motivated (Ryan and Deci, 2000). Third, *authentic happiness theory* postulates that pleasant life, engaged life, and meaningful life are the three concepts needed for well-being (Seligman, 2002). However, several limitations were found with this theory, and so he developed *PERMA-theory* (Seligman and Csikszentmihalyi, 2014): **P**ositive emotions (happiness, joy, excitement, satisfaction, pride, awe); **E**ngagement (flow); **R**elationships (work, familial, romantic, platonic); **M**eaning (purpose); **A**ccomplishments (success and mastery). In this review, we consider all of these conceptualizations of well-being in an attempt to discover as many immersive, interactive experiences that support well-being as possible.

Objectives and Research Questions

We Make Four Contributions in This Paper

First, we identify the design elements and interaction strategies that contribute to well-being and positive affective states. And, in this process, we unveil design nuances and note the obstacles users encounter in interacting with the particular XR technology, a term which includes virtual, augmented, and mixed realities. Second, we identify the input-output modalities of the system and the psychological outcomes of each study. Third, we present a framework for designing transformative experiences with immersive, interactive technologies whose goal is to elicit positive states and support positive human change. Fourth, we provide design considerations informed by the comparative analysis of the designs and a framework for future designs of positive interactive technologies with the goal of eliciting positive states and supporting positive change in users.

To assess the current state of the research in positive, immersive, interactive technologies, this scoping literature review will address two research questions:

RQ1: How can we most effectively employ different design elements and interaction strategies to support positive change in immersive, interactive technologies?
RQ2: What are the input and output modalities of immersive, interactive technologies that contribute to eliciting positive states?

METHODS

Scoping Review Protocol

We undertook this study as a scoping literature review based on guidelines proposed by Arksey and O'Malley (2005) and Levac et al. (2010). Scoping reviews are a process of mapping the existing literature or evidence base in order to identify research gaps and summarize research findings. Scoping reviews differ from systematic reviews in that they use broader research questions, inclusion/exclusion criteria can be developed post hoc, quality is not an initial priority, it may or may not involve data extraction, and synthesis is more qualitative and not typically quantitative (Armstrong et al., 2011). Still, both scoping and systematic reviews require rigor and time to complete. We decided on a scoping review over a systematic review because our research questions are explorative and our objective is to map the literature with a broad viewpoint, rather than to respond to narrow research questions. We registered our review on PROSPERO—registration # CRD42018082752. The following steps were taken in accordance to the scoping guidelines:

1. Identify the research questions,
2. Identify relevant studies,
3. Study selection,
4. Charting the data,
5. Collating, summarizing, and reporting results.

Identifying Relevant Studies

A systematic search of the literature was performed in four academic databases that were considered the most relevant due to their focus on HCI: ACM Digital Library, Web of Science, Design and Applied Arts Index (DAAI), and IEEE Xplore (IEEE/IET Electronic Library). Google Scholar was used as an additional academic search engine to ensure all relevant articles were found.

The search was focused on immersive and interactive technologies and experiences, which included virtual, augmented, and mixed realities, otherwise known as "XR." The XR experiences were related to positive well-being and not on clinical interventions relating to treating disease. We sought articles from any time until January 2018, the end of this search. We utilized the retrieval of relevant articles with the following search terms based on the definitions of immersive, interactive, and well-being for technologies:

> ("immersive" OR "interactive" OR "virtual realit*" OR "augmented realit*" OR "mixed realit*" OR "extended realit*") **AND** ("well-being" OR "wellbeing" OR "well-being" OR "wellness" OR "positive" OR "emotion*" OR "social" OR "autonomy" OR "competence" OR "relatedness" OR "pleasant" OR "engag*" OR "meaning*" OR "happiness" OR "joy" OR "excitement" OR "satisfaction" OR "pride" OR "awe" OR "flow" OR "relationship*" OR "purpose" OR "success" OR "mastery").

The first part of the search index includes technologies that are immersive and interactive. The second part includes terms taken directly from well-being theories: broaden-and-build model (Fredrickson, 2001), self-determination theory (Ryan and Deci, 2000), authentic happiness theory (Seligman, 2002), and PERMA theory (Seligman, 2012). We also decided to include the following search terms, which were part of a sub-search, based on the theoretical approaches we described in the introduction and list in **Figure 1** because they are directly related to supporting positive human functioning and well-being with technology:

> ("tech*" OR "computing") **AND** ("change" OR "support tool" OR "connection" OR "calm*" OR "essential self" OR "transcenden*" OR "transformative" OR "self-transcend*" OR "consciousness hacking" OR "UX for good" OR "spiritual" OR "persuasive" OR "lovingkindness" OR "metta" OR "mindful*" OR "meditat*").

We applied this search string to the title, abstract, full-text, and author keywords. Applicable articles were also identified through backward reference searching, i.e., by screening the reference lists of retrieved publications. Google Scholar was utilized for the backward reference searching to run general searches of specific references and to identify relevant articles.

Study Selection

Peer-reviewed articles as well as scholarly work such as dissertations, theses, and conference proceedings with the following characteristics, published from the beginning of the literature until January 2018, were included:

- written in English,
- having at least one immersive and interactive technology,
- having a goal to improve well-being.

We included other scholarly work, i.e., dissertations, theses, and conference proceedings, because these works were also relevant to the field, they often report studies that can be important for our research questions, and we wanted to be comprehensive in our study selection. Blog entries and websites, although can be insightful and managed by scholarly affiliations, were excluded because they often do not report studies and are difficult to compare to other literature types. Immersive, interactive technologies were chosen as the appropriate setups in order to keep the review the most up to date, and because they are relevant for transformative experience design. The immersive, interactive experiences themselves needed to include a well-being component or focus on positive human functioning in order to relate to the core elements of transcendent experiences.

Consequently, articles with the following characteristics were excluded:

- using exclusively desktop-based, tablet-based, or mobile virtual environments,
- non-interactive experiences,
- addressing solely conceptual matters, such as theoretical models, frameworks, reviews, etc.,
- using immersive, interactive technology as a tool for studying a different, unrelated topic.

The screening process and its results are visualized in **Figure 2**. The first and second author screened the results independently and then compared agreement. If there was a discrepancy, then the third author was consulted. The initial search elicited 984 articles from the four databases and four from the reference review, which were retrieved with Google Scholar. One hundred and three duplicates were identified and removed, leaving 885 articles to be screened. The initial screening of studies was based on their abstracts and titles, excluding noticeably irrelevant studies based on the inclusion/exclusion criteria listed prior. In total, 209 articles were identified as appropriate for inclusion, and they were moved to the second screening round. The second round of screening was based on the full text of the articles and the first and second authors independently reviewed each using the inclusion/exclusion criteria set before the search, as suggested by Levac et al. (2010). In total, 29 articles were identified as appropriate for inclusion and relevant to the current review. The authors reviewed all 29 articles independently. All reviewers together conjointly shaped the categories and themes of the review, based on the data extraction process. The authors discussed and settled any disagreements of the qualitative synthesis of the review before writing the final narrative.

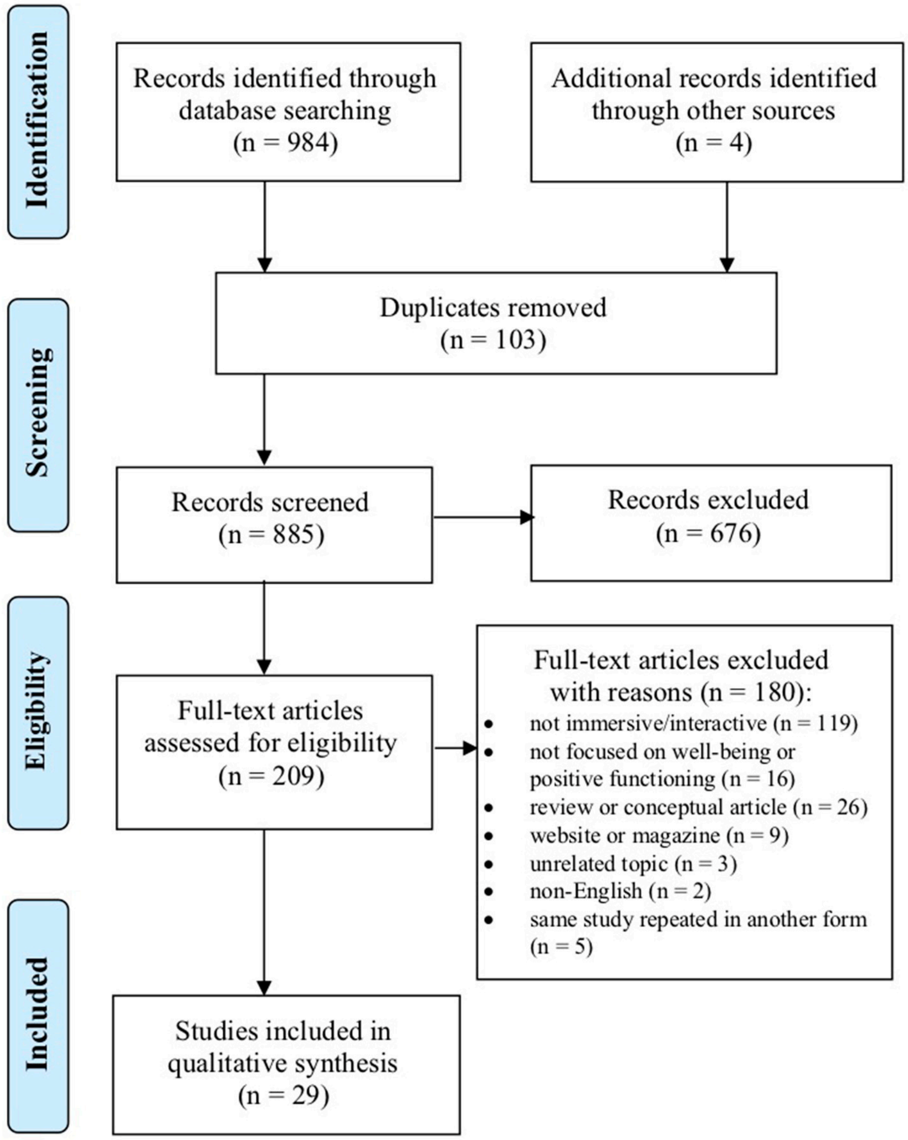

FIGURE 2 | Flowchart of the included and excluded articles from the assessment of screening and eligibility process.

Charting the Data

The screening process resulted in 29 articles that satisfied the inclusion criteria. The data extracted from each article were the following:

1. source and full reference
2. description and name of the immersive interactive system
3. relevance to well-being and positive functioning
4. type of XR
5. technology used
6. platform
7. target user
8. number of users in study
9. input/output modalities
10. design elements and interaction strategies used
11. outcome
12. how design elements and interaction strategies contributed to support positive change and/or elicit positive states

See **Supplementary Material** for a detailed table of the data extracted. If data were missing, the study authors were contacted. The first author performed the data extraction process.

Collating, Summarizing, and Reporting the Results

The collected data were synthesized by identifying themes emanating from information reported in each accepted paper and related to the research questions. Themes were classified into a concept matrix to facilitate comparisons. A concept matrix provides the transition from an author-to-concept-centric literature review, provides structure and helps in clarifying the concepts of the review for the reader.

The main themes identified were as follows:

- The design elements and interaction strategies used (addressing RQ1)
  - the article's relevance to positive functioning
  - how these elements and strategies support positive change
- Input/output modalities (addressing RQ2)
  - the type of XR
  - the technology used
  - the platform
  - the outcome

These themes were based on the description provided in the articles, as crosschecked with other related and/or peer reviewed publication in the field to establish their scientific soundness, mainly toward nomenclature and interaction features. Next, the identified themes were normalized and classified so they would be easily comparable and fit into the concept spreadsheet in a valid and lossless way. Comparative studies that included two or more immersive, interactive experiences were tabulated in a respective number of rows.

In order to assess risk of bias (quality), we used the Downs and Black 26-item QAT scale (Downs and Black, 1998). A review article looked at 60 research evaluation systems and identified the Downs and Black checklist as one of the best evaluation systems available (Deeks et al., 2003). The Downs and Black checklist provides an overall quality index and four sub-scales of quality assessment: reporting, external quality, internal validity bias, and internal validity confounding. Answers are scored 0 or 1, except for one item that scored 0–2 making the maximum score possible 27. Generally speaking, scores are considered "excellent" (24–28 points), "good" (19–23 points), "fair" (14–18 points) or "poor" (<14 points).

RESULTS

Of the 29 articles found in the scoping review process, some articles contained multiple systems and studies. Thus, we documented 33 immersive, interactive experiences relating to positive human functioning. However, we excluded 13 of those 33 XR experiences in the Downs and Black analysis because they were only proof of concept and did not have any participants, thus rendering the scale irrelevant. Therefore, we examined the remaining 20 experiences using the Downs and Black QAT scale. For the overall quality index, i.e., all 26 items comprising all sub-scales, a maximum score of 27 was possible. For the 20 experiences examined, the average overall quality index was 17.4 (SD = 2.96) with scores ranging from 12 to 23. Based on interpretations of this scale, these studies are considered fair to good with only one study performing poorly in terms of validity and reliability. One possible reason for the wide spread of scores is because the studies were for different audiences. For example, a psychology study might use similar metrics to the Downs and Black scale to assess quality and thus have a higher score compared to a user study or art installation that uses a different set of metrics to assess quality. Moreover, this metric was designed for medical intervention studies, which require a high degree of methodological quality; this is not necessarily the aim many of these articles we found here. Nonetheless, these results do show the range in methodological quality in the field and perhaps in the future researchers might consider using a similar metric to provide more rigor in their user study analyses.

Design Elements and Interaction Strategies

The 12 main themes that inform the design elements and interaction paradigms of the 33 documented immersive, interactive experiences are presented as follows.

- **Breath awareness**: Users' respiration data (inhale/exhale cycle) were recorded through either a respiration belt or microphone. These data were then employed in interaction design for users to become more mindful of their bodily processes (Davies and Harrison, 1996; Shaw et al., 2007; Hinterberger, 2011; Vidyarthi, 2012; Bal, 2013; Kitson et al., 2014; Prpa et al., 2015, 2016, 2017; Muñoz et al., 2016; Roo et al., 2016; Du Plessis, 2017) or achieve a relaxing state (van Rooij et al., 2016; Patibanda et al., 2017).
- **Concentration or focused attention:** Users' awareness of the present moment was supported through design that helps users bring their attention back when they have distracting thoughts. This was achieved explicitly through biofeedback (Shaw et al., 2007; Prpa et al., 2015, 2016; Amores et al., 2016; Kosunen et al., 2016; Muñoz et al., 2016) or implicitly by visual or auditory cues (Gu and Frasson, 2017; Navarro-Haro et al., 2017).
- **Connection:** Users can feel a sense of belonging and relatedness through telepresence and communication (Garau et al., 2003; Angelini et al., 2015; Sakamoto et al., 2015; Seaborn, 2016; Bernal and Maes, 2017; Quesnel and Riecke, 2017).
- **Emotional expression:** Emotions of the users can be expressed through audio and visual mappings, mainly through capturing physiological markers such as arousal (Bernal and Maes, 2017) and joy (Hinterberger, 2011).
- **Feedback of performance:** Users received some form of information about their performance. Feedback was given as virtual movement (Davies and Harrison, 1996; Amores et al., 2016; Kosunen et al., 2016; Du Plessis, 2017), change in visuals (Shaw et al., 2007; Hinterberger, 2011; Bal, 2013; Choo and May, 2014; Gromala et al., 2015; Prpa et al., 2015, 2017; Kosunen et al., 2016; Roo et al., 2016; van Rooij et al., 2016; Patibanda et al., 2017), or change in audio (Shaw et al., 2007; Hinterberger, 2011; Vidyarthi, 2012; Kitson et al., 2014; Prpa et al., 2015, 2016, 2017; Muñoz et al., 2016; Gu and Frasson, 2017).
- **Mind-body dialogues:** Users were able to explore the connection between their physical and mental states, the idea being that one similarly affects the other. A calm body breeds a calm mind: (Shaw et al., 2007; Bal, 2013; Gromala et al., 2015; Prpa et al., 2015; Kosunen et al., 2016; Muñoz et al., 2016;

Roo et al., 2016; van Rooij et al., 2016; Du Plessis, 2017). To change ourselves, we need to change our perspectives: (Davies and Harrison, 1996). Color transmits and translates emotion (Wiethoff and Butz, 2010; Hinterberger, 2011). Music is the mediator between the spiritual and the sensual life: (Vidyarthi, 2012; Kitson et al., 2014; Prpa et al., 2016, 2017).

- **Mindfulness meditation:** These experiences involved paying attention on purpose, in the present moment, and nonjudgmentally. Users were guided through a narration (Shaw et al., 2007; Choo and May, 2014; Prpa et al., 2015; Gu and Frasson, 2017; Navarro-Haro et al., 2017) or had the chance to playfully discover meditation practice unguided (Davies and Harrison, 1996; Vidyarthi, 2012; Bal, 2013; Kitson et al., 2014; Gromala et al., 2015; Amores et al., 2016; Kosunen et al., 2016; Prpa et al., 2016; Roo et al., 2016; Du Plessis, 2017), while another experience incorporated but was not explicitly about mindfulness meditation (Chittaro et al., 2017).
- **Movement:** Users physically moved their bodies in order to interact with the system. Movement was used as a way to promote health (Eubanks, 2011; Seaborn, 2016) and also further immerse the user in the virtual space through embodiment (Davies and Harrison, 1996; Bal, 2013; Sakamoto et al., 2015; Quesnel and Riecke, 2017).
- **Nature elements:** These experiences involved some aspects of nature. Some experiences used water as a visualization (Bal, 2013; Sakamoto et al., 2015; van Rooij et al., 2016; Gu and Frasson, 2017; Prpa et al., 2017), while others used animals (Shaw et al., 2007; Eubanks, 2011; Sakamoto et al., 2015). A common theme was using park or garden elements (Choo and May, 2014; Angelini et al., 2015; Roo et al., 2016; Chittaro et al., 2017), while other experiences focused more specifically on trees and the forest (Davies and Harrison, 1996; Gromala et al., 2015; Patibanda et al., 2017). One experience used a sunset scenery (Shaw et al., 2007), and another used the entire Earth (Quesnel and Riecke, 2017).
- **Physiological measures:** Use of instruments that provide information on physiological functions in order to gain greater awareness of internal states of a user. The processes can include brainwaves (Hinterberger, 2011; Choo and May, 2014; Prpa et al., 2015, 2016; Amores et al., 2016; Kosunen et al., 2016; Du Plessis, 2017; Gu and Frasson, 2017), skin temperature and conductance (Shaw et al., 2007; Hinterberger, 2011; Gromala et al., 2015; Bernal and Maes, 2017; Du Plessis, 2017), respiration (Davies and Harrison, 1996; Shaw et al., 2007; Hinterberger, 2011; Vidyarthi, 2012; Bal, 2013; Kitson et al., 2014; Prpa et al., 2015, 2016, 2017; Roo et al., 2016; van Rooij et al., 2016; Du Plessis, 2017; Patibanda et al., 2017), and heart rate and heart rate variability (Shaw et al., 2007; Hinterberger, 2011; Muñoz et al., 2016; Roo et al., 2016; Bernal and Maes, 2017; Chittaro et al., 2017).
- **Playfulness:** Users were invited to interact with the system that supports curiosity and creativity in order to make the experience as inviting and non-invasive as possible. This was achieved through exploring a narrative (Eubanks, 2011; Amores et al., 2016; Muñoz et al., 2016), employing gaming mechanics (Choo and May, 2014; Sakamoto et al., 2015; Muñoz et al., 2016; Seaborn, 2016; van Rooij et al., 2016; Patibanda et al., 2017), and using active and imaginative elements (Wiethoff and Butz, 2010; Hinterberger, 2011; Vidyarthi, 2012; Kitson et al., 2014; Prpa et al., 2015, 2016, 2017; Roo et al., 2016).
- **Social presence:** Users interacted with other users at the same time (Angelini et al., 2015; Sakamoto et al., 2015; Seaborn, 2016; Bernal and Maes, 2017) or avatars that felt as if they were real people (Garau et al., 2003).

Physiological measures ($N = 21$), feedback loop ($N = 19$), and mind-body dialogues/mindfulness-meditation/play (all $N = 16$) were the design elements or interaction strategies most utilized. These results can inform the answer to RQ1.

Input/Output Modalities

To address RQ2, we extracted the input-output modalities of the experiences, the type of XR, the technology employed, and the platform used. The type of XR and technology employed can be seen in **Figure 3**. For a more detailed description of these data, we also created a table (see **Supplementary Material**) that shows both the technology and the platform used by each system individually, grouped by XR type. In terms of the input-output modalities, we grouped all the immersive, interactive positive experiences and categorized them into three high level themes: biofeedback, physical movement, and controller. Within each of these three high level themes were different input modalities. For biofeedback, this contained four types of inputs: blood flow changes, skin electrical activity, respiration rate, and brain electrical activation (see **Figure 4**). The physical movement theme contained three input types: arm, body, and head. The controller theme had two input types: joystick and screen. We then mapped these inputs to output modalities. We grouped the outputs into six different themes: change in music/audio, change in light/color, change in object appearance/animation, object movement, levitation/floating, and user movement. Finally, we mapped the six different types of outputs to 16 types of outcomes: relaxed, content/happy, reflected affect, increased mindfulness, harmony/balance, appreciation, calm, decreased stress/anxiety, connection/empathy, clarity, focus, increased well-being, emptiness/disembodied/self-transcendence, engaged, presence/social presence/embodied, and increased risk perception. A depiction of the input-output-outcome modalities can be found in **Figure 5** and also accessed online here: https://akitson.github.io/.

DISCUSSION

Immersive interactive technologies have, so far, mainly been developed for applications such as entertainment and training. However, the potential for these technologies is vast and we are beginning to see the direction of the field shift toward more experiences of supporting positive human functioning and change (Fogg, 1999; Schiphorst, 2009; Sander, 2011; Riva et al., 2012; Brown, 2013; Desmet and Pohlmeyer, 2013; Kennedy, 2014; Buie, 2016; Gaggioli, 2016; Mossbridge, 2016). There are similar, yet separate, movements from different domains such as HCI, Psychology, and Computer Science all going toward this same

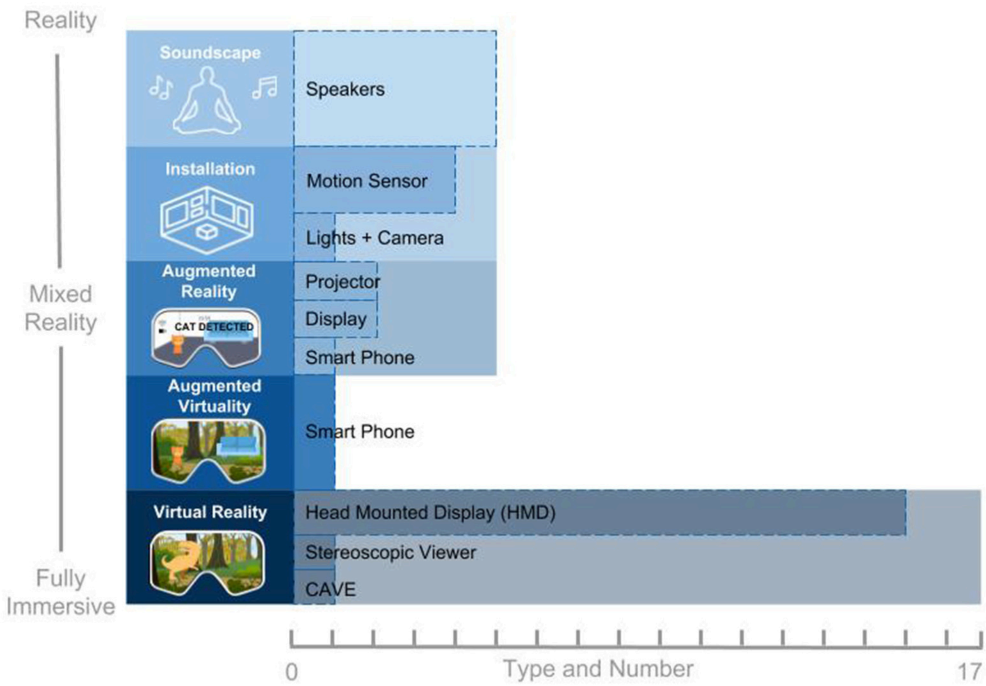

FIGURE 3 | The type and number of immersive, interactive experiences for positive functioning (x-axis). Types of immersive, interactive experiences are categorized on a virtuality continuum (y-axis) that increases in immersive properties from soundscape (least immersed) to virtual reality (fully immersed). Each type is broken down into the kind and number of technology used, and this is represented as the dotted bars within the larger bars representing the total number of experiences.

goal of designing and creating technologies that support positive human functioning (Norman and Draper, 1986; Weiser and Brown, 1996; Seligman and Csikszentmihalyi, 2014). Yet, there is not a clear overview of all of these domains and what they have contributed so far. The diversity of the domains could be one reason there has not been a general XR for positive change review. In general, the current scoping review showed that the recent resurgence of XR technologies that are low-cost and accessible offered an opportunity to explore the medium further. Moreover, it enabled designers and technologists that ability to create more experiences, thus providing grounds for a comparison and analysis of the design elements and interaction strategies used, as well as the input-output-outcome modalities. Overall, the authors find this review shows promise for a new era of XR for positive change and that there exist enough experiences for researchers to map it and further develop significant conceptual knowledge for the research community and the public.

Design Elements and Interaction Strategies for Supporting Positive Change in Immersive, Interactive Technologies

We can make several observations from the reviewed and studied XR design elements and interaction strategies in section Design Elements and Interaction Strategies.We have organized the above 12 themes into four higher-level themes: instruments of analysis, phenomena and theoretical constructs, content features, and physical activity.

Instruments for Analysis

First, **physiological measures** and **feedback of performance** are the most prevalent elements. There is considerable overlap between these two elements with all but one experience making use of physiological measures as a means to provide feedback on performance. Since its inception in the 1970s, biofeedback has been gaining popularity due to its use as a supporting mechanism that can offer explicit insights about the user's state and can guide a user to change their thoughts, emotions and behavior (Schwartz and Andrasik, 2017). However, biofeedback has been mainly used as a form of treatment in medicine and psychology and we have only recently seen more applications to immersive, interactive experiences; and this may be in part due to the dispersion of increasingly affordable and consumer-friendly physiological devices. The literature review also showed a preference for experiences using mind-body dialogues and mindfulness meditation interaction strategies. Both of these elements emphasize focusing on the body and noticing any sensations, thoughts or feelings that happen in the present moment (Kabat-Zinn, 2003). Studies have shown numerous benefits for mindfulness meditation such as reducing depression symptoms, stress, and anxiety (Chiesa and Serretti, 2010). Moreover, the same mindfulness processes understood by Buddhist traditions for many years have been brought to psychology and now to human-computer interaction design. Thus, it is perhaps not surprising that immersive, interactive technologies make use of these concepts to support positive change because they can provide a space one might not otherwise

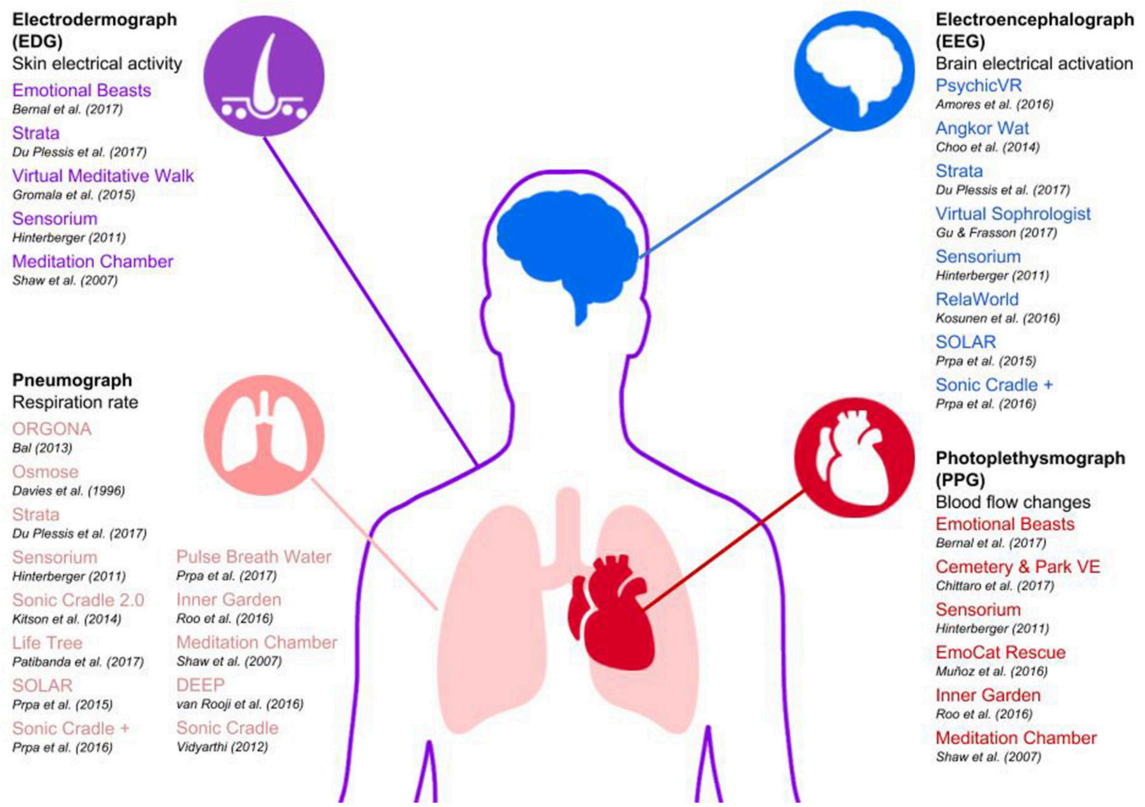

FIGURE 4 | Biofeedback types and their corresponding immersive, interactive experiences. There are four types of biofeedback represented: electrodermograph (EDG), pneumograph (respiration rate), electroencephalograph (EEG), and photoplethysmograph (PPG). The names of the experience along with the author's name is listed. Some experiences are listed multiple times, indicating they used multiple types of biofeedback in their system.

have access to explore their own internal bodily states. In fact, many experiences from the review also made use of two elements very closely related to mindfulness and mind-body dialogues: breath awareness and concentration or focused attention. Breath is often seen as an integral part of mindfulness meditation because it provides a focus point to bring one's attention back to the present moment when the mind wanders. Thus, bringing one's attention back to the breath, or some other focus of attention, works the mind and we gain more control over our internal states with each practice.

Phenomena and Theoretical Constructs

Another observation is that **emotional expression**, **connection**, and **social presence** are not studied or utilized as much as mindfulness meditation. One might expect more experiences with these elements given both that social integration and connectedness are important components in many psychological frameworks of well-being and positive human functioning (Ryff, 1989; Seligman, 2012; Venter, 2017), and that there is a movement in several domains to use technology as more than a distraction or consumption device and instead use it to connect with others as a part of health behavior change (Riva et al., 2012; Brown, 2013; Calvo and Peters, 2014; Kennedy, 2014; Mossbridge, 2016). Moreover, Höök has proposed the affective loop, where the system affects the user and the user affects the system (Höök, 2008). This represents a gap that can be addressed by future developments of immersive, interactive technologies for positive change.

Content Features

Nature was another common design element in the immersive, interactive experiences we reviewed. Research evidence suggests that connecting with nature is one path to flourishing in life and positive mental health (for a review see Capaldi et al., 2015). We found similar benefits of enhanced mood, reduced stress, and increased well-being across the XR experiences that involved nature. Thus, it appears that the benefits of being in contact with nature can be replicated in a virtual or augmented environment. This is promising for using XR experiences to help support positive change for those who cannot have much access to nature or the outdoors, such as those in urban areas or in medical facilities.

Physical Activity

Finally, about half of the experiences included in this review used the interaction strategies of **play** and **movement**. We can draw similarities between these elements and several existing theories: somaesthetics, the importance of the role of bodily experience

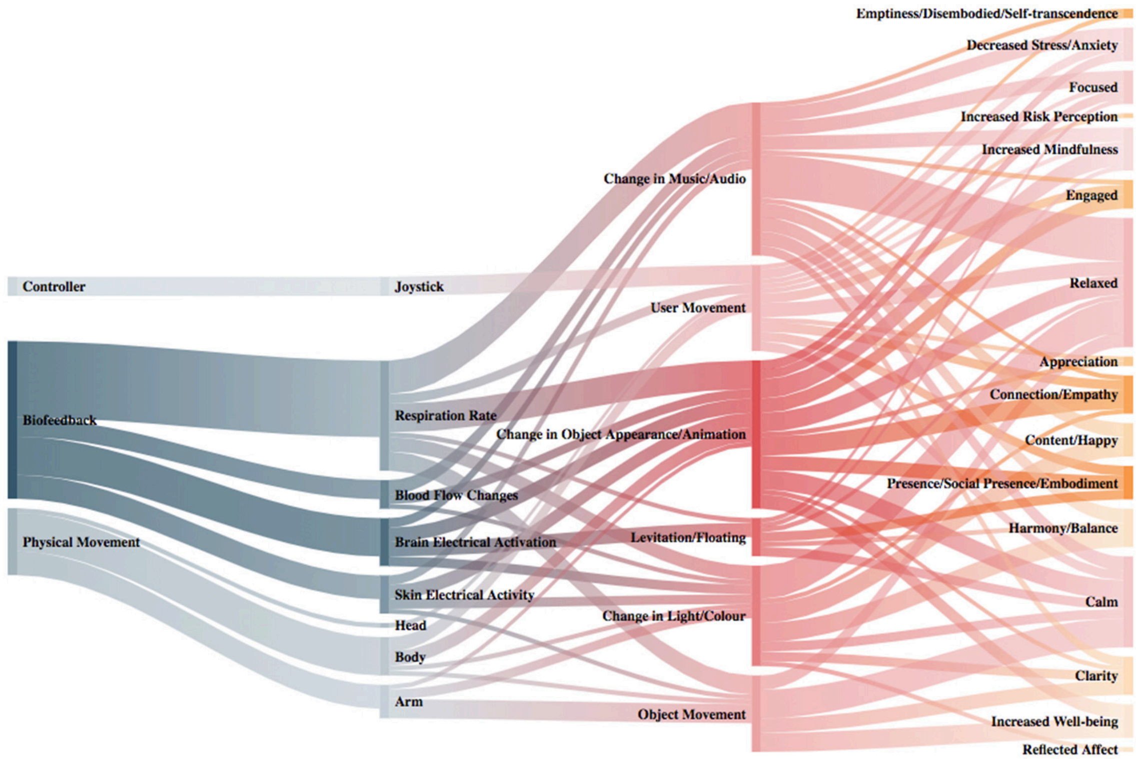

FIGURE 5 | Sankey diagram showing the input-output modalities and their corresponding outcomes for all experiences. Please note that some experiences use multiple types of input-output modalities, and some inputs correspond to multiple outputs and outcomes. Color intensity and stroke breadth indicate number of experiences for that category going left to right. This figure represents a static image of the data. For an interactive diagram that shows the number of experiences for each category, please see https://akitson.github.io/.

in aesthetic appreciation (Schiphorst, 2009; Shusterman, 2012); embodied cognition, our mental constructs are shaped by aspects of the body (Varela et al., 1992; Markman and Brendl, 2005); play, in being creative we can reach across domains of meaning and forge new conceptual connections leaning to insight or cathartic release (Clark, 2013); and game play, gaming activities embody immense concentration, enjoyment, relationships, and accomplishment that can lead to improved mood, reduced emotional disturbance, improved emotion regulation, relaxation, and reduced stress (Jones et al., 2014). Future XR experiences aimed at supporting positive change would be strengthened by incorporating these theories from other disciplines because they have already demonstrated their effectiveness for supporting flourishing and positive mental health.

Input-Output Mappings of Immersive, Interactive Technologies for Eliciting Positive Change

Immersive, Interactive Technologies

The review of technologies and platforms focused strongly on virtual reality (VR) technology. Therefore, it is perhaps unsurprising that VR, particularly the use of head-mounted displays (HMDs), is the most prevalent type of technology that we find compared to other mixed reality experiences. Immersive soundscapes are the second most common type of technology used for eliciting positive states. The use of other XR technologies along the mixed reality continuum of immersion seem to have been overlooked. One possible explanation could be that HMDs are being made increasingly more affordable and accessible, while also improving in overall quality; other mixed reality technologies are still in their infancy and lack the development support for designers to more easily create experiences. The authors would like to emphasize that simply because VR is currently the most prevalent technology used in eliciting positive states does not necessarily mean it is the best platform. Each design requires careful consideration of the intended experience and specific outcomes when selecting a platform, taking into account the context and its users, and more research is needed for determining the "best" platform for eliciting positive change.

Input

The review of input-output modalities showed that physiological data was the most predominant type of input, followed by physical movement and then controller (see **Figure 5**). When breaking down the type of biofeedback used, we found that respiration rate was overwhelmingly the most utilized type ($N = 16$). Measuring respiration rate is relatively non-invasive and the data is reliable compared to the other types of biofeedback such as EEG; this may partially account for its high use. As was discussed previously, breath is an important component in mindfulness meditation and a reliable way to decrease stress. Therefore, using respiration rate as an input is congruent with the mindfulness and mind-body dialogue interaction strategies used in these experiences for positive change.

One observation we made about the type of input is that there was a low number of experiences using controllers, such as joysticks or touch screens. This might be surprising considering that much of the XR industry is being fueled by entertainment and gaming applications that make use of traditional controller-based inputs. This review perhaps demonstrates that traditional controllers do not map well to eliciting positive states. We hypothesize this is due to controllers' arduous nature that might lead to a break in presence, immersion and flow, and subsequently distracting from the goal of eliciting positive states. However, further research is needed.

Physiological input was very prevalent in the studies and experiences we reviewed, with 34 instances of mappings involving physiological input. And, although there are many benefits to using physiological measures such as getting a more empirical measures of users' inner states, there are also several shortcomings that we would like to highlight in this review for designers and research hoping to use physiological measures in their XR experiences. First, there can be considerable noise in the data, especially EEG measures of brain electrical activation (Ramirez and Vamvakousis, 2012). Moreover, wearing physiological sensors might feel cumbersome to the user, which may distract from the desired user experience.

Output

Change in object appearance/animation was by far the most common type of output ($N = 18$), compared to change in music/audio ($N = 14$), change in light/color ($N = 11$), object movement ($N = 10$), user movement ($N = 10$), and levitation/floating ($N = 4$). Changes in music/audio and changes in object appearance/animation were more likely to be matched with respiration and relaxation or calm, whereas object and user movement were more likely to be matched with engagement and clarity. These outputs are in keeping with the literature: breath meditation can lead to relaxation and calmness (Carter and Carter, 2016), and physical activities can bring about engagement and positive health outcomes (Gao et al., 2015). The current state of the XR technology is primarily focused on visuals, so it is not surprising to find most experiences using this in their interactivity. Audio and music are also easily modified through speakers and headphones. One observation is that some of the other human senses are underutilized, such as smell, touch, and temperature. Some experiences make use of tangibles (Angelini et al., 2015; Sakamoto et al., 2015; Roo et al., 2016), but there is still a lot of work to be done in going outside visuals and audio for XR interactivity. In terms of well-being, emotion and memory are closely linked with the olfaction; odors that evoke positive autobiographical memories have the potential to increase positive emotions, decrease negative mood states, disrupt cravings, and reduce physiological indices of stress, including systemic markers of inflammation (Herz, 2016).

Outcome

Finally, the outcomes of using respiration rate as an input were relaxation, calmness, increased well-being, and decreased stress/anxiety. From these results, it appears that the main mechanism for eliciting positive states is through using biofeedback that is mapped to some kind of change in sensation in the XR environment, whether that be a change in music/audio, light/color, or object appearance/animation; this feedback of physiological performance then allows users to experience an internal state from a different perspective and thus start to form the ability to change that state. It appears that practicing an awareness and control of one's internal physiological states can lead to positive states such as relaxation, calmness, harmony/balance, clarity, focus, and increased well-being. From this mapping we saw that the outcomes were calmness, contentment/happiness, presence/embodiment, and engagement. Thus, the physical and virtual movement connection seems to have contributed to eliciting positive states. And, when we look at the interaction strategies employed for these systems, we see play and movement are important. This is, the sense of curiosity, imagination, and embodiment in these experiences are all common themes and elements that allow the user to explore a system in a more natural and familiar way than a more abstract way of interacting like the traditional joystick. This idea of natural interaction supporting the desired user experience of curiosity, imagination, and embodiment in XR is maintained by several studies (Beckhaus et al., 2005; Macaranas et al., 2015; Desai et al., 2016; Quesnel and Riecke, 2017).

A Framework for Immersive Interactive Technologies for Positive Change

Several frameworks have already been proposed for designing technologies for eliciting positive human functioning and well-being: Anthropology-Based Computing (Brown, 2013); Techno-spiritual Design (Buie, 2016); Positive Computing (Sander, 2011; Calvo and Peters, 2014); Positive Design (Desmet and Pohlmeyer, 2013); Persuasive Technology (Fogg, 1999); Computer-mediated Self-transcendence (Gaggioli, 2016); Technowellness (Kennedy, 2014); Transcendence Technology (Mossbridge, 2016); User-centered Design (Norman and Draper, 1986); Positive Technology (Riva et al., 2012); Calm Technology (Weiser and Brown, 1996); Affective Computing (Picard, 1995); Ergonomics (Jastrzebowski, 1857; Edholm and Murrell, 1973); Hedonomics (Helander, 2002); Value-Sensitive Design (Friedman and Kahn, 1992); Emotional Design (Norman, 2004)—see also **Figure 1**. However, these frameworks do not focus on immersive, interactive technologies (XR) in particular. Therefore, we offer a more focused and concrete framework for designing immersive, interactive technologies for eliciting positive states and supporting positive change (see **Figure 6**). This framework is constructed from the results of this scoping review: the interaction strategies and design elements, the input-output modalities that incorporate the use of XR technology, and

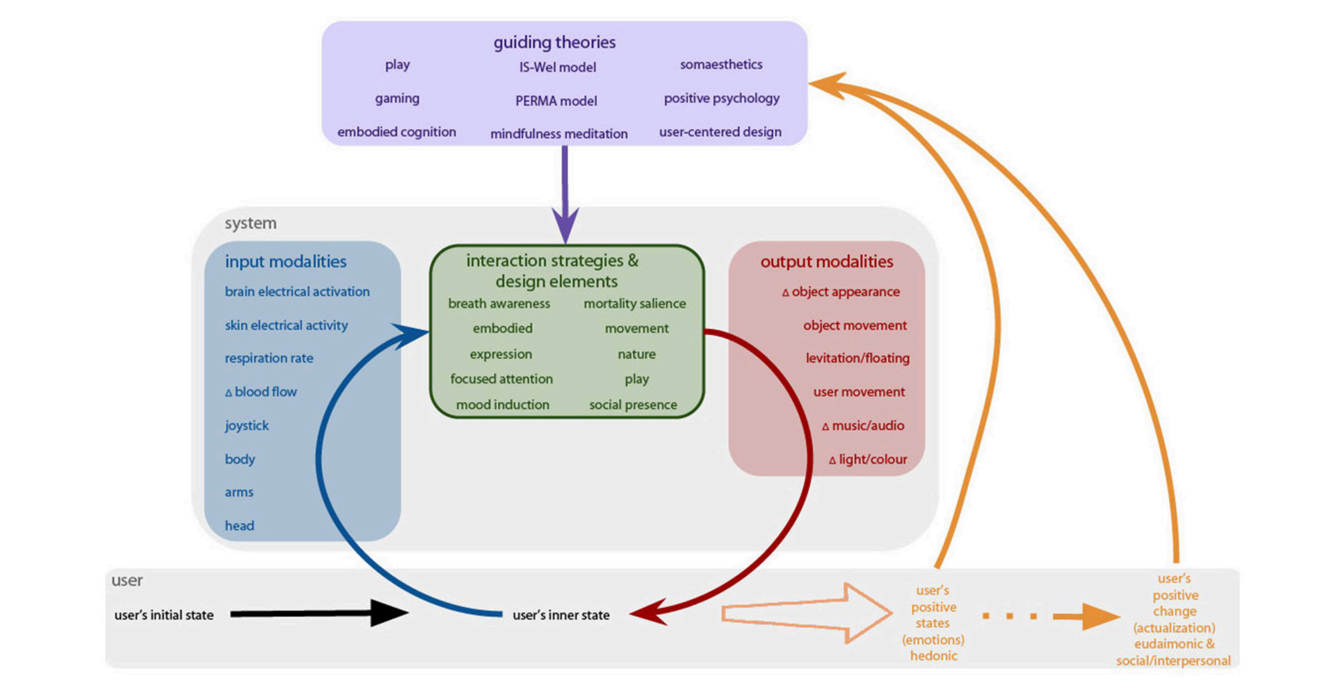

FIGURE 6 | A schematic of the framework for designing immersive, interactive experiences for eliciting positive states and supporting positive change.

the outcomes that resulted from the user's interaction with the system.

The designer or researcher has positive state(s) or positive change in mind as the outcome (orange). These outcomes will influence the theories and models considered when designing the experience (purple). Those theories in turn will help to inform the interaction strategies and design elements used (green). And, the interaction and design elements will then inform the feedback loop of input (blue) and output (red) modalities. Therefore, when the user is put into the system, their inner state is measured and collected via physiological measures and movement data. These data of the user's inner states are then fed into the system and represented/externalized in an abstracted way as the output modality. The user then experiences their own inner state that can change their initial state is then fed back into the system. Thus, the system and the user influence one another. This feedback loop over time can build positive experiences and contribute to a positive state. Eventually, this feedback loop shapes positive states, which then might lead to positive change in the user.

Design Considerations for Future Immersive Interactive Technologies for Positive Change

In addition to the themes listed and discussed above, which might be useful as descriptive tools for researchers, we now present a set of prescriptive design considerations to serve as tools for designers and developers interested in creating immersive, interactive systems, and experiences with the goal of eliciting positive states and supporting positive change. We want to note, however, that no formula exists to make someone have a given experience. We can only submit our best practices for giving the user suitable conditions and opportunities for them to engage if they wish.

Consider the Outcome and Human Experience First, Then Work Backwards

The intention or goal behind your work will shape every design decision, so it is important to have a clear sense of what specific positive state or positive change you wish to support with the XR technology. Trying to force the user to accommodate a technology that is not in keeping with their natural way of interacting and experiencing the world, even if it is a virtual one, can lead to frustration, negative emotions, and disconnect; this is in keeping with user-centered design and the existing frameworks for supporting positive functioning through technology (Norman and Draper, 1986; Fogg, 1999; Riva et al., 2012; Calvo and Peters, 2014).

Consider Using Sensory Changes to Support Relaxation, Contentment, and Harmony/Balance

Our results of the scoping review for the input-output modalities (RQ2) suggest that specific changes in either music/audio, object appearance/animation, or light/color can be associated with outcomes of relaxation, contentment, and harmony. These positive states are more subdued in feeling; therefore, the changes in the virtual environment too are subtle yet obvious enough to the user that there is in fact a change occurring. Hinterberger (2011) uses changes in light and sound to achieve all three of these positive states, while both Shaw et al. (2007) and Gromala et al.

(2015) use changing imagery of jellyfish and fog, respectfully, to support relaxation. These sounds, animations, and colors used in the XR experiences all seem to support their desired outcome in some way, whether that be red colors for engagement, soft music with a low tempo or a setting sun for relaxation.

Consider Using Movement to Support Calmness, Clarity, and Focus

Results showed that movement of any kind, i.e., user movement and object movement, was linked to positive states of calmness, clarity, and focus. More specifically, big sweeping physical movements of the user, and expanding/contracting of virtual objects in rhythm with the user's input helped to support positive states of calmness, clarity, and focus. This result is perhaps due to a release of bodily tension and stress, though more research is needed. These positive states are more active than the ones mentioned above because the user is physically engaged in the experience. Bal's (2013) ORGONA project serves as a good example of using physical movement to support these three positive states because the user engages their body and focuses on their breathing to move virtual objects. Another good example is Muñoz et al. (2016) EmoCat Rescue game where users must focus on controlling their breathing and heart rate in order to progress in the game.

Consider Using Biofeedback for Mediating Changes to the Virtual Environment

From the review, we found that physiological data was most commonly mapped directly to changes in the system, whether that be changes in music/audio, light/color, or object appearance/animation. Users reported feedback that allows them to externalize and notice their internal states in the virtual environment helped them to better understand their own internal states, and maybe even gain more control of them (Vidyarthi, 2012; Patibanda et al., 2017). Our finding is supported by other research that shows biofeedback is effective in interactive technologies aimed at improving mindfulness (for a review see Sliwinski et al., 2017). Moreover, the design considerations from Patibanda et al. (2017) provide positive evidence for using respiration rate as a form of biofeedback in games: use subtle onboarding, use non-interruptive breathing feedback, provide imitative breathing feedback, use a minimalist approach to designing naturalistic visuals, and use hardware that considers breathing performance and increases self-awareness of breathing. Other forms of biofeedback we found in the review include blood flow changes, skin electrical activity, and brain electrical activation. While there are less examples of concrete experiences for these biofeedback elements, we can still observe that the majority of mappings for both blood flow changes and skin electrical activity are to more subtle changes in music/audio and light/color, whereas brain electrical activation is primarily mapped to more obvious changes in object appearance/animation and levitation/floating. One reason for this might be that it is less obvious to the user when their brain state is changing rather than a change in heart rate or sweating, which we can physically feel or see more directly. Therefore, we suggest using a reverse proportional mapping—the harder it is to notice a physiological change, the more obvious the feedback should be in the virtual environment, and vice versa.

Consider Mapping Physical and Virtual Movement Together

We observed that the use of physical movement and controller interaction strategies were most often mapped to corresponding virtual object or user movement. The use of physical movement in a virtual environment is important because it allows the user to feel more immersed in the experience. One study examined how users experience movements in their interaction with interactive systems and identified four features of movement-based interaction that potentially influence immersion: natural control, mimicry of movements, proprioceptive feedback, and physical challenge (Pasch et al., 2009). The models of immersion in this study were based off of two theories: Csikszentmihalyi's (1990) Flow theory, a state of optimal experience where people typically have deep enjoyment, creativity, and total involvement in life; and Brown and Cairn's (2004) immersion framework of engagement, engrossment, and total immersion. Thus, physical movement and locomotion in immersive interactive experiences might help support positive states and change, especially if we are to follow the guidelines mentioned above put forth by Pasch et al. (2009), as well as maintain immersion and user experience.

Consider Natural Elements, Minimalist Design, and Child-Like Play for Design Elements and Interaction Strategies

Many theoretical papers have already proposed using natural elements, minimalist design, and child-like play in interaction design (Schultz and Tabanico, 2007; Vidyarthi and Riecke, 2014; Capaldi et al., 2015; Ahn et al., 2016; Gaggioli, 2016). And, indeed, we found this to be true in the experiences we reviewed. Several studies we reviewed also found that using nature elements in the virtual environment ($N = 15$), taking minimalist approach ($N = 7$), and adopting a child-like play concept for interaction design ($N = 16$) all contributed to positive states or positive change in users—see results section for details on the specific studies. The use of abstract imagery in particular for taking a minimalist approach seemed to help users focus their attention and block out any external distractions; this abstract imagery also helps users to focus on something that does not come with preconceived ideas or feelings that may trigger an unwanted emotional response.

Consider the Type of Technology Last Based on Your Desired Goals and User Experience

Finally, the type of technology used should be the last thing a designer should consider for their XR experience if they are to be in keeping with the principles of user-centered design. More explicitly, the technology or platform selected should support and enhance the desired user experience and outcomes. The goal should not be to use a certain technology simply because it is "cutting edge." We are seeing more and more XR technologies emerging, and that is promising for the field. However, the authors caution XR designers to think through why they are using a certain technology, and might another technology be a better fit? It should be clear how the XR technology elicits positive states and supports positive change, as well as how the extra effort of using XR technology is justified. The experiences we have seen so far, from this review, show that many are using virtual reality and in particular head-mounted displays. While this platform is great for total immersion, there still exist other forms of XR that might be equally or more beneficial; more research and development of experiences for other XR types is needed.

Limitations

The diverse nature of the various XR experiences and their accompanying studies presented challenges, leading to a series of compromises and assumptions that could be perceived as limitations in the literature review.

First, an XR experience can integrate two or more interaction strategies and input-output modalities to support positive change. For example, pulse, brain potential shifts, and skin conductance can all influence the virtual environment's visuals and audio in different ways (Hinterberger, 2011). These kinds of integrations include a dominant outcome. In this review, the XR components were analyzed based on their dominant outcomes. For example, in the example above the outcomes were contentment, relaxation, happiness, and harmony. However, the distinction of what elements contributed to which specific outcome could not be determined from this review and so were considered together.

A second limitation is the vast differences in using empirical methods in all the studies identified for this review. Several of the studies included were only proof of concept (Choo and May, 2014; Sakamoto et al., 2015; Muñoz et al., 2016; Bernal and Maes, 2017; Du Plessis, 2017); Thus we cannot determine for sure that these interaction techniques will reliably elicit those same outcomes.

Another limitation is in the generalizability of the reported outcomes because many studies used university students as participants. It is unclear whether the same outcomes will hold for the general population or more vulnerable populations.

Finally, the database query of the review is based on a predefined set of search terms. The defined search strategy conforms to the established procedures for scoping literature reviews, breaking down and addressing the research questions while ensuring reproducibility of the search. Yet, XR is a dynamic and vast field covering many different research fields; all of these fields have different terminologies and search terms that make it challenging to uncover every XR work that relates to positive states and change. For related reviews on neighboring topics see these works: Plaza et al. (2013), Capaldi et al. (2015), Mossbridge (2016), Spanakis et al. (2016), Valmaggia et al. (2016), and Sliwinski et al. (2017). Future scoping or systematic reviews on the topic might include the following terms, which are based on the key terms from the included literature in this review: virtuality, cinematic reality, computer-mediated reality, alternate reality, wearable computing, visuo-haptic mixed reality, games for health, HCI for peace, value-sensitive design, biofeedback, emotional design, holistic health, mediated communication, physiological computing, interactive art, multisensory experience, self-expression, prosocial behavior, cultural worldview, narrative exercises, mood-induction procedures, and self-regulation.

CONCLUSIONS

We presented a scoping literature review of existing immersive, interactive technologies whose primary aim is to elicit positive states or support positive functioning. We discovered several ways to most effectively employ different design elements and interaction strategies to support positive change in users, as well as how to use input-output modalities to contribute to eliciting positive states. From this review, we formed a conceptual framework that may help researchers and designers think about immersive, interactive experiences in the context of positive states and positive change. In order to put forth a more concrete strategy for designers and creators to use this knowledge, we also provided a set of design considerations that also build on existing literature. The work presented here provides both researches and designers with a more organized and coherent sense of the existing literature on the subject across multiple fields.

Future work might address empirical evidence of how immersive, interactive experiences can elicit positive states or support positive change as this was something we found lacking in the literature. Another potential gap for designers to address is the creation of immersive, interactive experiences for social/inter personal outcomes, opposed to hedonic and eudaimonic outcomes that we found to be a lot more prevalent.

AUTHOR CONTRIBUTIONS

AK, MP, and BR contributed conception and planning of the scoping review. AK and MP formulated the inclusion/exclusion criteria and identified articles relevant to the topic. AK performed the screening and eligibility process, and conducted a qualitative research synthesis of the data. AK wrote the first draft of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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The Potential and Challenges of Digital Well-Being Interventions: Positive Technology Research and Design in Light of the Bitter-Sweet Ambivalence of Change

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Along with the dissemination of technical assistance in nearly every part of life, there has been growing interest in the potential of technology to support well-being and human flourishing. "Positive technology" thereby takes the responsible role of a "digital coach," supporting people in achieving personal goals and behavior change. The design of such technology requires knowledge of different disciplines such as psychology, design and human-computer interaction. However, possible synergies are not yet used to full effect, and it needs common frameworks to support a more deliberate design of the "therapeutic interaction" mediated through technology. For positive technology design, positive psychology, and resource oriented approaches appear as particularly promising starting point. Besides a general fit of the basic theoretical conceptions of human change, many elements of established interventions could possibly be transferred to technology design. However, besides the power of focusing on the positive, another psychological aspect to consider are the bitter components inherent to change, such as the confrontation with a negative status quo, threat of self-esteem, and the effort required. The present research discusses the general potential and challenges within positive technology design from an interdisciplinary perspective with theoretical and practical contributions. Based on the bitter-sweet ambivalence of change as present in many psychological approaches of motivation and behavior change, the bitter-sweet continuum serves as a proxy for the mixed emotions and cognitions related to change. An empirical investigation of those factors among 177 users of self-improvement technologies provides initial support for the usefulness of the bitter-sweet perspective in understanding change dynamics. In a next step, the bitter-sweet concept is transformed into different design strategies to support positive change. The present article aims to deepen the discussion about the responsible role of technology as a well-being enhancement tool and to provide a fruitful frame for different disciplines involved in positive technology. Two aspects are highlighted: First, investigating well-being technology as a form of "therapeutic interaction," focusing on the need for sensible design solutions in the emerging dialogue between technology and user. Second, a stronger consideration of the bitter-sweet ambivalence of change, utilizing (positive) psychology interventions to full effect.

Keywords: positive technology, technology design, well-being interventions, user experience, bitter-sweet ambivalence, positive change strategies

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INTRODUCTION

Nowadays, technology provides assistance in nearly every part of life. Besides being a tool for practical tasks, an important channel to fulfill psychological needs such as popularity and relatedness, technology also functions as a medium to support physiological and psychological health and personal self-improvement. Under umbrella terms such as "positive technology" or "positive computing," research and design explores technology for well-being and human potential (e.g., Sander, 2011; Botella et al., 2012; Calvo and Peters, 2012, 2014; Riva et al., 2016b, 2017). More specifically, the positive technology approach aims at combining the objectives of positive psychology with technology design (Botella et al., 2012; Riva et al., 2016b). The positive computing approach defines a similar aim, i.e., "the study and development of technologies designed to support well-being, wisdom, and human potential" (Calvo and Peters, 2012, p. 29). Beyond this and more generally it argues for the "the inclusion of well-being and wisdom into the experience design of all technologies," suggesting that "even companies like Facebook and Apple should be evaluating how their products affect wisdom and well-being as part of the iterative design cycle" (Calvo and Peters, 2012, p. 29). Other approaches come from a more clinical perspectives and use technology as a new medium for therapy and health care. Along with this, e-health and behavioral intervention technologies have become a popular and promising approach among health care providers (see Free et al., 2013; Mohr et al., 2013 for recent reviews) and especially for workplace health promotion (e.g., Ebert et al., 2014). Also, in the field of consumer technology, self-optimization apps and gadgets have reached an enormous popularity, supporting self-improvement in various domains such as nutrition, meditation and mindfulness, time management and stress reduction, as well as sleeping habits, sports and physical activity (e.g., Conroy et al., 2014; Yang et al., 2015). Though relating to different domains and backgrounds, all these approaches share the endeavor to support positive change and self-improvement in their users and see technology as a valuable means. In this vein, the term positive technology is here used in a broader sense, relating to different kinds of technologies with the aim to support positive change and self-improvement, and not only explicitly positive psychology based ones.

While assigning technology the role of a personal coach or psychotherapist, supporting their users in personal development or even to counteract mood disorders (e.g., Braun et al., 2016), technology design assumes high responsibility. Designing for a positive human experience and well-being is a complex task (e.g., Desmet and Hassenzahl, 2012; Desmet and Pohlmeyer, 2013; Pohlmeyer, 2013), and possibly even more in the sensible domain of behavior change which asks for a careful consideration of psychological factors (e.g., Hassenzahl and Laschke, 2014). As highlighted in the present research, the support of behavior change must also consider the typically related bitter-sweet experience, consisting of mixed, positive and negative emotions. In the context of technology-supported change, this poses the question how to translate psychological knowledge into technology design, to find a representation that actually makes use of the interactive potential of technology, and to integrate knowledge from various disciplines. The field of positive technology obviously asks for a close collaboration between psychologists, designers, technology engineers, and others. However, until now, possible synergies between psychology and technology design are not used to full effect. Recent reviews in the context of health and well-being technologies (e.g., Free et al., 2013; Mohr et al., 2013; Conroy et al., 2014) suggest that literal interdisciplinarity is still missing.

On the one hand, psychology disregards the potential of interactive technology to affect people's routines beyond written instructions, e.g., through feedback, visualizations, and deliberate interaction design. Instead, psychology-based e-health interventions often transfer established trainings (e.g., cognitive behavioral therapy trainings) from offline mediums into videos and websites, so that technology is just an alternative way of distributing content. For example, a recent review on online positive interventions to promote well-being and resilience among adolescents (Baños et al., 2017) revealed a very limited number of utilized technologies, and strongly argues for a more intense utilization of smartphones, other mobile devices, sensors, and virtual/augmented reality technologies.

On the other hand, more technological advanced tools for behavior change often disregard the relevant psychological knowledge. A recent analysis of behavioral change techniques in mobile apps for physical activity found that the vast majority of commercial apps have not been evaluated using scientific methods and only few are explicitly grounded in theories of psychology or health behavior (Conroy et al., 2014). Overall, there is a strong focus on educational and cognitive aspects, but a disregard of the critical role of emotional and motivational factors for behavior change and long-term engagement (Conroy et al., 2014; Hollis et al., 2015; Yang et al., 2015). If the product does not "speak" to the user in the right way, change is sabotaged before it really started (see also Niess and Diefenbach, 2016). A survey among users of self-improvement technologies revealed a considerable ratio of users stopped using the technology before making significant progress, due to not feeling well supported (Diefenbach et al., 2016). Besides negative emotions while using the product (e.g., "made me constantly feeling guilty," "was getting on my nerves") such users complained about the product as being "too dominant," "bossy," "demanding," or "stubborn." In contrast, more satisfied users characterized the product as "motivating," "gently reminding," or "amusingly warning," thereby hinting at the ambivalent character of inconvenient advices.

Altogether, the emerging dialogue between product and user and its emotional and motivational consequences appear as a central link between psychology and technology design for well-being. Though being aware that essentially just an algorithm is giving them advice, people accept technology as a coach and even develop a bond with it (e.g., Beun et al., 2016). Hence, parallel to the patient practitioner relationship as an important medium and vehicle of change in psychology (Ryan et al., 2008), and the product as an "argument in material form" in design (Redström, 2006), positive technology becomes a "medium of therapeutic interaction," initiating a dialogue about change and ways to enhance well-being. The term "therapeutic" does not imply an exclusive focus on "serious" matters but emphasizes the responsibility related to any technology intervening in people's lives, behaviors, thoughts and feelings. More generally, if people see an aspect of themselves as a "project" to be improved, self-improvement technologies may be a way to support their wish for change. However, to be successful, it is of crucial importance to understand the user's experience of such technologies and to design these in a way that they trigger experiences and emotions that have proven as beneficial for positive change and achievement in psychological theory (e.g., control-value theory, Pekrun, 2006), see section Change as a Bitter-Sweet Experience for a detailed discussion.

To support this endeavor and synergies between disciplines, an important question is how to "translate" concepts from one discipline to another, as for example, how to consider psychological perspectives in interaction design. The present research provides one possible starting point for the translation of psychological knowledge about motivation and behavior change into the design of positive technology. More specifically, it focuses on the explicit consideration of the bitter-sweet ambivalence of change, as defined by the fact that any wish for change stems from the view that something is not ideal yet, which is basically a challenging, "bitter" experience. Regarding technology design, this poses the question how interactive technology could take a helpful "therapeutic attitude," what would be an appropriate way to "speak" to the user and how this might be systematically realized through particular design elements that take the bitter and sweet components into account.

While many existing design approaches already utilize psychological theory to support positive user experience (e.g., Desmet and Hassenzahl, 2012; Desmet and Pohlmeyer, 2013; Hassenzahl et al., 2013), the present research advances these by a focus on the "bitter-sweet ambivalence" inherent to any wish for change and possibly related positive and negative emotions. While experiencing progress toward a goal is attractive, committing to a goal also comprises the confrontation with current deficits and the risk of failure. As already discussed in the approach of "frictional feedback" as a design strategy for behavior change, breaking up routines never comes without friction (Hassenzahl and Laschke, 2014; Laschke et al., 2015). Changing one's routines is always an effort and a challenging situation from a psychological and design perspective.

The following paragraphs summarize the general strength of positive psychology and resource-oriented approaches in the context of technology-mediated self-improvement as well as possible advancements of such approaches by an explicit consideration of the bitter and sweet aspects of personal change. Based on a working model, a preliminary empirical study explored the relevance of both kinds of change factors among users of self-improvement technologies. As a next step, three general strategies/starting points for the support of positive change and possible realizations through technology design are discussed. In sum, the motivation of the present paper is to provide a psychologically founded but not overly complex perspective on behavior change and hopefully a working ground for the area of positive technology, especially for interdisciplinary research and practice.

POSITIVE PSYCHOLOGY INTERVENTIONS AS A STARTING POINT FOR TECHNOLOGY-MEDIATED CHANGE

Potential

In many respects, the core assumptions of humanistic psychology, positive interventions (e.g., Seligman et al., 2006; Biswas-Diener, 2010; Parks and Biswas-Diener, 2013; Vella-Brodrick, 2013) and resource-oriented approaches such as solution-focused coaching (Greene and Grant, 2003; Bamberger, 2011) go hand-in-hand with the idea of technology as a coach for personal change (see also Diefenbach, 2017 for a detailed overview).

First, there is the general belief in people's will and potential for personal growth and the client-as-expert view. Change is conceptualized as a function of autonomous motivation (e.g., Ryan et al., 2008), and being built on the utilization and revelation of the client's individual resources (e.g., Bamberger, 2011). The coach/therapist is considered an agent of change and moderator of development (Hermer, 1996), an assistant for self-management (Kanfer et al., 2006) or a supervisor of interaction with the outside world (Schmidt, 1996). In order to activate the client's potential for change, it just requires the right triggers and questions. This view makes it conceivable that a digital coach could trigger some of this potential as well. In contrast, within a psychoanalytic line of thinking—emphasizing the therapist's personal expertise and interpretation of the patient's reports, and phenomena such as transference and countertransference in therapist-patient communication—it would be hardly conceivable for technology to slip into the role of a coach or therapist.

Second, positive, resource-oriented approaches are indication independent, that is, they are not asking for the origin or development of problems but for solutions for the future. More important than what has been in the past are visions about a possible future. In fact, it is even argued that a focus on the problem, keeping thoughts turning in paralyzing circles, can often prevent rather than initiate positive change, which de Shazer et al. (de Shazer et al., 1986; de Shazer and Dolan, 2012) call "problem trance" or "problem hypnosis." In contrast, new perspectives and imaginations, triggered through unusual and inspiring questions or exercises such as role plays, are appreciated as a playground to experience how it could be. This future-oriented view makes it much easier for technology to set helpful triggers, than if a full analysis of reasons, as in the past, was needed.

Third, the typical "toolset" of positive approaches, i.e., systematic sets of questions, framings, and reflections on goals and solutions that have proven promising triggers to individual solutions (e.g., Greene and Grant, 2003; Gamber, 2011), is transferable to technical representations. Many of these techniques, such as positive framing, systematic questioning, coaching as an invitation to face the challenges of the future, reflections through role plays, sculpture techniques, scaling questions, visualizations and working with metaphors and images could possibly be translated into online interventions, apps or even gameful approaches. Furthermore, technology could provide an advanced representations of such techniques beyond face-to-face coaching, e.g., by vividly showing "problem constellations" from different angles (visualizations) or making the effort for reaching gradual goals tangible through touch parameters representing psychological effort (section Strategies for Positive Change: Application of the Bitter-Sweet Concept in Psychological Interventions and Technology Design, strategies for positive change, discusses some of these ideas in more detail). A particular interesting potential is provided by augmented/virtual reality technologies, which are already used to promote positive change in different areas of behavioral health. Besides providing a controlled setting to develop and exercise new skills, such technologies are particularly useful to generate the feelings of personal efficacy and self-reflectiveness required for change (see Riva et al., 2016a for a recent review).

Finally, positive approaches put a high value on everyday practicing and the integration of positive activities in daily routines. Here, interactive technologies such as smartphone provide an easy channel to transfer positive interventions into existing routines, and support the practicing of new routines through memory functions etc. Given that the smartphone is already a daily companion for many, it offers a playful and lightweight way of reflection on personal strengths and potentials for change.

All the aspects discussed above provide generally good conditions for the integration of positive psychological approaches in technology design. However, in addition, the positive focus within the support of individual change also comes with particular challenges and limitations.

Challenges and Limitations

Per definition, the field of positive psychology at the subjective level is primarily concerned with the positive and valued subjective experiences, including "well-being, contentment, and satisfaction (in the past); hope and optimism (for the future); and flow and happiness (in the present)" (Seligman and Csikszentmihalyi, 2014, p. 280). However, this does not necessarily imply to trigger exclusively positive emotions as an ultimate goal. For example, considering the development of positivity in a long term perspective, one may ask "how much delayed gratification is necessary to increase the chances of long-term well-being?" (Seligman and Csikszentmihalyi, 2014, p. 293). Besides, already in a short term perspective, it may not be evident whether positive-focused interventions will actually have positive effect for the individual. In sum, one central challenge within positive psychology interventions seems to find the right level of positivity to support positive change in a given situation, particularly if transferred by technology. In the present context, the question of the right level of positivity is particularly relevant in two regards.

At first, it refers to finding appropriate forms for rewards and positive therapeutic reinforcement, to keep positive framing in a sensible range. Many people seem to like the "motivational quotes" of the running app Runtastic such as "I am not here to be average, I am here to be awesome!," "Be the type of person you want to meet." However, the same quotes can appear inappropriate, e.g., when the "personal journey to weight loss" turns out as a terrible failure. If the same "encouraging" comments follow each behavior, one's actions become at some point meaningless. While a human coach can more sensibly react to individual situations, technology has a more difficult job to detect what motivation one actually needs to flourish. Positivity is surely a good starting point, but still, the right dosage is needed.

Second, the sole focus on the positive can even be dysfunctional; positive psychology interventions can "backfire" and positive goals will reveal a "dark side" (Biswas-Diener, 2010, p. 66). The imagined ideal self becomes a source of frustration instead of motivation, and evokes anxiety rather than hope and inspiration. Contrasting the "real you" against the "ideal you" can give crucial feedback for the personal change process and illuminates areas for growth, but at the same time it can cause people to feel dejected instead of inspired (Biswas-Diener, 2010, p. 47). In general, interventions for positive change can have unintended negative side effects on different levels—also discussed as "persuasive backfiring" in the context of persuasive technology (Stibe and Cugelman, 2016). Though many supportive strategies can make change "sweeter" there are still "bitter" components, which one needs to acknowledge when developing the most helpful strategies for positive change. Again, a sensible consideration of bitter and sweet factors seems especially relevant in the context of technology-mediated behavior change, where no human coach can intervene in the critical moment.

While the low threshold related to "seeking advice" from interactive technology generally can be seen as an advantage—a lightweight possibility for self-reflection, a little tool one can test in a playful manner, not necessarily associated with a confession of needing help—technology also provides a low barrier to abandon the whole process. Trying to change may result in frustration or the simple insight that change is actually hard work. It is only a small step to delete "the damn app" and to get rid of the frustration. Here, the experienced or imagined bitterness may be a reason to stop or even not start projects of change. As already concluded by Kanis and Brinkman (2009, p. 127), "there is clearly an opportunity to employ technology for positive change, but how this can be achieved is more difficult to determine."

The present article suggests that one critical aspect for the successful design of positive change technologies is the explicit consideration of the "bitter components" of change, i.e., the potential hurdles and barriers that might arise when trying to implement positive goals in daily life and the nearly inevitable confrontations with shortcomings on the way to change. To have full effect, positive technology must not stay focused on the positive alone but also support people in dealing with challenging situations (Sander, 2011).

CHANGE AS A BITTER-SWEET EXPERIENCE

The intention to change is always a bitter-sweet experience, typically accompanied by mixed emotions and a combination of positive and negative feelings. Considering a wish for personal change as a gap between the actual and ideal self, this naturally includes a feeling of inadequacy, often coming with dejection-related emotions such as disappointment, dissatisfaction or sadness (Higgins, 1987). Hence, on the sweet side of change there are the attractive goals, the positive belief of being able to achieve such goals, the vision of becoming the person he or she wants to be, and if quick progress is achieved- the encouraging feedback. On the bitter side, there are the confrontations with current deficits, the risk of failure and self-blaming, the threats to self-esteem and the necessary effort to approach one's ideals. In the following, the bitter-sweet perspective forms a working concept for different facets of conflicting or antagonizing forces. This view is in parallel to many psychological approaches and models in the area of motivation and behavior change. While not being exhaustive, the aim of the present compilation is to point out the tension bitter and sweet components, and to exemplify representatives of the bitter-sweet ambivalence in change and progress with regards to existing theory.

An example of bitter-sweet conceptions in theory of change is provided by the intentional change theory (ICT, Boyatzis, 2006), and the role of positive and negative emotional attractors in personal change (e.g., Howard, 2015). While the positive emotional attractor (PEA) comprises personal hopes, dreams, possibilities, strengths, optimism and self-set goals that make up our ideal self, the negative emotional attractor (NEA) comprises the present reality, fears, problems, shortfalls, pessimism and improvement goals related to our real self. Also, the famous flow theory (Csikszentmihalyi, 1990) emphasizes that positive experience and progress results from challenge (rather bitter) and skill (rather sweet) at the same time. Bitter and sweet components may also be related to the formation of concrete action plans, as suggested in many theories on self-regulation and behavior change (e.g., Gollwitzer, 1999; Schwarzer, 2008). Gollwitzer (1999) recommends the formulation of clear implementation intentions, that is, concrete if-then plans to implement behavior change in daily life. On the sweet end, such action plans offer the opportunity to change, or a concrete way to goal attainment that "just has to be followed." On the bitter end, the concreteness of such action leaves no space for escape and excuses. Even if self-prescribed—when confronted with the inevitable call for action—the clear demand to change may be experienced as restriction of autonomy and result in reactancy (Brehm, 1966).

Another example highlighting a form of bitter-sweet interplay is the optimal margin of illusion hypothesis (Baumeister, 1989). It associates optimal psychological functioning with a slight-to-moderate degree of distortion in one's perception of oneself, and suggests a balance between a realistic (rather bitter—if not being perfect) and an optimistic, positive view of oneself (sweet). Though the optimal margin hypothesis has also been challenged (e.g., Brookings and Serratelli, 2006), it might still form a helpful metaphor when thinking about design strategies for behavior change. To keep people in the optimal margin, a coach (human or digital) would confirm people in their positive view, thereby utilizing first small changes as a resource for power and further change, but without becoming overly optimistic and losing out of sight what still needs to be done.

Similarly, theories of persuasion and message design include bitter-sweet dimensions as well. For example, the Persuasive Health Message (PHM) Framework (Witte, 1995, p. 146) suggests that in order to motivate change, a threat message is needed, to make the audience feel susceptible to a severe threat (bitter) as well as an efficacy message, to convince individuals that they are able to perform the recommended response (sweet). Negative emotions such as fear can be an inhibitor but also a motivator (Witte, 1998), so that, in the right dosage, the experience of a bitter component might support transformation. While originally the PHM framework refers to health-message design for public campaigns, positive technology designs health and well-being messages in the form of technology.

Finally, interesting parallels can be drawn to research on academic learning and achievement, especially the control-value theory (CVT) introduced by Pekrun et al. (e.g., Pekrun, 1992, 2006; Pekrun et al., 2006). In parallel with the present consideration of bitter and sweet components of behavior change, CVT provides a dedicated description of the combined functions of positive and negative emotions in self-regulation and learning. More specifically it describes the interplay of positive outcome-related (e.g., anticipatory joy, hope) and activity-related emotions (e.g., enjoyment) as well as negative outcome-related (e.g., anxiety, sadness) and activity-related (e.g., anger) achievement emotions, and their relations to control and value appraisals. An important aspect related to the present idea of the bitter-sweet ambivalence of behavior change, and the explicit acknowledgment and utilization of bitter change factors, is the view of negative emotions as not necessarily being detrimental to self-regulation and learning and positive emotions not necessarily being beneficial. CVT acknowledges that positive achievement emotions do not always exert positive effects, and negative achievement emotions do not always produce negative effects (Pekrun, 2006, p. 327). Besides the valence of emotions, also their activating potential does play a role. Pekrun (2006 p. 326) concludes that for most task conditions "the effects can be assumed to be beneficial for activating positive emotions like enjoyment of learning, detrimental for deactivating negative emotions like boredom and hopelessness, and more ambivalent for both deactivating positive emotions such as relaxation, and activating negative emotions such as anxiety of such emotions." Another interesting perspective in CVT is the emphasis on habitualized emotions. As Pekrun (2006) explains, based on procedural schemes, situational perceptions alone can be sufficient to induce particular habitualized emotions and names the example of a student's habitualized anxiety upon entering the classroom. Obviously, such habitualized emotional reactions can be a serious barrier to positive behavior change. However, interactive technologies could be a chance to break up such pattern and provide a new frame and a chance to develop, other, more beneficial emotional reactions. Pekrun (2006 p. 324) lays out that, "whenever the situation changes [however], appraisals come into play again, and changes of appraisals may change habitualized emotions." In sum, the assumptions of CVT thus provide a useful frame for the present idea of the bitter-sweet ambivalence in context of interactive technologies supporting behavior change.

Note that for some of the above mentioned concepts and theories the bitter-sweet parallel refers to an explicit negative-positive differentiation and the interplay of both types of emotions (e.g., Boyatzis, 2006; Pekrun, 2006). In other cases, the negative–positive interplay is less explicitly formulated (e.g., threat vs. efficacy messages, Witte, 1995) or results from the present interpretation of different concepts in combination and potential arising conflicts. This, for example, refers to the double-sided psychological effects of concrete behavior plans, i.e., the positive/sweet activating power of implementation intentions (Gollwitzer, 1999) in contrast to the negative/bitter deactivating power of reactancy (Brehm, 1966). In order to cover such manifold perspectives and provide room for a broad interpretation, it was a deliberate decision not to limit the concept to a clear cut negative–positive differentiation, but to use the more colloquial and ambiguous term bitter-sweet. This also refers to the interdisciplinary perspective, aiming to provide starting points for various disciplines concerned with the research and design of positive technology, instead of restricting the scope to particular psychological concepts.

A Working Concept: Bitter vs. Sweet Components and Crucial Stages Along the Change Process

In simplified terms, bitter-sweet experiences of change can be envisioned along a continuum (see **Figure 1**). The bitter component is inevitable and needed to a certain degree. A wish for change often originates from the bitter experience of a discrepancy between real and ideal self. However, the interplay between bitter and sweet components is critical to change success. If the bitter component is too dominant, no change takes place. Even if one becomes aware of a discrepancy between real and ideal self, and catches a glimpse of one's own wish for change, an escape back into the *blind zone* is possible. The blind zone is considered to be a comfort zone, where the confrontation with deficits becomes "invisible" again, e.g., through denial or the avoidance of confrontation with discrepancy between real and ideal self. Thus, a first critical stage for change is crossing the barrier from where the degree of bitterness seems "do-able," and one can commit oneself to a wish for change. This is the starting point for the actual *arena of change*. Having arrived at this point, the primary challenge lies in sustained engagement in change. Only if the first steps of change are a rewarding experience, one will enter the *spiral of positive change*, where change becomes increasingly sweeter and further fuels the motivation to change. Such kind of positive escalation corresponds to the concept of *early reactivity*, i.e., a rapid increase in positive emotions after starting an intervention, which has been acknowledged as vital factor for successful positive psychology interventions (e.g., Cohn and Fredrickson, 2010; Proyer et al., 2015). Increasing competency, feelings of self-efficacy and approaching one's ideal, and at the same time, reduced effort, disappointment and self-threat, could all add to the experience of positive reinforcement. In contrast, if one experiences his or her first steps of change as ineffective/failure, one will fall back into the *danger zone* around the critical change barrier. As such, the perceived bitterness of change can become even stronger than before—failing after having commitment to change tastes more bitter than it did before having tried. For the sake of self-protection and dissonance reduction (Festinger, 1962), one may declare the original goal as "wrong" and deny one's original ideals. A lack of early reactivity thus forms one of the most severe dangers in the process of change. If a chosen intervention path for change does not have any positive effects, it is suggested to acknowledge this and search for another, more promising alternative, rather than prevailing in the experience of ineffectiveness (see also Proyer et al., 2015).

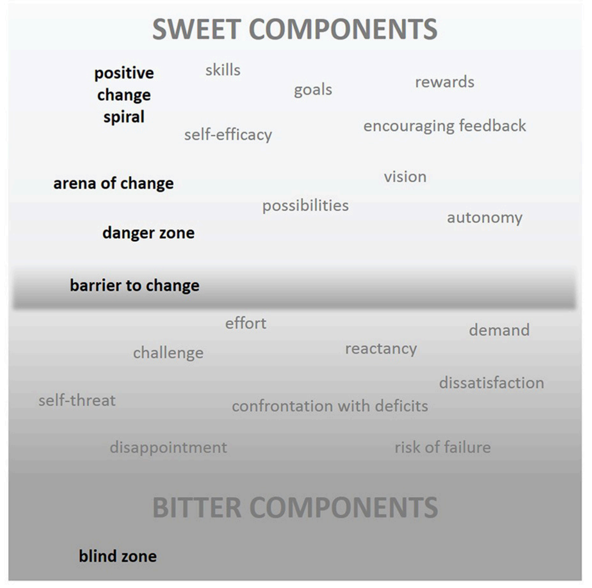

FIGURE 1 | A working concept: change as a bitter-sweet experience.

Key Assumptions and Possible Applications of the Bitter-Sweet Concept

In sum, the present conceptualization of change assumes the following: Change always includes bitter and sweet components. Setting goals includes the risk for failure and self-threat, and change (i.e., breaking up routines) is struggling *per se*. Even if the ultimate goal is to enjoy the sweet side (e.g., finally experiencing sports as an intrinsically motivating activity that actually feels good—and not as a duty), the bitter side should not be neglected, but could be even utilized as a vehicle of change (the power of dissatisfaction). However, bitter and sweet components must be in a bearable ratio—if the bitter is too dominant, one might rather deny the wish to change. Thus, instead of solely focusing on the positive, and thereby risking unforeseen consequences and backfire effects, strategies for change should actively consider its bitter-sweet character. From a design perspective, this could imply thinking about factors evoking rather bitter/negative (e.g., confrontation with deficits) or sweet/positive emotions (e.g., encouragement).

The present perspective on change, whereby the bitter-sweet concept serves as a proxy for the ambivalence of change (**Figure 1**), allows to delineate user's current position within a change process, relevant forces and mechanisms, the most needed kind of support, and related design strategies. The core intention is to create a representation of the inherent ambivalence of change, and to make this graspable within the envisioning of strategies and technology design for positive change.

The bitter-sweet concept can provide a common frame for different disciplines involved in the field of positive technology, i.e., relations to psychological theory and mechanisms, and at the same time concrete starting points for design and the utilization of technology to support change. As recently stated by Gaggioli et al. (2017, p. 496) when discussing a research agenda for the field of positive technologies, "Finding the right way of communicating ideas, in a way that resonates with distinct academic communities is not trivial and is maybe in itself the first important topic of any research agenda." In this vein, the present research aims to provide a simplified but psychologically-oriented view on change processes and related user experiences, with potential for different communities. Note, however, that the suggested working concept does not claim to represent distinct psychological processes, nor does it make hypotheses about specific interrelations of the different bitter and sweet components. While this might be a goal for future research, the present paper aims at a first exploration of the general usefulness and viability of the concept.

The next section presents a preliminary empirical investigation of the bitter-sweet conceptualization among 177 users of self-improvement technologies. The section thereafter explores different design strategies for positive change along the bitter-sweet continuum.

PRELIMINARY EMPIRICAL INVESTIGATION: BITTER AND SWEET CHANGE FACTORS IN SELF-IMPROVEMENT TECHNOLOGIES

A user study within the context of self-improvement technologies served as a first empirical exploration of the potential relevance of bitter and sweet factors in processes of personal change. The study focused on four change factors in particular, i.e., *confrontation with deficits* and *demand* on the bitter end as well as *autonomy* and *encouraging feedback* on the sweet end. *Confrontation with deficits* addresses the confrontation with deficits, such as visualizations of the status quo and gaps between ideals and reality. *Demand* comprises the clear and definite call to change, including concrete instructions, which, however, might also be experienced as negative and cause reactancy (Brehm, 1966). Both factors, *confrontation with deficits* and *demand*, thus address change from the bitter end: change is initiated through the confrontation with a negative state that is declared as not acceptable. This also parallels the "notion of activity trackers as "deficit" technologies, to which people turn when they are afraid of failing" (Gouveia et al., 2015, p. 1309). In other words, the motivation to change is to prevent the negative. In contrast, *autonomy* and *encouraging feedback* refer to positive attractors of change, namely, actively influencing conditions for progress, experiencing oneself as creator of change, and confirmation of success. *Autonomy* refers to the degree a product supports autonomous decisions regarding the way of change and goal attainment. *Encouraging feedback* refers to positive responses to the user's actions; for example, by means of rewards for first small steps in the change process.

Methods

One hundred and seventy seven users of self-improvement technologies answered a survey and provided reports on their personal change process as well as ratings on the used technology by various measures. As an incentive, three 15-euro gift vouchers were raffled among all participants. The study was conducted online via unipark (unipark.com) and a convenience sample (127 female, mean age 31 years, min = 18, max = 65) was recruited via various university mailing lists and social media groups. Though we do not have exact data about the popularity of self-improvement technologies among women and man, the skewed female sample is in line with other studies exploring self-improvement technologies and similar approaches within convenience samples (e.g., Yang et al., 2015; Chittaro and Vianello, 2016). Similarly, a recent survey about the share of smartphone owners using fitness apps in Germany also showed a higher ratio of female users (Statista, 2015).

The study was carried out in accordance with the APA ethical standards and the German Psychological Society's (DGPs) ethical guidelines (2016). According to the DGP's ethics commission, an institutional research board's ethical approval is only required if any funding is subject to such an ethical review. No such requirements were present for this study. Participation in the study was voluntary. Participants were assured of anonymity and confidentiality. Participants were informed about the purpose of the research, expected duration, procedures, the study incentive, their right to cancel and withdraw their consent for participation at any time during the study, and a contact person for any questions or concerns regarding the study. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

After having provided their consent, participants were asked to name a self-improvement technology which they are currently using, and describe their product and experience by various measures.

Each of the above described bitter and sweet change factors (*confrontation with deficits, demand, autonomy, encouraging feedback*) was assessed with three items (as listed in the Appendix, see also Mehner, 2016). Sample items are "The product ..." "makes me realize that have not yet reached my ideal" for the factor *confrontation with deficits* or "provides positive feedback" for the factor *encouraging feedback.* The item development was inspired by relevant conceptualizations in psychology, coaching, persuasive technology design and health research. More specifically, the items to assess *confrontation with deficits*, were oriented on the transtheoretical model of health behavior change (Prochaska and Velicer, 1997), which emphasizes raising awareness of a problem and the need to change in the phase of contemplation before entering the phase of preparation, in which people are intending to take action in the immediate future, as well as the principles of motivational interviewing

(Miller and Rollnick, 2012). One of these principles, namely, "develop discrepancy" suggests that change is motivated by highlighting the discrepancy between patient's perceived goals and values vs. current behavior. In line with the prominent three-component description of psychological attitude (e.g., Eagly and Chaiken, 1993), the items covered affective (… confronts me with my dissatisfaction), behavioral (… that I haven't done enough yet) and cognitive (… makes me realize that I have not yet reached my ideal state) aspects of deficit confrontation.

The assessment of *demand* was oriented on the taxonomy of behavior change techniques by Michie et al. (2011) and the behavior model for persuasive design by Fogg (2009). One of the behavior change techniques described by Michie et al. (2011) is "action planning." Compared to other more abstract techniques such as goal setting, action planning asks for detailed planning of what the person will do including, as a minimum, when, in which situation and/or where to act. This clear link between specific situational cues and behavioral responses does hardly provide room for excuses or avoid getting active any longer. Also in Fogg's model (Fogg, 2009) there is an emphasis on signal triggers that serve as a reminder to start the intended behavior. This relentless attitude and the initiation of change through particular (situational) triggers was represented in items such as "The product … does not accept that I put off getting active any longer" or "… definitely reminds me to start the planned behavior change."

The user's perceived *autonomy* within the process of change and goal attainment was assessed in parallel to items on autonomy and self-determination in the working domain and the research by Spreitzer (1995) on psychological empowerment in the workplace. Sample items from the self-determination scale by Spreitzer (1995) are "I have considerable opportunity for independence and freedom in how I do my job" or "I can decide on my own how to go about doing my work." In the present context, this was translated into items such as "The product … provides considerable freedom about how to reach my goals" or "… leaves it up to me how to design the change process."

Finally, the items to assess *encouraging feedback* were derived from typical formulations used in the context of solution-focused coaching (Greene and Grant, 2003; Bamberger, 2011). Solution-focused coaching shift the client's focus on resources, improvement, first signs of reaching the goal and the appreciation of already taken steps toward the envisioned future. The coach typically expresses encouraging feedback such as "I am deeply impressed how you managed this difficult situation" or, to activate the client's resources, "Which resources did help you to initiate this first step?" In the context of self-improvement technologies, this attitude was reflected in items such as "The product … … praises me for my actions" or "… acknowledges small steps on the way to self-improvement."

For each item, participants indicated their degree of agreement on a seven-point-scale (1 = not at all, 7 = completely). Scale values were computed by averaging the corresponding items; the internal scale consistency was satisfactory (Cronbachs alpha: *confrontation with deficits*: 0.71, *demand* 0.76, *autonomy* 0.79, *encouraging feedback* 0.83). A principal component analysis (varimax rotation, 72% explained variance) with four components to be extracted revealed a satisfactory solution with no loadings larger than 0.30 on other components, expect for one cross-loading between *demand* and *confrontation with deficits* (0.54), and one between *encouraging feedback* and *autonomy* (0.32), see Appendix for the matrix of factor loadings.

TABLE 1 | Self-improvement technologies under study.

Product category	Frequency	Sample products/apps
Fitness apps	53 (30%)	Runtastic, Freeletics, 7 Min Workout
Nutrition apps	34 (19%)	Weight Watchers App, MyFitnessPal, Lifesum
Language apps	32 (18%)	Babbel, Busuu, Duolingo, Obenkyo
Fitness gadgets	20 (11%)	Polar M400 running watch, Mi Band fitness & sleep tracker
Health apps	16 (9%)	Health, S Health, Global Corporate Challenge
Relaxation apps	6 (3%)	7Mind, Provider Resilience
Other	16 (9%)	card2brain, NeuroNation, Memrise

Besides ratings on the bitter and sweet factors, participants further rated their product and experience of change by the following measures: global product evaluation (1 = bad, 7 = good), positive and negative affect (1 = not at all, 7 = extremely) and point of time within the change process (1 = early stage, 7 = advanced stage). Change success was assessed with three items (Cronbachs alpha 0.89, namely, "I have reached my goals with the help of the self-improvement technology," "I realize I already made progress toward my goals" and "The self-improvement technology supported me in becoming who I want to be." Again, participants indicated their degree of agreement on a seven-point-scale (1 = not at all, 7 = completely).

Findings and Discussion

The sample of self-improvement technologies consisted of smartphone apps and gadgets from various domains. The most commonly rated products were fitness apps, nutrition apps, language learning apps, and fitness gadgets such as step counter wristbands. **Table 1** lists frequencies and sample products/apps for the different product categories.

The pattern of correlation revealed that the sweet factors, *autonomy* and e*ncouraging feedback*, are more relevant for a positive product evaluation (see **Table 2**, row 7–8) than the bitter factors, *confrontation with deficits* and *demand* (**Table 2**, row 4–5). However, both kinds of factors, bitter and sweet, were positively correlated to change success. Even though the bitter factors may not lead to "liking" the product, participants are well aware of their impact on personal change. A stepwise linear regression, using change success as the criterion and all four change factors and interaction terms as predictors revealed the interaction term *demand* × *autonomy* as most relevant predictor ($R = 0.59$, R^2 adjusted = 0.31, $\beta = 0.56$, $p < 0.001$). This suggests that the process of change is especially successful if

TABLE 2 | Correlations between bitter/sweet factors of change, product evaluation, and change success ($N = 177$).

	Product evaluation	Change success
BITTER FACTORS		
Demand	0.17*	0.46**
Confrontation with deficits	0.07	0.30**
SWEET FACTORS		
Autonomy	0.34**	0.35**
Encouraging feedback	0.28**	0.46**

*$p < 0.05$, **$p < 0.01$.

TABLE 3 | Correlations between bitter/sweet factors of change, product evaluation, and change success for early stages ($n = 89$) and advanced stages of change ($n = 88$).

	Early stages of change		Advances stages of change	
	Product evaluation	Change success	Product evaluation	Change success
BITTER FACTORS				
Demand	−0.04	0.40**	0.29**	0.44**
Confrontation with deficits	−0.06	0.23*	0.17	0.34**
SWEET FACTORS				
Autonomy	0.31*	0.28**	0.16	0.20
Encouraging feedback	0.29**	0.51**	0.24*	0.42**

*$p < 0.05$, **$p < 0.01$.

the product provides a clear demand to action, but at the same time, offers some degree of autonomy in the implementation. Beyond this, *encouraging feedback* was the only further predictor that could explain significant additional variance ($R = 0.52$, R^2 adjusted $= 0.37$, $\beta = 0.29$, $p < 0.001$).

Another deciding factor for participant's product evaluation and experience, and the relevance of the bitter and sweet change factors, was the point of time within the change process. In general, with advanced stages of change, users felt more positive ($r = 0.30$, $p < 0.001$), less negative ($r = -0.33$, $p < 0.001$), reported a higher degree of change success ($r = 0.44$, $p < 0.001$) and rated to the product more positively ($r = 0.30$, $p < 0.001$). Moreover, a contrast of users in rather early stages (see **Table 3**, column 2–3) and rather advances stages (**Table 3**, column 4–5) by median split showed differences in the correlation pattern between bitter/sweet factors, product evaluations and successful change completion. While in the early phases, the sweet factors are more important for product evaluations and perceived change success; later on, the bitter factors become relatively more important.

A possible interpretation of this correlation pattern is the following: In the early stages of change, bitter factors of change are associated with negative experience and must remain in low levels to be acceptable. It takes some time for users to experience that some bitterness is actually helpful for reaching their personal goals, thereby adding to a positive product evaluation. Thus, in later stages of change, users may even acknowledge the motivation activated through bitter factors and hard words. Users learn that rewarding sweet experience results from personal efforts and bitter and sweet factors may go hand-in-hand. If one has experienced the positive change spiral at once, this serves as an additional attractor for ongoing engagement and occasional bitter experience becomes more bearable. Although failure and rebounds are still frustrating, the increasing ability to cope with bitter factors may become a rewarding experience itself.

This line of interpretation is also in parallel with the description of positive and negative feedback loops in relation to the above-mentioned (CVT) (Pekrun, 2006), referring to reciprocal causation effects between achievement emotions and appraisals in the context of learning and emerging dynamics over time. CVT posits two groups of appraisal as of specific relevance for achievement emotions (Pekrun, 2006 p. 317): (1) control appraisals, i.e., the subjective control over achievement activities and their outcomes (e.g., expectations that persistence at studying can be enacted, and that it will lead to success); and (2) value appraisals, i.e., the subjective values of these activities and outcomes (e.g., the perceived importance of success). As Pekrun (2006 p. 327) further points out control and value appraisals are assumed to be important determinants of emotions, but emotions can also reciprocally affect these appraisals. Such reciprocal causation can consist of positive feedback loops (e.g., enjoyment of learning and mastery at learning reinforcing each other) but also negative feedback loops (e.g., test anxiety inducing motivation to avoid failure, and resulting success reducing test anxiety). The dynamics of feedback loops can take place within varying time frames, from fractions of seconds, within learning episodes, or over days, weeks, and years (Pekrun, 2006 p. 327).

From the perspective of CVT, the present finding of an increasing importance of bitter factors over time could be related to a change in relevant appraisals over time. If users experience an increasing mastery to handle the challenges the technology asks for, this is an increase in control appraisals, here, being capable to actually take advantage of a product's "bitter" demand and confrontation with deficits. In other words, the user gains competency in making use of the potential of bitter factors, which as time goes by, actually do not seem so bitter anymore. Similarly to an experienced but strict sports coach, which may be advantageous for advanced sportsmen in later phases but totally demotivating for beginners in early phases of learning.

Nevertheless this is only one possible line of thinking why a gradually increasing degree of bitterness induced by the self-improvement technology could be desirable. Another limitation of the present findings is that the here applied measure of the point of time within the change process did not ask for the exact duration (e.g., in days, weeks, or months) but just captured a broad contrast of early vs. advanced stages. Future studies must thus substantiate these tendencies and provide a more complete picture, also including longitudinal research.

However, the revealed pattern already suggests that specific user needs may play a role in different stages of change processes. Based on the initial support for the general relevance of bitter and sweet factors in change in the user study, the next sections discuss how design strategies for positive change might address these factors. Note that while the user study underlined the general relevance of bitter and sweet for experienced change success, the following strategies are not inferred from the user study but rather depict general starting points to address the bitter-sweet concept in psychological interventions and how to integrate it in technology design. All strategies pick up existing psychological concepts or elements of established coaching techniques, however, future studies must explore their actual usefulness and applicability in the context of interactive technology.

STRATEGIES FOR POSITIVE CHANGE: APPLICATION OF THE BITTER-SWEET CONCEPT IN PSYCHOLOGICAL INTERVENTIONS AND TECHNOLOGY DESIGN

The notion of change along a bitter-sweet continuum provides a ground to conceptualize general strategies for positive change as well as their consideration in technology design (see **Figure 2**). This includes, for example, the positive connotation of bitter component, by making deficits appearing as a potential. Another example is represented by the support of self-enhancing processes in the positive change spiral, further strengthening the sweet components of change. Though taking different paths, the three strategies altogether aim at strengthening the chances for positive change by a helpful ratio between bitter and sweet, and preventing an escape back into the blind zone, where one denies one's wish to change, due to too much experienced "bitterness." The following paragraphs draft these possibilities in more detail. For each strategy, a general introduction and relations to psychological concepts and coaching techniques is provided, followed by some suggestions how to address these aspects in interaction and technology design. Note, however, that the listed strategies are not meant to be exhaustive. The primary aim of the present collection is to highlight the different general options how to utilize the bitter and sweet in conceiving strategies for change—some primarily related to the bitter (e.g., alternative connotation), some primarily related to the sweet (e.g., early experience of change). **Table 4** provides a summary of the different strategies, starting points along the bitter-sweet continuum, intended effects, related concepts from psychology and coaching, as well as possible realizations through technology.

Strategy 1: Alternative Connotation of the Bitter

A first strategy addresses situations around the critical barrier, before full commitment to change. The idea is to provide an alternative connotation of bitter components that transfer pure bitterness into a more positive and energizing construct, thereby still keeping the potential energy for change: the insight that "something needs to be done" in order to reach a positive goal. Such an alternative connotation of bitter components in the individual's reflections on change, related feelings and expectations and especially a reduction of self-threatening connotations, may enhance the odds for crossing

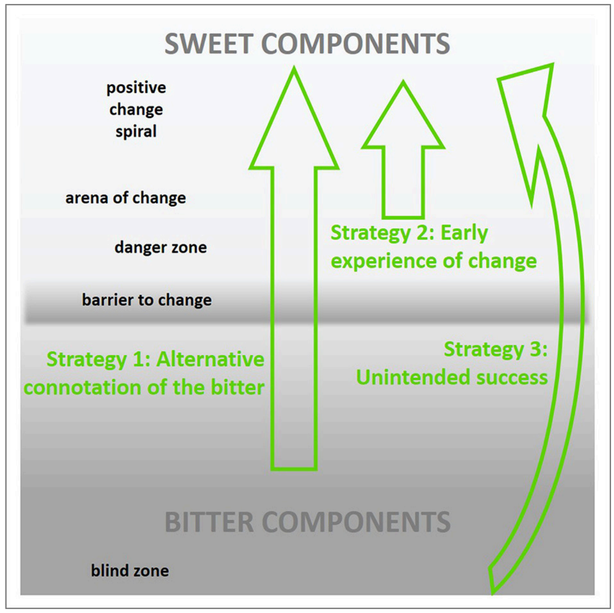

FIGURE 2 | Different strategies for the utilization of bitter and sweet components in positive change interventions and design of interactive technology.

the barrier to change. This idea is in parallel to typical re-framing interventions in the context of positive psychology and solution focused coaching (e.g., Greene and Grant, 2003). Instead of "fighting against being wrong" change becomes an act of "caring for oneself." This approach also represents a form of de-medicalization (e.g., Broom and Woodward, 1996). Often, taking a medicine means being ill (self-threatening); thus, relabeling the medicine as an energy pill can turn a bitter situation in a sweeter one. Marketing professionals know very well that people feel better with using a "beauty serum" instead of "anti-wrinkle cream," "pure products" instead of "anti-allergy products" or "fitness food" instead of "diet food." Alike, it makes a difference whether an intervention is framed as "anti-stress training" or as "personal well-being training." While the first term reminds one of being wrong (self-threatening) the second emphasizes the possibilities a change entails and evokes a desire to change in this way.

Interactive technology could create alternative, "sweeter" connotations of change in different kinds of manifestations. For example, when thinking about smartphone apps or online interventions, labels and stories embedding the intervention could trigger a sensible therapeutic frame. This could be, for example, a "well-being treasure hunt," taking up a metaphor from solution-focused coaching: The client turns into a successful treasure hunter, hunting for his or her own strengths and resources. In this scenario, the coach only assists the client to seize the treasure and bring it to consciousness (e.g., Bamberger, 2011, p. 45). In an interactive game, the user could thus take the role of a treasure seeker or adventurer on an exploration tour. On a smaller level, positive framing could inspire the names of weekly missions, e.g., a nutrition app, which invites the user to a "fitness week" (sweet, emphasizing gains) instead of labeling the same thing as a "meat-free week" (bitter, emphasizing restrictions). In general, all kinds of game-like interpretations of change processes offer a great opportunity to play with one's own abilities in the form a noncommittal "test wise" change. By pushing considerations about self-threat and potential failures to the background the barrier to change becomes lower. Such playful, self-esteem neutral reflections or invitations for "tentative change" are a typical and very effective element from systemic therapy and solution-focused coaching (e.g., Greene and Grant, 2003). Also scaling questions (Bamberger, 2011) and other techniques which provide a supportive perspective on problems vs. progresses (i.e., the bitter-sweet ratio), could be easily realized, and even more, enhanced through visualizations in interactive technology.

Strategy 2: Early Experience of Change

A second strategy addresses the processes in the arena of change, after the barrier has been crossed and first trials have started. The aim is to push people into the loop of positive change and prevent a drift back into the danger zone, where they might give up. As discussed above, a central element in the arena of change is early reactivity, that is, a rapid perceivable effect of one's activities to change, confirming the general effectiveness of an intervention (Cohn and Fredrickson, 2010; Proyer et al., 2015). To give an everyday example: aching muscles after a first workout may signal "development in progress" and that one's activity actually had "some effect." Positive comments by others such as "You look good today, somehow fitter," may further support the experience of self-efficacy.

The foremost advantage of interactive technology to create such an early experience of change is the omnipresence of technology in daily life. For many, smartphones are constant companions. Unlike a human coach, smartphones may accompany the client through the hurdles of daily life and re-activate resources when needed. A common problem in classical face-to-face coaching is that the client actually shows progress, but does not recognize the already performed change to full extent. Here, technology could support a continuous documentation and appropriate expression of progress. In fact, the specific way that progress is documented can be crucial to its motivating power. For example, instead of hard, fixed numbers and physical metrics, progress could be expressed through a more appropriate, more flexible "currency." An effort based time reduction from 25:30 min to 25:05 in a five kilometer running distance is not appropriately acknowledged by raw time data. Getting 100 progress points acknowledges this improvement considerably more. Similarly, in the field of nutrition: Keeping up the motivation after the first gains have been achieved and the curve of change becomes flatter is a difficult task. While losing the first kilos might be a relatively easy process, further progress is not reached with the same gradient. To prevent demotivation, visualizations and scores provided by technology could acknowledge the many parallel positive effects in other areas of healthy nutrition. Hence, every healthy day could be acknowledged as a day of value, by adding extra acknowledgments on different levels of well-being and long-term goals such as vitality, life-expectancy, or simply joy of life. Occasional backlashes on one level will become more bearable when set against progress on other levels. Inevitably, the user is confronted with what has already been achieved, activating one's skills and resources for further change.

Besides the advantages of technology to support the experience of change through their ubiquitous presence, technology also offers advanced opportunities for the continuous activation of a positive therapeutic frame on different levels of interaction design. In contrast to face-to-face settings, where the coach repeatedly re-activates supportive perspectives through reflection, exercises and dialogue, interactive technology could do this continuously. Mobile apps, for example, could trigger helpful perspectives and reflections through interface design, menu titles, visualizations, or also interaction attributes. "Psychological weight" (e.g., heavy accuses, heavy problems, high barriers) could be represented through physical weight, realized through the force needed to move elements by touch gestures on a display. Likewise, technology could shift the focus from problems to solutions. For example, zooming in and out of a problem plays with the metaphor of standing right in front of a problem wall, where one sees nothing but the problem and overlooks all the ways around it. While performing the zoom gesture, one can actually experience the opportunities to change the perspective and thereby, experiences the diverse paths of positive change (see **Figure 3** for a prototypical visualization). This approach of (here: visually) shifting the focus away from to problems to solutions is in parallel to basic theoretical concepts of solution-focused coaching (e.g., de Shazer et al., 1986; Bamberger, 2011; de Shazer and Dolan, 2012). As already outlined in section Potential, these approaches assume that the focus on the problem, turning in paralyzing circles, does not foster but rather prevents any positive change, often called problem trance or problem hypnosis. Zooming out of the problem and experiencing the power of this more distanced perspective, thus, could be a first step out of the problem trance.

Strategy 3: Unintended Success

A third strategy could be to avoid the challenging barrier and arena of change and actually initiate change (=success) without a prior clear intention. The unintended success may provide a full dose of sweetness, a lure for further success. The more conventional path of change, that is, realizing a discrepancy between ideal and real self, committing and trying to change, always includes the risk for failure and self-blame. Fear and negative thoughts may suck energy that is better spent on the actual change. In contrast, the unconventional path of unintended success is virtually risk free. The moment one becomes aware of the change, it was already successful and maybe easier than thought. This provides a safe basis for commitment to further change, since one already knows that change is possible. If the (unintended) change is not successful, it is also not a failure—since one never committed to wanting that change.

The aim is not to nudge people into a direction they would not consider attractive. Instead, the idea of unintended success is to create some positive surprise about oneself. One may hesitate to consider (secret) ideals as explicit goals, simply because the way appears too bitter. However, if for some reason we are pushed into an unexpected challenge, some of these challenges might

TABLE 4 | Three strategies for positive change.

Strategy	Starting point	Intended effect	Related concepts/coaching techniques	Possible realization through interactive technology
Alternative connotation of the bitter	Around the critical barrier, before full commitment to change	Transfer pure bitterness into a something sweeter, more energizing	Positive re-framing De-medicalization Tentative change Scaling questions A treasure hunt for own strength and resources	Labels, stories Visualizations Game-like interpretation of change processes Well-being treasure hunt
Early experience of change	Arena of change	Push into the loop of positive change Prevent drift back into the danger zone	Early reactivity Self-efficacy Re-activation of positive resources Confrontation with own success, activating further resources Acknowledging positive side effects Alternative perspectives Solution focus	Constant documentation of change Reminders, push-up notifications Visualizations, interaction attributes Feeling psychological weight and change in perspectives through gestural interaction
Unintended success	An (unplanned) jump from bitter to sweet, avoiding the barrier to change	Risk-free change No self-blame *Post-hoc* commitment	Ordeals Positive surprise about oneself Awareness of hidden skills, activation of positive resources Prevention of self-blame	Apps providing missions/tasks Hidden missions within general missions Retrospective reflection on success

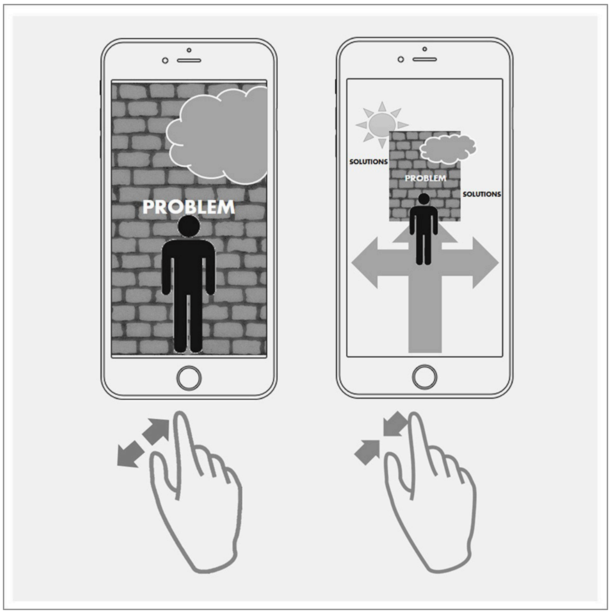

FIGURE 3 | Prototypical visualization of using the zoom gesture to change perspectives on problems and solutions: standing right in front of a problem wall **(Left)** vs. exploring possible ways around the wall **(Right)**.

turn out to be easier to manage than we expect. For example: Friends taking us on a hiking tour turning out much longer than expected, gets us to over-accomplish our aims. Furthermore, a small holiday resort with no cigarette machine nearby effects the smoking behavior and thereby indicates that a smoke-free day is possible. Ordeals as a possibility to detect one's actual skills are also a prominent technique in solution focused coaching (e.g., Bamberger, 2011); also Milton H. Erickson already used ordeals in a therapeutic context (Zeig, 2013). In hindsight, one may even be thankful for being pushed into that challenge and having discovered one's strength and abilities. Unintended success thus provides a basis for *post-hoc* commitment.

Likewise, a healthy nutrition app making meal suggestions each day could skip fish and meat for 1 week. However, only after the week has passed, the user hears "congratulations on your first vegetarian week!" Speaking in terms of Tromp et al. (2011), who differentiate product influence on behavior along the dimensions of force and salience, such an approach could be classified as rather strong but with a (at first) hidden influence. The user is aware of the fact that the app cares about healthy nutrition, but is not aware that this includes also attempts of vegetarian living. After having unintendedly succeeded in having a vegetarian week, the user may commit to a goal such as having a vegetarian day once a week, may decide to become vegetarian, or deliberately decide against it.

Altogether, the strategy of unintended success probably represents the most challenging one, also from an ethical perspective. It may be difficult to decide what kind of "success" actually creates "positive surprise about oneself" and corresponds to the user's personal ideals. There is a high responsibility to navigate between positive support and manipulation. Note, however, that the essence of this strategy is not to trick the user, but just to initiate an action before a critical reflection happens. The strategy aims to create a frame of success on previous actions that allows the user to feel proud, and then opens up the possibility to further engage in the change, if wanted.

CONCLUSIONS

The present work highlights the responsible role of technology as a mediator of well-being and therapeutic interaction and discusses possible ways for a practical integration of psychology and technology design. A particular emphasis is on the bitter-sweet ambivalence of change, including potential relapses and risks of self-threat, so that technology-mediated interventions adapted from (positive) psychology can have a positive impact to full effect.

All people will likely profit from approaching their ideals, but for some of them, bitter components and barriers to change appear more difficult than for others. Especially the former turn out as a relevant target group for self-improvement technologies. Stibe (2016) calls this group "January 1st": people who would like to change their routines, but rarely succeed in doing so. On the contrary, people with comparatively high levels of motivation and skills for self-improvement are "self-driven people," and Stibe (2016) even argues that persuasive technologies might become unnecessary for this group. However, many existing behavioral intervention technologies are primarily suited for this non-target group, i.e., people who are already passionate about self-optimization, supporting intentional self-change through reminders and feedback. Those who could profit the most (e.g., insufficiently active people), are highly sensitive to user experience issues and especially hesitant toward technology as a means for behavior change (Yang et al., 2015). Thus, it is primarily important that the design of self-improvement technologies is adjusted to the special needs of the people who actually require support in changing themselves.

The present model aims for anyone to enter the positive change spiral by actively considering bitter and sweet components. Being rooted in the ideas of positive psychology and the belief in people's capability, it assumes that self-initiated change is possible, but further acknowledges that implementing it into daily life is a highly strenuous process. Hence, understanding what makes change more bitter or sweeter for people appears as a key factor for success.

As an interdisciplinary field, positive technology requires a frame to combine best knowledge from different disciplines. The collective task is to translate insights about human behavior and motivation from psychology and the social sciences into design concepts and product-mediated interventions, realized through technology. The present conceptualization of change wants to provide a contribution in this direction. It may function as a frame for the systematic identification of potential to support people during the process of change. It depicts relevant forces and possible strategies in order to support change and possible ways for technology to intervene. The present model is no substitute for the exhaustive study of psychological theory. However, it aims to provide an easy and catchy frame for designers and HCI specialists in the field of positive technology to position their project. Designers can sketch the kind of change they want to support and become aware of relevant psychological mechanisms. As such, the bitter-sweet concept can be a starting point for the definition of general strategies and "therapeutic goals," which can be then further refined by reference to relevant theory.

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The author confirms being the sole contributor of this work and approved it for publication.

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Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX

Items to assess bitter and sweet factors of change and principal component analysis (varimax rotation).

Scale/Item	Component			
The product …	**1**	**2**	**3**	**4**
Bitter: Confrontation with deficits				
… makes me realize that I have not yet reached my ideal state	0.79			
… confronts me with my dissatisfaction with the current state	0.78			
… shows me that I haven't done enough yet	0.71			
Bitter: Demand				
… does not accept that I put off getting active any longer		0.89		
… definitely reminds me to start the planned behavior change		0.82		
… clearly states that it is time to act	0.55	0.53		
Sweet: Autonomy				
…leaves it up to me how to design the change process			0.86	
… lets me make autonomous decisions how to proceed			0.88	
… provides considerable freedom about how to reach my goals			0.76	0.32
Sweet: Encouraging Feedback				
… praises me for my actions				0.88
… provides positive feedback				0.85
… acknowledges small steps on the way to self-improvement				0.76

All items were originally in German; component loadings <0.30 are suppressed.

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Implementation of a Positive Technology Application in Patients With Eating Disorders: A Pilot Randomized Control Trial

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Background: Positive psychological interventions (PPIs) have been suggested to produce benefits in patients with eating disorders (ED) by improving well-being, which might act as a buffer of the harmful effects caused by the disorder. Best Possible Self (BPS) is a PPI which consists of writing and envisioning a future where everything has turned out in the best possible way. In this regard, positive technology (PT) can be of considerable benefit as it allows to implement specific PPIs that have already shown efficacy.

Objective: This study tested the preliminary efficacy of the BPS exercise implemented through a PT application and carried out for 1 month, in improving positive functioning measures, compared to a control condition, in patients with ED. Follow-up effects were also explored at 1 and 3 months later.

Methods: This is a pilot randomized controlled trial, with two experimental conditions. Participants were 54 outpatients, who were receiving ongoing specialized treatment in ED services. 29 participants were randomly allocated to the BPS intervention and 25 to the control exercise. The sample was composed mostly by females and the mean age was 27 years. In the intervention group, participants had to write about their BPS. In the control group participants had to write about their daily activities. The exercise was conducted through the Book of Life, which is a PT application that allows users to add multimedia materials to the written content. Measures of future expectations, affect, dispositional optimism, hope and self-efficacy were assessed at different time frames.

Results: Findings showed that all participants improved over time and there were no statistically significant differences between conditions on the specific measures. These effects were not influenced by prior levels of ED severity. Within-group effect sizes indicate a greater benefit for the participants in the BPS condition, compared to the control condition, on nearly all the measures.

Conclusion: Results indicated that PT produced modest improvements in patients with EDs that are receiving current treatment for ED. More empirical attention is needed to explore the potential benefits of PPIs as supporting tools in the prevention and treatment of EDs.

Trial registration: clinicaltrails.gov Identifier: NCT03003910, retrospectively registered December 27, 2016.

Keywords: eating disorders, positive psychological intervention, best possible self, optimistic thinking, affect, positive technology

INTRODUCTION

Eating disorders are considered serious psychiatric disorders which cause functional impairment, emotional distress and different health problems, producing a negative impact in the quality of life of the patients (Hudson et al., 2007; Mond et al., 2012). It has been found that individuals with ED symptoms present higher levels of neuroticism and lower levels of life satisfaction and optimism compared to healthy peers (Brannan and Petrie, 2011; Góngora, 2014; Garcia et al., 2017). Various studies have shown that patients with ED have an impoverished self-concept characterized by many negative self-schemas and few positive ones, contributing to the formation and persistence of the disorder (Cash and Deagle, 1997; Fairburn et al., 2003; Claes et al., 2009). Consequently, these patients often have a pessimistic view of recovery, and they find it quite difficult to imagine a better future (Stein and Corte, 2007; Malson et al., 2011).

Regarding treatment, EDs are very difficult conditions to be treated and in many cases patients remain ill over years, becoming chronic patients (Geller et al., 2001; Noordenbos et al., 2002; National Institute for Clinical Excellence, 2017). In regards to evidence-based treatments for these conditions, only bulimia nervosa has been shown to be effectively treated with cognitive-behavioral therapy (CBT) showing strong effects, but the current evidence does not suggest any preference for any treatment in anorexia nervosa or non-specified EDs in relation to efficacy (Fairburn and Harrison, 2003; Fairburn, 2005). Given the limited efficacy of conventional treatments, a new treatment approach, called the recovery approach, has emerged with a change on the focus of treatment goals, from the full recovery and weight restoration, to the reestablishment of quality of life and well-being (Slade, 2010; Dawson et al., 2014). Thus, within this approach, patients are encouraged to be proactive, optimistic and decisions about treatment are taken collaboratively between patients and their practitioners (Turton et al., 2011). Based on this approach, one study (Touyz et al., 2013) adapted two existing psychotherapy protocols for severe patients with anorexia nervosa (CBT vs. specialist supportive clinical management) and compared the effectiveness by making quality of life the focus of the treatment, instead of weight restoration. Results showed that, even with the shift in the treatment goals, changes in weight restoration and symptom reduction were achieved, along with high retention rates at the end of the treatment.

The focus on well-being as a treatment goal emphasizes the role of positive emotions, which might act as buffers against the deleterious effects of ED symptomatology (Brannan and Petrie, 2011). Following this vein, some authors have proposed the inclusion of positive psychology strategies for the prevention and treatment of patients with ED (Steck et al., 2004; Kirsten and du Plessis, 2013). It is claimed that the development of interventions focused on improving well-being and meaning in life on patients with ED could act as a protective factor against the negative impact of ED symptoms and body dissatisfaction by promoting a more positive attitude toward the self (Brannan and Petrie, 2011; Góngora, 2014). Also, Tchanturia et al. (2015) suggest that the inclusion of PPI could play a role in recovery of patients with EDs by enriching current programs and even enhancing their impact. These PPIs have been found effective for depressive patients on improving subjective well-being and decreasing depressive symptoms (Bolier et al., 2013; Mongrain et al., 2015; Chaves et al., 2016). To our knowledge, there are no randomized control trials testing the effects of PPIs on well-being for ED patients. Indeed, only one pilot study showed that implementing a positive psychology group intervention in an ED impatient service with young females was feasible and participants benefited from the program (Harrison et al., 2015). However, the results, although encouraging, were preliminary in nature due to the lack of a control group and the small sample size consisted of eight young female inpatients.

Given the potential benefits of implementing PPIs in patients with ED, it is important to select those strategies with the greatest ability to produce benefits based on the needs of the individuals (Lyubomirsky and Layous, 2013). In the case of patients with ED, some authors suggest that therapeutic practices aimed to develop personally meaningful and optimistic views about recovery and reflect on a prospective self beyond the disorder might be of considerable benefit (Malson et al., 2011). In this line of research, PPIs have shown their effectiveness in improving optimism (Malouff and Schutte, 2016). Specifically, the review conducted by Malouff and Schutte (2016) brought to light that the most powerful exercise to enhance optimism levels was the BPS exercise (Malouff and Schutte, 2016). This exercise consists of thinking and imagining about a future in which everything has turned out as well as it possibly could (King, 2001; Sheldon and Lyubomirsky, 2006). Besides,

Abbreviations: ANOVA, analysis of variance; BPS, best possible self; DHS, Dispositional Hope Scale; EAT-26, Eating Attitudes Test; ED, eating disorder; GAF, Global Assessment of Functioning; GSES, General Self-Efficacy Scale; LOT-R, Life Orientation Test – Revised; PANAS, Positive and Negative Affect Scale; PPI, positive psychological intervention; PT, positive technology; SD, standard deviation; SPT, subjective probability task.

this exercise has also been tested with depressive patients, showing that it is able to promote positive affect and life satisfaction, and to reduce depressive symptoms (Pietrowsky and Mikutta, 2012; Sergeant and Mongrain, 2015). Recent controlled studies conducted by our group explored the effects of this intervention in university students finding positive effects in terms of optimistic thinking compared to controls (Enrique et al., 2017a). Another controlled study with a similar design examined the effects of BPS in a sample of patients with fibromyalgia finding benefits on affect and optimism after 1-month training (Molinari et al., 2017). Given the promising findings observed in other populations and the importance of developing optimistic views about the future in patients with ED, BPS exercise can be of considerable benefit for patients with this disorder.

A recent movement within the positive psychology field is the combination of these evidence-based strategies with Information and Communication Technologies (ICTs). This movement is called PT and is presented as a scientific and applied approach that uses technology for improving the quality of our personal experience with the goal of enhancing well-being and resilience (Botella et al., 2012). It is argued that PT can influence the personal experiences at three different levels. First, PT has the ability to improve emotional quality through the generation of positive and pleasant experiences. Second, PT can produce engaging and self-actualizing experiences. Lastly, PT can also be used to improve social integration and connectedness (Gaggioli et al., 2017; Guillén et al., 2017). In fact, all previous studies testing the efficacy of BPS that were conducted by our group implemented this exercise through PT, and found high levels of acceptability by the patients (Enrique et al., 2017a; Molinari et al., 2017).

Rationale of the Study

The present study outlines a first approximation of PT to the ED field by studying the preliminary efficacy of the BPS exercise on a sample of patients who are receiving ongoing treatment. The design and procedure followed in the present study is very similar to prior controlled studies conducted by our group, which also implemented a PT application (Enrique et al., 2017a; Molinari et al., 2017). We only focused on examining the effects of this intervention on building positive aspects as opposed to reduce the negative, since this is aligned with the use of PPIs in clinical populations (Meyer et al., 2012; Schueller et al., 2014). Therefore, the goal of this study is to test the efficacy of the BPS exercise implemented through a PT application on different positive functioning measures on a sample of patients with ED. To our knowledge, this is the first controlled study to test this intervention in a sample of patients suffering this pathology.

The first hypothesis is that patients will present higher scores of positive expectations and positive affect and lower scores of negative expectations and negative affect after a single session, compared to a control condition in a sample of patients with ED. The second hypothesis is that the observed changes after one session will remain after 1 month training, compared to a control group. Furthermore, it is expected that the exercise will have an impact in self-efficacy, dispositional optimism and hope. Lastly, because there is a lack of empirical evidence about the maintenance of the effects over time, we preliminarily explored the effects after 1 and 3 months follow-up.

MATERIALS AND METHODS

Design

This is an experimental, repeated-measures pilot study with two independent groups. Participants ($N = 54$) were randomly assigned to two conditions: 29 participants who performed the BPS exercise and the other 25 performed the daily activity exercise (control condition). The random assignment of the participants to the BPS and the control condition was carried out by an independent researcher who had no knowledge about the study. Random allocation was performed through a randomization list created by the Random Allocation Software, version 1.0. To ensure the homogeneity of the two experimental conditions, randomization was stratified by the level of functional impairment (mild-moderate-severe) rated by the therapists (GAF). The participants did not know the characteristics of the different experimental groups.

The study was registered in the United States National Institute of Health Registration System[1] with Clinical Trials Registration Number: NCT03003910. Moreover, the study was approved by the Research Ethics Committee of the Provincial Hospital of Castellón. The recruitment processes and the data collection took place from October 2014 to September 2015.

Assessments were conducted at five different moments (**Figure 1**): Prior to the exercise (pre), after the first session (post-session) and 1 month later (post-training). Moreover, two follow-ups were conducted 1 (1st follow-up) and 3 months (2nd follow-up) after finishing the training period (post-training).

Participants

The total sample was composed by 54 participants, 52 women (96.3%) and 2 men (3.7%), who were recruited from four different outpatient psychology clinics where they were receiving treatment as usual for eating and personality disorders, mainly cognitive-behavioral therapy (Pike et al., 2015) and dialectical-behavior therapy (Linehan, 1993). Mean age was 27.1 years (SD = 8.6). Primary diagnoses of the patients were: ED (51.9%), or a comorbid diagnosis of eating and personality disorder (48.1%). Functional impairment of the patients was

[1] http://www.clinicaltrials.gov

FIGURE 1 | Assessment moments.

also collected, according to the GAF of the Diagnostic and Statistical Manual of Mental Disorders (4th Edition, American Psychiatric Association [APA], 2000) and they were categorized into mild (>60), moderate (51–60), and severe (<51). It is important to note that the diagnoses of the patients were based on the DSM-IV, given that they were collected from prior clinical records and the clinicians still used this classification. The GAF was measured by the personal therapist of each patient. 64.8% were categorized as mild, 31.5% as moderate, and 3.7% as severe in terms of functional impairment. **Table 1** includes detailed information of the participants regarding the assigned condition.

Inclusion and Exclusion Criteria

The inclusion criteria used to select the participants were: (1) Aged between 18 and 70 years old, (2) Not suffering from a severe physical illness, (3) Not suffering from substance dependence, (4) Suffering from an ED condition.

TABLE 1 | Descriptive data about demographic variables, diagnosis, functional impairment and medication.

	BPS condition	Control condition	Total sample
Age			
Mean (*SD*)	27.65 (9.00)	26.44 (8.22)	27.1 (8.60)
Sex			
Male	1 (3.4%)	1 (4%)	2 (3.7%)
Female	28 (96.6%)	24 (96%)	52 (96.3%)
Marital status			
Single	24 (82.8%)	24 (96%)	48 (88.9%)
Married	3 (10.3%)	1 (4%)	4 (7.4%)
Divorced	2 (6.9%)	0 (0%)	2 (3.7%)
Level of studies			
Elementary school	1 (3.4%)	1 (4%)	2 (3.7%)
High school	10 (34.5%)	12 (48%)	22 (40.7%)
University degree	18 (62.1%)	12 (48%)	30 (55.6%)
Diagnosis			
Anorexia nervosa	4 (13.8%)	5 (20%)	9 (16.7%)
Bulimia nervosa	7 (24.1%)	4 (16%)	11 (20.4%)
Binge eating disorder	2 (6.9%)	2 (8%)	4 (7.4%)
EDNOS	16 (55.2%)	14 (56%)	30 (55.6%)
Functional impairment			
Mild	19 (65.5%)	16 (64%)	35 (64.8%)
Moderate	9 (31%)	8 (32%	17 (31.5%)
Severe	1 (3.4%)	1 (4%)	2 (3.7%)
Medication			
No medication	16 (55.2%)	12 (48%)	28 (51.9%)
Only anxiolytics	0 (0%)	1 (4%)	1 (1.9%)
Only antidepressants	2 (6.9%)	1 (4%)	3 (5.6%)
Only antiepileptics	1 (3.4%)	1 (4%)	2 (3.7%)
Only antipsychothics	0 (0%)	0 (0%)	0 (0%)
Combination of medications	10 (34.5%)	10 (40%)	20 (37%)

BPS, Best Possible Self; EDNOS, Eating Disorder Not Otherwise Specified; Combination of medications: Any combination that include more than one type of medication.

Measures

Primary Outcomes

Positive and negative expectations

We used the Spanish adaptation of the SPT (MacLeod, 1996; Dragomir-Davis, 2014). This instrument measures positive and negative expectations about events that will occur in the future. It consists of 30 items, 20 of them related to negative expectations about events that can take place in the future and 10 referring to positive expectations. The instrument asks individuals to judge the likelihood of an event happening in the future on a 7-point scale (from 1 "Not at all likely to occur" to 7 "extremely likely to occur"). Some studies have found appropriate internal consistency levels for positive and negative expectations (α = 0.80–0.82 and 0.91, respectively (Peters et al., 2010; Meevissen et al., 2011).

Positive and negative affect

To measure affect, we used the Spanish adaptation of the PANAS (Watson et al., 1988; Sandín et al., 1999). This instrument is composed of 20 items: 10 items measuring positive affective states and 10 items measuring negative affect states. Participants rate on a five-point scale (from "Not at all" to "Extremely") the degree to which they usually feel a specific affective state. PANAS is one of the most widely used instruments to measure affect because it shows excellent psychometric properties (Cronbach Alpha's from 0.87 to 0.91).

Secondary Measures

Dispositional optimism

We used the Spanish adaptation of the Life Orientation Test (LOT-R; Scheier et al., 1994; Otero-López et al., 1998). This scale measures the extent to which a person generally expects favorable outcomes. It includes 10 items: 3 items refer to positive expectations, 3 items refer to negative expectations, and 4 items are fillers. Answers are rated on a 5-point scale (from 0 "strongly disagree" to 4 "strongly agree"). Higher scores reflect a higher level of dispositional optimism. Other studies have found an internal consistency for the eight items of $\alpha = 0.76$ (Meevissen et al., 2011).

Self-efficacy

The Spanish version of the GSES-12 was used (Bosscher and Smit, 1998; Herrero et al., 2014). This questionnaire evaluates general aspects of self-efficacy. The internal consistency coefficient for the scale is appropriate ($\alpha = 0.86$).

Dispositional hope

It was used the Spanish version of the DHS (Espinoza et al., 2016). This instrument evaluates dispositional hope. It is composed of 12 items, with an 8-point Likert scale. It has shown good psychometric properties ($\alpha = 0.89$).

Psychopathology Measure

Eating attitudes

We used the shortened Spanish version of the EAT-26 (Garner et al., 1982). This is a self-report measure that assesses disordered eating behaviors and attitudes. It is composed by 26 items rated following a 6-point Likert scale, in which "never," "rarely," and "sometimes" are scored as 0, "often" is 1, "usually" is 2 and "always" is 3. Higher scores indicate greater eating pathology. Scores of 20 or more indicate elevated risk of ED pathology. The instrument has shown excellent psychometric properties (Toro et al., 1989; Rivas et al., 2010).

Positive Technology Applications

The Book of Life

It is a virtual application that seems like a personal diary and it is composed of different chapters where users are asked to write about different topics each targeting different psychological resources (Baños et al., 2014; Botella et al., 2016). Multimedia content such as audio, images and videos, can be added in order to enrich the experience and enhance the content of what they had written. For the purposes of this study, a new chapter was created with the instructions of the BPS exercise (Meevissen et al., 2011). Book of Life is a module of a self-applied technological system called EARTH, which, as a whole, has been proven effective in inducing positive moods (Botella et al., 2016). **Figure 2** illustrates a screenshot about how the exercise is displayed once the users have developed the content and selected the multimedia content.

TEO (Emotional-Online Therapy)

It is a web-based system that allows patients to do their homework assignments at home through the Internet (Quero et al., 2012). TEO permits clinicians to develop personalized therapeutic materials supported by multimedia content and share it with the patients in a simple and effective way[2]. In the present study, the exercise developed by the participants on the Book of Life was uploaded to TEO, including the multimedia materials, so that patients could practice it at home.

Interventions

Best Possible Self

Participants in this condition were asked to write and imagine about a future in which all has gone in the best possible way and they have reached all their goals in four different domains: personal, professional, social and health domains. Participants were asked to develop the exercise through the Book of Life, where they could support the content they had written with multimedia content. Thereafter, this content was uploaded to the website TEO, so that they could access to this content with their own username and password.

Daily Activities (Control Condition)

Participants in this condition were asked to report activities, thoughts and feelings that had happened in the past 24 h. They were told that this exercise would help them to identify problematic areas in their lives and work on improving them.

[2]https://www.teo.uji.es

FIGURE 2 | Screenshot of the positive technology application, Book of Life (embedded picture provided by Shutterstock, ID: 60967345).

These instructions were adapted from other studies (Sheldon and Lyubomirsky, 2006; Meevissen et al., 2011). Participants in this condition were provided with a PowerPoint document where they wrote about the daily experiences, feelings and thoughts that happened to them in the last 24 h. The first slide included the instructions of the exercise and participant could add as much slides as they wanted.

All participants were given 20 min to complete the exercise. They were encouraged to write the content of the exercise in the format of a personal story to facilitate the visualization.

Procedure

Sample recruitment was carried out by contacting the different coordinators of the outpatient clinical services. These clinics were specialized in the treatment of EDs and they were told that the intervention could have a positive influence on patients' mood. Thereafter, the coordinators explained the information of the study to the psychologists at these units and they informed about the study to those patients who met the inclusion criteria. Thus, patients were explained about the features of the study and, if they agreed to participate, they were enrolled in a list of potential participants together with contact information. The experimental sessions were carried out in the clinical centers or in the university (depending on the preference of the patients) and they were carried out by the researchers. Patients were contacted by the researchers in order to make an appointment for the first session. When participants arrived, they were explained about the study and they signed an informed consent stating that they participated in the study voluntarily. Next, they were briefly screened about demographic information and completed the pre-test assessment (primary, secondary, and psychopathology measures). After that, the participants received the instructions for the corresponding exercise in audio format and on paper. For the performance of the exercise, participants on the BPS condition used the computerized program through a laptop provided by the researchers and the participants on the control condition used a PowerPoint file using the same computer. Then, participants were left alone in the room in order to avoid distracters and stimulate concentration on the exercise. All participants in both conditions prepared the exercise during 20 min. In the case of BPS condition, if multimedia content was not still selected, participants were encouraged to do it, allowing them to spend a maximum of 5 min. When the established time was over, participants of both conditions were asked to perform a 5-min visualization exercise in which they imagined their written BPS essay or their daily activities of the past 24 h. Specifically, participants of the BPS condition performed the imagery exercise through another display of the book of life, where they visualized the content of the exercise together with the multimedia content selected previously (**Figure 2**). In the case of the control condition, participants were also asked to read and visualize the content of their essays through the full screen mode of the PowerPoint file, in order to reproduce a similar methodology in both conditions.

To end the session, all the participants completed again the PANAS and SPT questionnaires with the items disorganized to reduce repetition effects. Furthermore, participants of both conditions were asked to practice the visualization exercise 5 min a day during a 1-month period. During this training period, two weekly text messages were sent to the participants' mobile phones in order to remind them to perform the exercise. The content developed by the participants during the first session was either uploaded to the website TEO with the multimedia content in the case of patients in the BPS condition or sent by email in the case of patients in the control condition (powerpoint file). This was to allow participants continuous access to the exercises from their own homes.

At the end of the month, participants were given a second appointment to complete the post-assessment (primary and secondary outcomes). Finally, a follow-up assessment (primary and secondary outcomes) was conducted online 1 and 3 months after the post-training. During the follow-ups, all participants were encouraged to continue practicing the exercise at their own pace and they were told to practice at least 2 or 3 days per week to ensure that they would continue practicing. Besides, a text message was sent once a week until the end of the follow-up period.

Data Analysis

Paired *t*-tests and chi-squared tests were conducted to explore the existence of significant differences in socio-demographic variables and baseline measures between conditions. CONSORT guidelines were followed to ensure the methodological quality of the study (Schulz et al., 2010). Missing data were treated following the procedure suggested by Hair et al. (2013). First, it was explored the type of missing data observing that it was at a construct-level and, thus, susceptible for imputation. Second, the quantity of missing values for each of the measures was explored, determining that none of the measures exceeded the recommended limits (Arias et al., 2015). Third, a diagnosis of the random pattern of missing data was carried out with the Little MCAR test ($\chi^2 = 60.98$; $p > 0.05$), concluding that missing data were completely at random. Lastly, intention to treat (ITT) analyses were carried out using Maximum Likelihood (ML) estimation performed via Expectation Maximization (EM) imputation method and sensitivity analyses comparing results of completers with the estimated values were conducted. These comparations showed that there was no chance of falling into biased estimations by using the ML estimation.

Before conducting the main analyses, correlations between ED severity, measured through the EAT-26, and the change in the outcome measures were conducted in order to explore whether severity was influencing the results. Thereafter, three sets of analyses were conducted to test the specific hypothesis. To test the first hypothesis, single-session effects (pre/post-session) were examined through analyses of covariance (ANCOVA; with condition as the between-subjects variable and pre-session scores as the covariate) to compare the effects of the intervention on affect and future expectations (primary outcomes) in the BPS and DA conditions. To test the second hypothesis, ANCOVA analyses (using condition as the between-subject factor and pre-session scores as the covariate) were carried out to explore the efficacy of the intervention at post-training for each primary and secondary outcomes. Finally, the effects of the intervention over time (pre, post-training, 1 month follow-up, 3-month follow-up) were examined by carrying out a 2 × 4 mixed ANOVA for each measure. All the assumptions for the ANOVAs performed were checked. In the case of mixed 2 × 4 ANOVAs, the degrees of freedom were corrected using Greenhouse–Geisser in those cases where the sphericity assumption was not fulfilled. Bonferroni correction was used for multiple comparisons. Effect sizes (Cohen's *d* Cohen, 1992; Botella and Sánchez-Meca, 2015) and confidence intervals were calculated for within-group changes.

All statistical analyses were conducted using IBM SPSS Statistics 22.

RESULTS

Participants Flow

Of the 75 patients initially included on the list of potential participants, 59 met the inclusion criteria, and they were randomly allocated to the conditions (**Figure 3**). Finally, the total sample receiving the allocated intervention was composed of 54 participants. During the training, the drop-out rate was 24.1% in the BPS condition and 16% in the control condition and these rates were slightly lower to those obtained in a prior study conducted by our group (26.3% in the BPS condition vs. 20% in the control condition; Enrique et al., 2017a). A total of seven participants did not respond to the

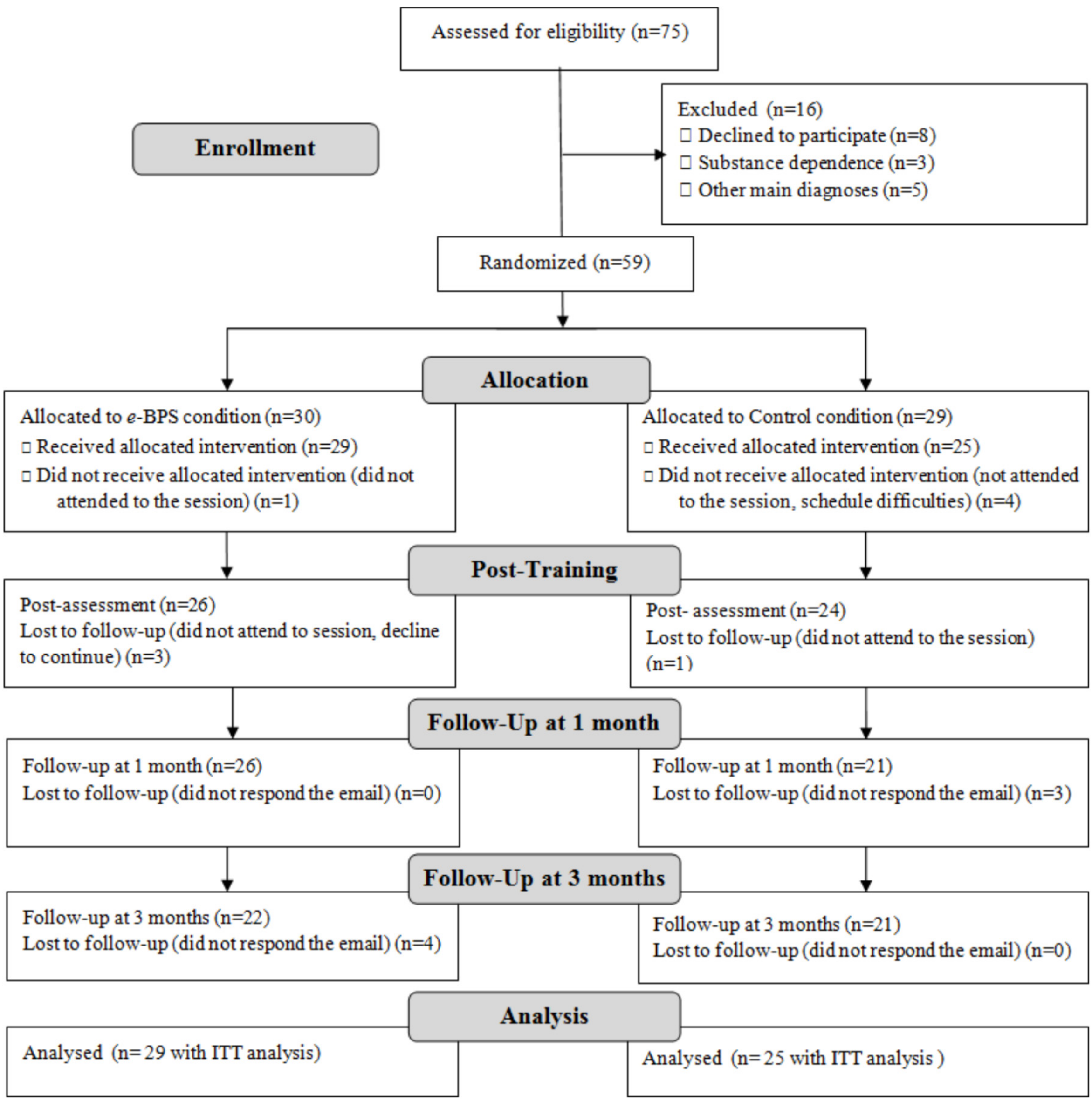

FIGURE 3 | Participant flow (following consort flow diagram 2010).

online assessments at the follow-ups. There were no significant differences in drop-out rates between groups, $\chi^2(1,54) = 0.55$, $p = 0.46$.

Pre-treatment Data

We first explored differences between groups at pre-treatment on any demographic variables, diagnosis, functional impairment and medication. The statistical analyses did not found significant differences between conditions on any of these variables. Correlations between EAT-26 and the change on primary and secondary measures at the different time points were conducted. None of these correlations were significant ($p > 0.05$), indicating that ED severity was not related to the changes in the outcome measures.

Regarding the frequency of practice, participants practiced on average 4.96 days per week over the training period (*SD*: 1.96) and this frequency decreased among the first ($M = 2.94$ days, $SD = 2.03$) and second follow-up ($M = 2.40$ days, $SD = 1.73$). There were no differences between conditions in the frequency of practice in the post-training and the first follow-up; however, in the second follow-up the participants on the BPS condition reported a significant higher frequency compared to controls [$t(45) = 2.28$, $p = 0.03$].

Single-Session Effects

ANCOVAs analyses on the baseline-corrected post-session scores showed a statistically significant effect of condition for positive [$F_{(1,51)} = 9.88$, $p < 0.01$] and negative expectations [$F_{(1,51)} = 8.58$, $p < 0.01$], revealing that there was a significant increase in positive expectations and a significant decrease in negative expectations in the intervention group compared to controls. In the case of affect, ANCOVA analyses did not show any significant condition effects on post-session changes for positive [$F_{(1,51)} = 0.04$, $p > 0.05$] and negative affect [$F_{(1,51)} = 0.74$, $p > 0.05$] subscales. **Figure 4** shows the graph of the change in scores for BPS and control conditions as well as the effect size for both measures. As the figure shows, both positive and negative future expectations revealed a significant moderate effect size ($d = 0.53$, 95% CI 0.25 to 0.81; $d = 0.48$, 95% CI 0.26 to 0.71, respectively) in the BPS condition, whereas no effect was found in the control condition. Regarding affect, participants in the BPS condition reached a significant small effect size ($d = 0.24$, 95% CI 0.02 to 0.45) for positive affect and a non-significant small effect size for negative affect ($d = 0.20$, 95% CI −0.02 to 0.39). In the control condition, both the positive and negative affect subscales revealed non-significant effects.

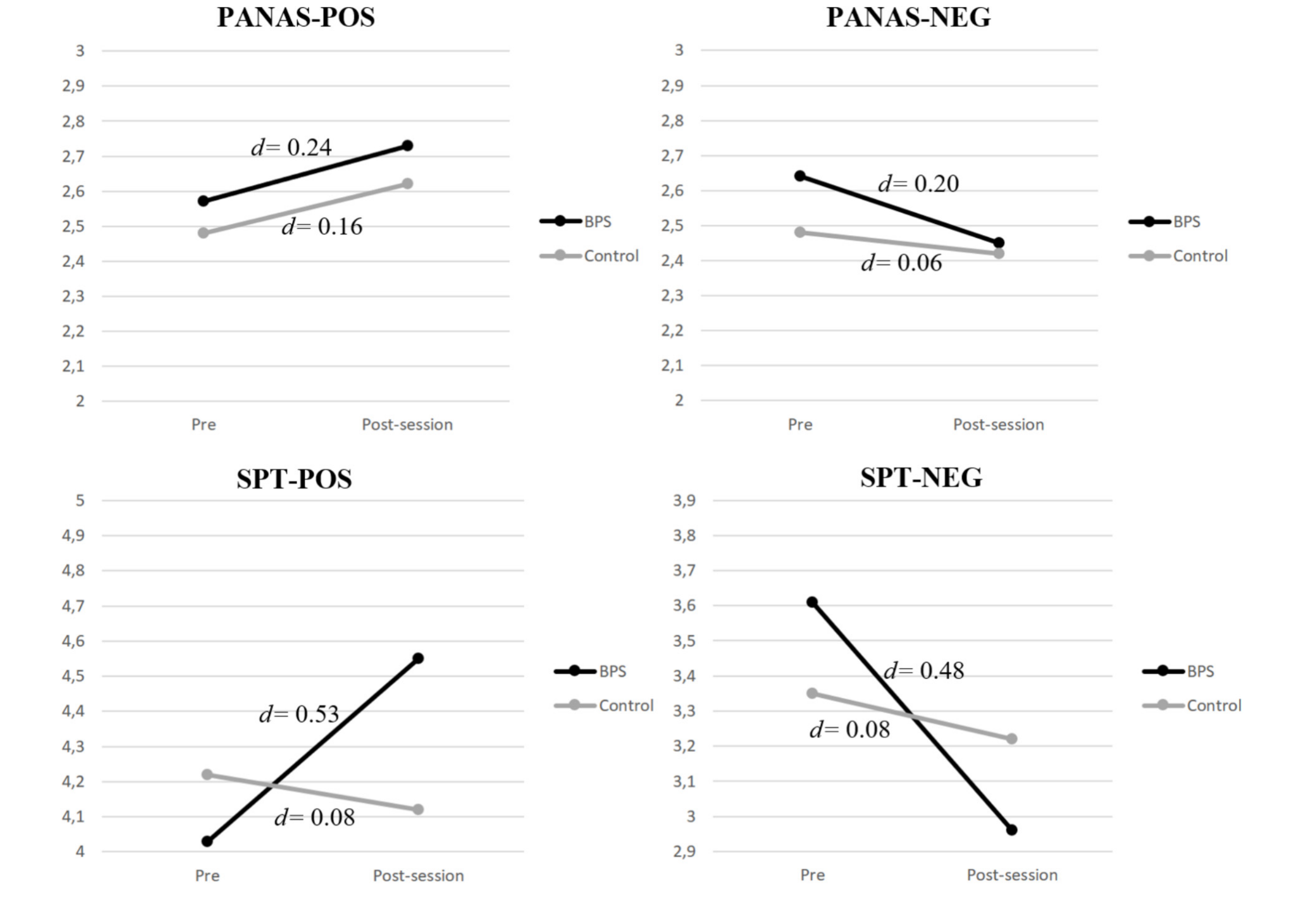

FIGURE 4 | Single session effects on SPT and PANAS subscales separated by conditions.

Post-training Effects

The ANCOVAs on the baseline-corrected post-training scores were conducted for the different measures included in the post-training assessment, namely future expectations (positive and negative), affect (positive and negative), dispositional optimism, dispositional hope and general self-efficacy. Analyses showed a marginally significant condition effect for negative expectations [$F_{(1,51)} = 3.74$, $p = 0.06$], suggesting larger decreases in negative expectations in the BPS group, compared to the control group at post-training. Regarding the rest of the measures, ANCOVA analyses did not show any significant condition effect for positive expectations [$F_{(1,51)} = 0.11$, $p > 0.05$], positive affect [$F_{(1,51)} = 0.91$, $p > 0.05$], negative affect [$F_{(1,51)} = 0.01$, $p > 0.05$], dispositional optimism [$F_{(1,51)} = 0.83$, $p > 0.05$], dispositional hope [$F_{(1,51)} = 1.06$, $p > 0.05$] and general self-efficacy [$F_{(1,51)} = 0.21$, $p > 0.05$].

Focusing on within-group effect sizes, comparing pre-to post-training (**Table 2**), the improvements were more pronounced in the BPS condition. The average effect size for the different outcomes when comparing pre-post was 0.28 for the BPS condition and 0.18 for the control condition. Regarding the effect size in the specific measures, a moderate effect size was found for the BPS condition on negative future expectations ($d = 0.57$), while no effect was found for the control condition on this measure. Low effect sizes were observed on negative affect for both conditions, BPS ($d = 0.34$) and control ($d = 0.37$) groups. Besides, a low effect size was observed on positive affect for the control group, while this effect was not observed in the BPS group.

Follow-Up Effects

To explore the effects of the intervention on the long-term, a 2 × 4 ANOVA analyses were conducted for each of the measures.

Regarding affect, analyses did not show interaction effects on positive [$F_{(2.41,125.35)} = 0.24$, $p > 0.05$] and negative affect [$F_{(3,156)} = 0.74$, $p > 0.05$] subscales. However, there was a significant time effect on both positive [$F_{(2.41,125.35)} = 5.95$, $p < 0.01$] and negative affect [$F_{(3,156)} = 4.58$, $p < 0.01$]. Regarding the latter, although the interaction effect was not statistically significant, pairwise comparisons revealed statistically significant differences between the pre- and first ($p < 0.05$) and second follow-up ($p < 0.05$) for the intervention group, while these effects were non-significant for the control condition. In the case of future expectations, ANOVA analyses did not show interaction effects between conditions for positive [$F_{(3,156)} = 0.51$, $p > 0.05$] and negative future expectations [$F_{(3,156)} = 1.83$, $p > 0.05$], but there was a time effect in both, positive [$F_{(3,156)} = 6.99$, $p < 0.01$] and negative future expectations [$F_{(3,156)} = 5.58$, $p < 0.01$]. In this regard, pairwise comparisons for positive future expectations, showed significant improvements from pre- to first follow-up ($p < 0.05$) and from pre- to second follow-up ($p < 0.05$) in the intervention group, while no significant effects were found in the control condition. Likewise, pairwise comparisons for negative future expectations showed a significant decrease from pre to second follow-up ($p < 0.05$) and from post to first follow-up ($p < 0.05$), and these effects were not found in the control group. Regarding other measures no interaction effects were found for dispositional optimism [$F_{(2.60,135.14)} = 0.51$, $p > 0.05$] and hope [$F_{(2.33,121.26)} = 0.47$, $p > 0.05$], neither time effects were observed. Lastly, results in general self-efficacy again did not show interaction between conditions [$F_{(3,156)} = 0.76$, $p > 0.05$], although a significant time effect was observed [$F_{(3,156)} = 5.34$, $p < 0.01$].

Focusing on the size of the change observed over time in terms of effect sizes, it is depicted in **Table 2**. On the 1st follow-up, the average effect size of the different outcomes was $d = 0.37$ for the BPS condition and $d = 0.17$ for the control condition. Likewise, at the 2nd follow-up, an average effect size of 0.43 was found for the BPS condition, and 0.28 for the control condition. Regarding the primary outcome measures, in the 1st follow-up, the positive subscales (SPT-POS and PANAS-POS) reached moderate effect sizes in the BPS condition ($d = 0.66$ and $d = 0.56$, respectively), and small to moderate in the control condition ($d = 0.25$ and $d = 0.46$, respectively). At the 2nd follow-up, in the case of SPT-POS, a large effect size was found for the BPS condition ($d = 0.80$), in contrast to a moderate effect size for the control condition ($d = 0.50$). Likewise, on the negative subscales, at the 2nd follow-up (SPT-NEG and NA), only the BPS condition reached a moderate effect size. Regarding secondary outcome measures, LOT-R and DHS showed a small effect size in the BPS condition in the different time frames, in contrast to the control condition, which did not produce observable effects. Finally, the effect size for GSES-12 was small for both conditions, with similar results.

DISCUSSION

This is the first pilot study randomized control trial to test the efficacy of a positive psychological exercise, the BPS, implemented through a PT application in a sample of patients with ED. The BPS exercise was tested again an active control group. Overall, the intervention produced a modest impact on the positive functioning outcomes included in the trial. The effects were more notorious at short-term, mainly in terms of future expectations, and these effects were vanishing over time.

Regarding the first hypothesis, it is partially confirmed. Results indicate that participants in the BPS condition significantly improved their levels of optimistic thinking compared to those in the control condition. However, these differences were not statistically significant for positive and negative affect, although in the case of positive affect, participants in the BPS condition reached a significant small effect size. These results agree with previous studies on the BPS exercise in the general population (Sheldon and Lyubomirsky, 2006; Peters et al., 2010), indicating that this exercise is also effective in inducing optimistic thinking and positive affect in patients with ED. Likewise, the absence of effects on negative affect found in this study is similar to results obtained in other trials with the BPS (Burton and King, 2004; Peters et al., 2010), suggesting that this exercise does not produce short-term effects on negative affect.

Given the potential benefits of the continued practice of the BPS exercise, the effects of the intervention over

TABLE 2 | Means, standard deviations and within-group effect sizes for the outcome measures in the different time-point assessments.

		Mean (*SD*)		Within-group effect size, *d* [95% CI]	Mean (*SD*)		Within-group effect size, *d* [95% CI]	Within-group effect size, *d* [95% CI]
		Pre	**Post-training**	**Pre—post-training**	**1st follow-up**	**2nd follow-up**	**Pre—1st follow-up**	**Pre—2nd follow-up**
SPT-POS	BPS	4.03 (0.95)	4.12 (1.44)	0.09 [−0.32−0.50]	4.67 (1.08)	4.81 (1.17)	**0.66 [0.23–1.08]**	**0.80 [0.31–1.28]**
	Control	4.22 (1.20)	4.37 (1.46)	0.12 [−0.20−0.44]	4.53 (1.42)	4.84 (1.10)	**0.25 [0.02–0.48]**	**0.50 [0.02–0.98]**
	Total	4.12 (1.06)	4.24 (1.45)		4.60 (1.24)	4.83 (1.13)		
SPT-NEG	BPS	3.61 (1.31)	2.84 (1.12)	**0.57 [0.21–0.92]**	3.32 (1.42)	3.07 (1.29)	0.22 [−0.11–0.55]	**0.40 [0.08–0.72]**
	Control	3.35 (1.51)	3.11 (1.60)	0.15 [−0.04–0.35]	3.30 (1.61)	3.28 (1.61)	0.03 [−0.18–0.24]	0.04 [−0.15–0.23]
	Total	3.49 (1.40)	2.97 (1.35)		3.31 (1.50)	3.17 (1.44)		
PA	BPS	2.57 (0.64)	2.69 (0.98)	0.18 [−0.12–0.49]	2.94 (0.91)	2.95 (0.96)	**0.56 [0.16–0.96]**	**0.58 [0.12–1.03]**
	Control	2.48 (0.86)	2.79 (0.96)	**0.35 [0.07–0.62]**	2.89 (1.15)	2.99 (0.88)	**0.46 [0.12–0.80]**	**0.57 [0.06–1.09]**
	Total	2.53 (0.74)	2.74 (0.96)		2.92 (1.02)	2.97 (0.92)		
NA	BPS	2.64 (1.00)	2.29 (0.84)	**0.34 [0.06–0.62]**	2.26 (0.98)	2.19 (0.81)	**0.37 [0.09–0.65]**	**0.44 [0.05–0.82]**
	Control	2.48 (0.84)	2.16 (0.91)	**0.37 [0.07–0.67]**	2.27 (1.07)	2.30 (1.07)	0.24 [−0.06–0.55]	0.21 [−0.08–0.50]
	Total	2.56 (0.93)	2.23 (0.87)		2.27 (1.01)	2.24 (0.93)		
LOT-R	BPS	18.24 (5.16)	18.94 (4.55)	0.13 [−0.24–0.5]	19.27 (5.10)	19.68 (5.27)	0.19 [−0.04–0.43]	0.27 [−0.01–0.55]
	Control	18.84 (5.31)	18.23 (6.76)	−0.11 [−0.39–017]	18.87 (6.84)	19.49 (6.01)	0.01 [−0.28–0.29]	0.12 [−0.25–0.49]
	Total	18.52 (5.19)	18.61 (5.64)		19.09 (5.92)	19.59 (5.57)		
DHS	BPS	40.58 (10.68)	44.17 (9.31)	0.33 [−0.02–0.67]	43.76 (9.76)	42.92 (11.78)	0.29 [−0.03–0.61]	0.21 [−0.09–0.52]
	Control	42.16 (13.32)	42.89 (12.64)	0.05 [−0.22–0.33]	43.40 (11.77)	43.84 (14.10)	0.09 [−0.21–0.39]	0.12 [−0.28–0.52]
	Total	41.31 (11.88)	43.58 (10.88)		43.59 (10.63)	43.35 (12.79)		
GSES	BPS	39.71 (6.66)	41.99 (6.94)	**0.33 [0.03–0.63]**	41.76 (7.54)	41.82 (7.54)	0.30 [−0.09–0.69]	0.31 [−0.06–0.67]
	Control	37.12 (9.19)	40.73 (10.16)	**0.35 [0.04–0.66]**	39.63 (10.89)	41.80 (7.81)	0.14 [−0.14–0.41]	**0.40 [0.02–0.78]**
	Total	38.51 (7.97)	41.40 (8.52)		40.77 (9.21)	41.81 (7.59)		

Values marked in bold indicate significant effect sizes based on the Confidence Intervals (CI), which do not include zero. SPT-POS, Positive expectations; SPT-NEG, Negative Expectations; PA, Positive Affect; NA, Negative Affect; LOT-R, Life Orientation Test; DHS, Dispositional Hope Scale; GSES, General Self-Efficacy Scale; BPS, Best Possible Self.

time were explored. Results showed that the BPS exercise produced larger decreases marginally significant in negative expectations after 1-month training compared to the control exercise. These effects are in line with prior results in general population (Meevissen et al., 2011; Enrique et al., 2017a), indicating that BPS exercise implemented through PT has the ability to decrease negative expectations in patients with ED. This is important given that these patients use to have a pessimistic view about the future (Malson et al., 2011), so that PPIs as the BPS exercise can produce benefits at this level. Contrary to our expectations, no statistical differences between conditions were found for the other primary and secondary outcomes when comparing the effects at post-training. Likewise, the analyses including the follow-up effects on the different outcomes did not show any statistically significant interaction between conditions. These results contradict some of the findings about the ability of BPS exercise to produce effects in future expectations, positive and negative affect, dispositional optimism and self-efficacy observed in general (Sheldon and Lyubomirsky, 2006; Meevissen et al., 2011) and clinical populations (Pietrowsky and Mikutta, 2012; Molinari et al., 2017).

Despite the absence of statistical differences between conditions, the average within-group effect size when combining the different measures was higher in the BPS condition than the control group across the different time frames. In this sense, the lack of statistically significant results could be explained by the fact that both conditions followed a trend toward improvement, explained by patients involvement in the psychological treatment for the ED, along with the small sample size, which might be complicating the emergence of significant results. Focusing on the difference between conditions in primary outcomes, future expectations and affect, both measures had a significant improvement over time. Indeed, future expectations was the variable that shed more pronounced differences between conditions, suggesting that BPS exercise was more effective on improving this measure, even reaching a large effect size on positive expectations subscale at the second follow-up. The cognitive nature of the BPS exercise (Erikson, 2007) could explain the larger effects in future expectations, in detriment of effects at an emotional level. In terms of affect, results were quite similar between conditions in terms of positive affect, suggesting that the change might be due to the treatment and not to a condition effect. Effects on negative affect were more pronounced in the BPS condition at long-term, suggesting that BPS exercise might had an influence in this decrease, although more studies are needed to confirm these trends. These results are not in line with prior literature which indicate that BPS exercise implemented with healthy and depressed samples have more impact on positive affect than on negative affect (Layous et al., 2012; Pietrowsky and Mikutta, 2012). However, the levels of negative affect in this population are higher than other clinical populations, which also allow a bigger room for improvement.

Looking at secondary measures, only general self-efficacy showed a significant improvement at post-training and results between conditions were quite similar, suggesting that the changes were due to the treatment and not to the condition. Dispositional optimism and hope showed non-significant changes in any of the conditions. These results could be explained by the fact that optimism and hope refer to personality traits that hardly can be changed (Pietrowsky and Mikutta, 2012). In this sense, even being non-significant, it is noticeable that results on these measures were slightly better in participants of the BPS condition, suggesting a positive trend that need to be confirmed by further studies with larger samples.

It is important to note that the BPS manipulation consisted of repeating the exercise of visualizing the best possible future over the training period and the follow-up based on the exercise developed in the first session (Enrique et al., 2017a). This situation could produce hedonic adaptation, meaning that the exercise no longer produces the same benefits observed at short-term (Diener et al., 2006). Different authors suggest that the integration of PPIs into more complex interventions would allow users to choose these strategies from a broader variety of exercises, avoiding the effects of the hedonic adaptation (Lyubomirsky and Layous, 2013). Therefore, it is possible to improve the efficacy of these interventions by combining different PPI and by introducing technologies as the ones displayed in this study (Enrique et al., 2017a; Molinari et al., 2017).

Although this study did not allow to draw conclusions about the role of the PT, its implementation was expected to make the exercise more rich and engaging. As a matter of fact, the patients included in this study were asked about their acceptability levels with the intervention and they informed adequate levels of satisfaction and usefulness. These results were published elsewhere (Enrique et al., 2017b). As Gaggioli et al. (2017) suggest, one of the goals of the PT is to improve the personal experience of the individuals by offering multisensorial experiences in which the content is offered through more than one senses, as the ones included in this trial. Future studies should explore if the inclusion of PT produces differential effects on the personal experience compared to the practice of the exercises without technologies.

This study has some limitations. First, the control condition focuses on the past as the participants had to think about the last 24 h, whereas the BPS exercise is future-oriented. Although other studies about BPS have used the same control condition (Sheldon and Lyubomirsky, 2006; Peters et al., 2010), future studies should include a control condition with the same temporal orientation in order to compare the results. Furthermore, given that it was established as a pilot study, sample size was not calculated and that lead to a little sample size ($N = 54$), which perhaps acted as a barrier for observing significant differences and affected to the generalization of the results. Still, our sample size was similar to other studies related to the field (Meevissen et al., 2011) and it was a clinically relevant sample. Regarding the technology used, it is important to note that the efficacy of the technologies was not compared to a condition without technologies, which means that we cannot know if technology is playing a role in the benefits obtained from the exercise. Another limitation is related to the description of the clinical sample because we did not collect information about the body mass index or the duration of the disorder, and both factors might influence the results obtained in this study. Yet, our results showed that severity of the ED pathology was not related to the change on the different outcome measures. Furthermore, half of the sample had a comorbid diagnosis of personality disorders, which keeps us from drawing conclusions only in terms of patients suffering from ED conditions. Thus, future studies should study the efficacy of PPIs in a sample with pure ED conditions in order to explore whether these PPIs act in the same way.

CONCLUSION

This study illustrates the modest impact that a simple positive strategy implemented through PT has in patients with ED. This is the first study that tests the efficacy of the implementation of a PPI through PT in an ED sample. In this sense, it can serve as a reference for the design of new interventions aimed to improve well-being or quality of life on samples suffering ED. The trends observed in this study support the hypothesis that PPIs can act as supporting tools in the treatment of EDs by generating positive emotions that can protect against the harmful effects produced by ED conditions (Brannan and Petrie, 2011). However, more studies are needed to confirm these assumptions as there is a compelling need to provide these patients with positive resources in order to facilitate their recovery process (de Vos et al., 2017). Future studies should continue exploring the efficacy of different PPIs and their combination in ED samples in order to find out which strategies work better in what type of patients (Layous et al., 2012). If that should happen, it might contribute to generate additional resources in order to support the recovery process of patients with ED.

ETHICS STATEMENT

This study was approved by the Research Ethics Committee of the Provincial Hospital of Castellón. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

AE drafted the manuscript with important contributions from JB-L, FF-A, RB, and CB. AE in collaboration with GL, CB, and JB-L designed the study and participated in each of its phases. PR collaborated in the data analysis and the report of the results.

GM collaborated in the manuscript development and participated in each study phase. VG and GL made important contributions in terms of sample recruitment. All authors participated in the review and revision of the manuscript and have approved the final manuscript to be published.

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Promoting Emotional Well-Being in Older Breast Cancer Patients: Results From an eHealth Intervention

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Breast cancer is the most common cancer in women worldwide, with increases in diagnoses at all ages. Due to several age-related factors, older breast cancer patients show particular difficulties in adjusting to breast cancer and its related treatments. One consistent indicator of vulnerability to long-term complications is emotional distress occurring within 3 months of diagnosis. Thus, it is critical to develop early interventions specifically aimed at mitigating distress and promoting emotional wellbeing in older breast cancer patients. By taking advantage of the opportunities of online interventions, the present study aimed to test the efficacy of a 2 weeks e-health stress inoculation training (SIT) intervention on emotion regulation and cancer-related well-being, compared with a control group without such intervention. Twenty-nine women with a diagnosis of breast cancer, who had received radical surgery and who were suitable candidates for adjuvant chemotherapy with anthracyclines and taxanes (mean age = 62.76; *SD* = 6.19) voluntarily took part in the current study after giving written informed consent. To test intervention efficacy, self-report questionnaires were administered to all participants at baseline, at the end of the 2 weeks intervention, and 3 months after the end of the intervention. Results showed that after 2 weeks of ehealth intervention, patients did not achieve significant change, however, they significantly reduced emotional suppression and increased cancer-related emotional well-being 3 months after the end of the intervention. Furthermore, by monitoring at a distance the emotional experience during the online intervention, we found an increase in relaxation and a reduction of anxiety. Finally, patients in the experimental group reported a good level of acceptance of the ehealth intervention. To conclude, designing and developing eHealth interventions as part of the regular care path for breast cancer patients of all ages represents both a challenge and an opportunity; in particular, online interventions can be an important step in universal psychosocial care within a tiered model of care.

Keywords: emotion regulaton, well-being, positive technology, eHealth, breast cancer

INTRODUCTION

Breast cancer is the most common cancer in women worldwide. With increases in diagnoses at all ages – even if more slowly between 50 and 80 years of age (DeSantis et al., 2011) – more women will have to deal with breast cancer and its consequences (van Ee et al., 2017b).

From a psychological point of view, the literature is not consistent about women' experiences related to age. Although women of different ages have many experiences in common regarding breast cancer that imply a deterioration of well-being and quality of life (Montazeri, 2008; Campbell-Enns and Woodgate, 2016), older women do not have to deal with the non-normative nature of a chronic disease at a relatively young age, which typically causes disruption in multiple life roles (Dunn and Steginga, 2000; Thewes et al., 2004). They are less challenged by job demands, taking care of a young family, and fertility issues (Rana et al., 2017). Nevertheless, a variety of age-related aspects can make it more stressful for older patients to deal with the diagnosis and treatment of breast cancer (Park et al., 2011).

Several studies showed the emergence of psychosocial distress soon after the diagnosis of cancer and before the beginning of treatment (Nosarti et al., 2001; Andreu et al., 2012). Since high levels of distress during or immediately after surgery (Nosarti et al., 2001; Gallagher et al., 2002; Lam et al., 2007; Mertz et al., 2012) can lead to higher psychological vulnerability in the subsequent treatment period (Neerukonda et al., 2015), it is crucial to address this risk early on in the treatment process (Henselmans et al., 2010; Lam et al., 2012). In particular, chemotherapy treatment has been reported as distressing and traumatizing (Richer and Ezer, 2002), including for post-menopausal women (Browall et al., 2006), with hair loss, nausea and fatigue frequently ranked among the first three worst side effects (Carelle et al., 2002).

According to a recent review, emotional distress, measured within 3 months of diagnosis, is the only consistent predictor that the distress will persist long-term (Cook et al., 2018). Emotional distress is associated less with the patient's actual clinical condition than it is to the patient's own subjective opinion of their health and prognosis (Millar et al., 2005). The persistence of distress as an enduring problem, at least for a third of patients in treatment or long-term follow-up (Cook et al., 2018), supports the need for assessing distress and developing early interventions specifically aimed at mitigating distress and promoting individual wellbeing (Casellas-Grau et al., 2014).

In the scientific literature, attention to the effectiveness of psycho-oncological interventions for patients with breast and other cancers seems to diminish with increasing age, specifically after 60 years of age (van Ee et al., 2017a). Thus, psychological interventions designed to reduce anxiety in older women and increase their control over the treatments and treatment-related effects (Treacy and Mayer, 2000; Seçkin, 2011) and evidence-based recommendations represent a future challenge (Petrakis and Paraskakis, 2010; Biganzoli et al., 2012).

THE OPPORTUNITIES OF eHEALTH INTERVENTIONS

Computer-based and web applications have demonstrated their potential for supporting psychological interventions aimed to help people cope with health-related distressing experiences. The Positive Technology approach suggests various options for using advanced technology to facilitate psychological health and wellbeing (Botella et al., 2012; Riva et al., 2012; Villani et al., 2016a). According to this approach, positive technologies can be categorized according to their effects on three features of personal experience: *hedonic*, such as technologies used to induce positive and pleasant experiences; e*udaimonic*, such as technologies used to support individuals in reaching engaging and self-actualizing experiences; and *social/interpersonal*, such as technologies used to support and improve the connectedness between individuals, groups, and organizations. Positive technology tools can be used to effectively promote patients' clinical change; but to reach this challenge, they must adapt to the specific stage of the patients' change process and sustain their engagement within the provided experience (Riva et al., 2016). Within the positive technology approach, eHealth interventions allow the development of sustainable and patient-centered services, alternatively focused on several experiential dimensions (i.e., cognitive, emotional or behavioral) of patient engagement related to their healthcare management (Barello et al., 2016). Over the last decade, the application of eHealth interventions in psycho-oncological care has grown (McAlpine et al., 2015), and cancer patients are becoming Internet users, independently of their age, breast cancer stage and length of time since diagnosis (Fogel et al., 2002).

The Internet has become an accessible source for individuals to research information, including for their medical issues, and patients with cancer are among the most frequent such users (Drewes et al., 2016). This reflects the development of Internet educational programs available for breast cancer patients that, at the moment, are focused mostly on increasing patients' knowledge through information related to both the disease and the procedures (Warren et al., 2014). Clear, accurate and informative websites can be seen as a first level of supportive care, but the mere provision of educational material does not significantly improve compliance or patients' wellbeing. Thus, it is possible to recognize eHealth interventions that are more oriented to sustaining women's well-being (Villani et al., 2016b). In one recent study, women with cancer identified Web-based applications, email, and blogs as appropriate vehicles to meet their needs for psychological and informational support and specified their preference for topics such as ability to cope, anxiety and depressive feelings (Ringwald et al., 2017).

These interventions vary from (1) the use of personal websites aimed to enhance the emotional wellbeing of women with breast cancer through the development of narrative experiences and the expression of their feelings (Harris et al., 2015); (2) the development of online peer support interventions aimed to enhance social support, which have been appreciated by older women (Seçkin, 2011); and (3) more sophisticated training aimed at teaching self-guided coping skills principally oriented toward the management of patients' affective state (Owen et al., 2005).

Coherently with this third approach, another opportunity is offered by adapting Meichenbaum's stress inoculation training (SIT) (Meichenbaum, 1985) within eHealth interventions. SIT is a cognitive behavioral therapy designed to strengthen the patient's coping strategies to deal with stress. In the breast cancer context, the aim is to prepare women for chemotherapy treatment and side effects by helping them reduce the potential negative cognitive, emotional, and behavioral reactions. The clinical rationale behind this approach is that to effectively manage stress it is crucial to "inoculate" the stressor: using a combination of graded exposure with the acquisition of effective coping skills. SIT has been already validated in clinical contexts, to help patients in facing particularly strenuous conditions (Amiri et al., 2017) and it has also been applied to cancer patients, showing its effectiveness in altering anxiety-related behaviors (Moore and Altmaier, 1981).

According to the results of a recent systematic review (Serino et al., 2014), the combination of a traditional SIT intervention with advanced technologies appears to be a promising clinical approach. In oncological care, Villani et al. (2013) showed the effectiveness of a mobile SIT intervention in reducing anxiety and improving active coping skills in oncology nurses.

As explained above, to target specifically the needs of aging breast cancer patients, we decided to set up and test this validated intervention on this population. Thus, we developed an eHealth intervention for older cancer patients based on a 2 weeks protocol consistent with the general SIT objectives: (1) increasing women's knowledge about the emotional distress process, (2) developing emotion-regulation skills, and (3) helping women to apply the acquired coping skills in "real" contexts (which were simulated in this specific intervention).

The aim of the study was to test the efficacy of the e-health SIT intervention on emotional well-being, compared with a control group without intervention. Specifically, we expected an increase of adaptive emotion regulation strategies, defined as the "processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals (Thompson, 1994, pp. 27–28)"; and an increase of cancer-related well-being, with a specific focus on the emotional dimension of well-being, consistently with the focus of the intervention on improving emotional coping skills.

MATERIALS AND METHODS

Participants

Patients were recruited primarily through direct patient contact with consecutively scheduled patients by two oncologists at two hospitals in Milan (ASST Rodhense and S. Giuseppe Multimedica Hospital). The study was proposed to all breast cancer patients fulfilling the following inclusion criteria: diagnosis of breast cancer with radical surgery; age over 55 years; negative staging for distant metastases; and suitability for adjuvant chemotherapy with anthracyclines and taxanes. Prior to analyzing data, we calculated the sufficient sample size needed to detect a medium effect size in our analyses. By convention, an f-value of 0.10 for effect size is considered small, 0.25 is medium and 0.40 is large. We used the software G*Power and we found that 28 individuals were needed to provide 80% power to detect a medium effect size (f = 0.25) with a repeated measure design-within/between interaction (number of groups: 2; number of measurements: 3; correlation among repeated measures: 0.5).

By taking in consideration the clinical dimension, we decided to propose the study to forty patients to overcome drop-out at follow-up due to negative treatment-related side effects. Thus, the study was proposed to forty patients, but four gave up after the first meeting for personal reasons or hospital change and seven were not interested in participating (acceptance rate 72.5%; 29/40). Ultimately, 29 women (mean age = 62.76; SD = 6.19) voluntarily took part in the current study after signing giving informed consent. They were mostly married (79.3%; 23/29) and not employed (69%; 8/29 housewives and 12/29 retired). As concerns the educational level, 8 women had a primary school certificate, 8 women had a high school diploma, 10 women had a master degree and 3 women had obtained a post-master degree.

To investigate the effectiveness of the e-health SIT intervention, women were randomly allocated into two groups: the "e-Health Group" (EHG, N = 15) and the "Control Group" (CG, N = 14). Patients allocated to the control group received the traditional medical assistance offered by the hospitals, consisting of waiting for the first chemotherapy infusion. Psychological support before chemotherapy was not provided as usual care but only if requested by patients.

The study, conducted in compliance with the Helsinki Declaration (of 1975, as revised in 2008), was approved by the Ethics Review Board of the Department of Psychology of the Università Cattolica del Sacro Cuore of Milan (Italy).

E-health Intervention

To support elderly breast cancer patients in their upcoming chemotherapy and offer them effective coping strategies, an e-health intervention based on SIT was specifically designed and delivered online through a dedicated website[1]. Following the guidelines proposed by Meichenbaum (1985), the training was composed of three phases.

The first phase –*conceptualization*– aimed at helping patients to be aware of the nature of their own psychological stress. In the first meeting, during a face-to-face consultation with a psychologist, patients were helped to recognize the nature of their psychological stress related to the disease and the upcoming treatment. To facilitate awareness about the upcoming situation and its psychological impact, they experienced a live-video simulation of a chemotherapy session that they would receive within a few weeks. In particular, they were encouraged to reflect about their stress responses and the perceived threats and skills that could manifest in the different phases of the treatment. At the end of this first session, patients followed the intervention online at home for a period of 2 weeks; they were instructed on how to access the online intervention with personal account credentials. However, the psychologist's contact was provided to all patients in case of personal difficulties during the treatment.

[1] www.conilsenodipoi.it

The e-health intervention comprised the other two phases of the traditional SIT, i.e., the *skills acquisition and rehearsal* (sessions 1–7) and the *application and follow-through* phase (sessions 8–10). The *skills acquisition and rehearsal* aimed at providing patients with effective coping skills and techniques to manage potential negative emotions that might occur during chemotherapy. Each session (25 min) was divided into two parts.

First, they were invited to watch live-video interviews with women who had gone through breast cancer experiences, to reflect upon their thoughts and emotions, to deeply understand chemotherapy side effects, and especially, to learn effective strategies through modeling to cope with physical and emotional changes. Specifically, interviews were focused on different crucial topics: women's expectations, hopes and fears before starting chemotherapy; emotional experiences related to the disease and its impact on the quality of life; chemotherapy side effects, in particular hair loss, both from a practical and emotional point of view; the impact of the disease and therapies on several aspects of women's life (physical, psychological, social, professional, etc.); potential activities that could be done during treatment to ameliorate side effects; suggestions and tips offering new perspectives that some women might find in this experience with social support.

Then, they were invited to experience relaxing videos with guided meditation audios to learn how to relax in disturbing moments. Included techniques were progressive muscle relaxation (Jacobson, 1938) and mindfulness-inspired strategies such as thought contemplation and detached mindfulness, aimed to help women to be aware of their thoughts and related emotions, and to accept their internal states (Kabat-Zinn, 2003). Even though there is considerable variability in mindfulness interventions being delivered in cancer care and reported benefits are related mostly to sub-clinical supportive care symptomology (Shaw et al., 2018), mindfulness strategies for women diagnosed with breast cancer during and subsequent to adjuvant treatment are recognized as effective short-term interventions in reducing affective difficulties, such as anxiety and depression (Haller et al., 2017).

Eventually, the aim of the *application and follow-through phase* was to expose women to the effects of their upcoming chemotherapy and help them to apply the acquired coping skills in a "real" context. Also, in this case, each session included two parts: first, participants were exposed to a series of live-video interviews of breast cancer patients' currently undergoing chemotherapy – both with and without wigs. These videos also included tips and advice on how to cope with possible typical side effects occurring during the treatment. Then, with the help of relaxing videos embedded with guided meditation audios, participants were invited to apply the meditation exercises in a real context. **Figure 1** provides a synthesized overview of the entire e-health protocol.

Measures

Intervention Efficacy

The e-health intervention was delivered with an online training lasting 2 weeks, while the CG only participated in the introductory and closing face-to-face consultations (see **Figure 2**).

To evaluate its efficacy in providing participants with effective emotional coping skills and in improving well-being related to disease, the following self-report questionnaires were administered to all participants at three time points: baseline (T0), after the 2 week intervention (T1), and 3 months after the end of the intervention (T2).

The Emotion Regulation Questionnaire (ERQ, Gross and John, 2003; Balzarotti et al., 2010) is a 10-item self-report questionnaire on a 7-point Likert scale [from 1 (strongly disagree) to 7 (strongly agree)] investigating individual differences in the use of the fundamental emotion regulation strategies. *Cognitive reappraisal* (6 items) refers to the ability to reinterpret the meaning of an emotional event to change its emotional impact (e.g., "When I want to feel more positive emotion, I change the way I'm thinking about the situation"; Cronbach's alpha 0.775), while *emotional suppression* (4 items) refers to the tendency to inhibit the emotional expression elicited by a situation (e.g., "I control my emotions by not expressing them"; Cronbach's alpha.746). The two scales were obtained by calculating the mean scores from the items, ranging from 1 to 7.

The Functional Assessment of Chronic Illness Therapy – Breast (FACT-B, Bonomi et al., 1996; Brady et al., 1997) is a self-administered questionnaire on a 5-point Likert scale that measures health-related well-being. The FACT-B comprises 29 general items that measure four subscales of quality of life: physical well-being (*PWB,* e.g., "I have a lack of energy," reverse score item; Cronbach's alpha 0.864), social well-being (*SWB*, e.g., "I get emotional support from my family"; Cronbach's alpha 0.814), emotional well-being (*EWB*, e.g., "I feel nervous," reverse score item; Cronbach's alpha 0.624), and functional well-being (*FWB,* e.g., "I am able to work"; Cronbach's alpha 0.651). Total score is obtained by summing individual subscale scores (FACT-General total score).

Emotional Changes and Intervention Acceptance

To investigate the fluctuations in the emotional experience during the online intervention, participants receiving the e-health intervention (EHG) were evaluated before and at the end of each online session about their level of anxiety and relaxation through a 7-point visual analog scale.

Actually, as the acceptance of ehealth technologies is a critical factor influencing their effective use and thus fostering the active role of patients in their healthcare, the intervention acceptance was measured. According to the technology acceptance model (TAM), which is one of the most influential models in explaining user acceptance of information technology (Davis, 1989), it is possible to hypothesize two fundamental factors: *perceived usefulness* and *perceived ease of use.* In adjunct, as analyzed by other studies (Villani et al., 2018), the *positive affective attitude* toward technologies also represents an important dimension of technology acceptance. Following this theoretical model, the intervention acceptance included five online *ad hoc* questions presented upon completion of the daily protocol investigating the pleasantness, the perceived utility of the contents and (only for meditation videos) the perceived easiness of the proposed exercises.

eSIT phase	Sessions	Content of experience
Conceptualization phase	Session face-to-face	Live-video simulation of a chemotherapy session; Face-to-face consultation with a psychologist
Skills acquisition and rehearsal phase	Sessions online 1-7	Live-video interviews with women who have gone through breast cancer experiences; Relaxing videos with guided meditation audios.
Application and follow - through phase	Sessions online 8-10	Live-video interviews of breast cancer patients' interviews currently undergoing chemotherapy - both with and without wigs; Relaxing videos embedded with guided meditations audios.

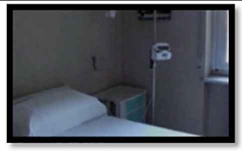

FIGURE 1 | eSIT protocol.

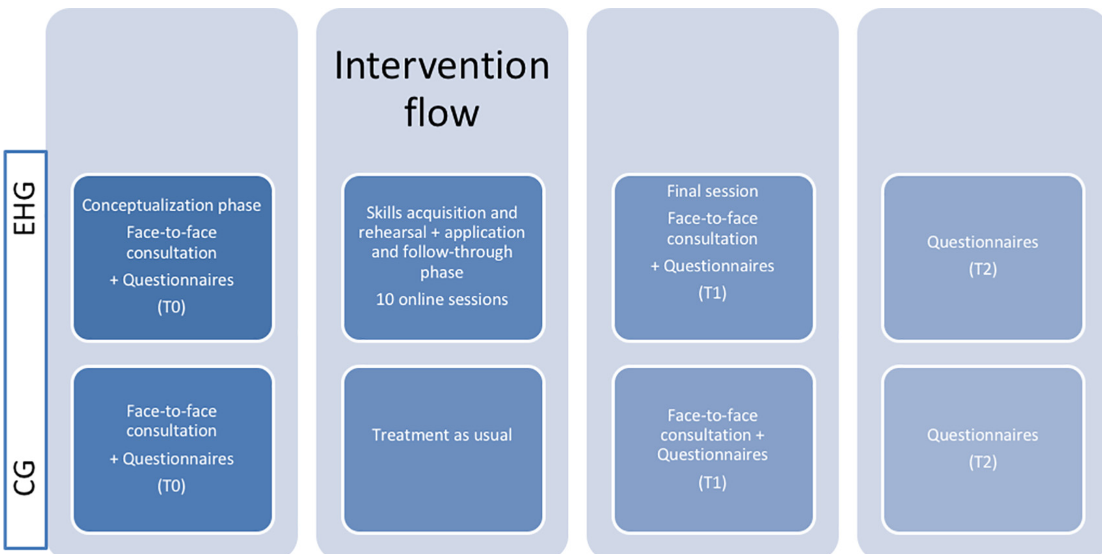

FIGURE 2 | Intervention flow.

To monitor whether participants were accessing any other forms of psychosocial intervention during the weeks of intervention and until the follow up assessment, we added the following question to the T2 assessment: "Have you received a psychological support (privately or through the referral hospital's facilities) since you agreed to participate in this study?"

RESULTS

We compared the E-Health Group (EHG) and the Control Group (CG) at the baseline in order to detect any difference in the considered variables at the beginning of the study. Independent sample *t*-tests indicated that the two groups did not differ either in their emotion regulation strategies (ERQ - cognitive reappraisal: $t(27) = 0.928$, $p = 0.361$; emotional suppression: $t(27) = -1.156$, $p = 0.258$), or in their wellbeing related to the cancer [FACT-B – PWB: $t(27) = 1.587$, $p = 0.124$; SWB: $t(27) = 1.669$, $p = 0.107$; EWB: $t(27) = 0.695$, $p = 0.493$; FWB: $t(27) = 0.979$, $p = 0.336$; FACT-General Total Score: $t(27) = 1.802$, $p = 0.083$].

Table 1 provides a detailed overview of the descriptive statistics of considered variables at three time points [baseline (T0), after the 2 week intervention (T1), and 3 months after the end of the intervention (T2)] divided for the two groups.

Three months after the end of the intervention (T2), only 3 women (2 of the EHG group and 1 from the CG) declared that they received a psychological support (all of them from the referral hospital's facilities), while 15 women (8 of the EHG and 7 of the CG) did not. This very low participation in psychological consultations by women involved in the study was not considered in the subsequent analyses aimed to test the effectiveness of the intervention.

TABLE 1 | Descriptive data for EQR and FACT-B questionnaires.

				Mean	St. Dev.	Min.	Max.
ERQ	Emotional suppression	T0	EHG	2.93	1.80	1.00	5.50
			CG	3.63	1.38	1.50	6.00
		T1	EHG	2.91	1.68	1.00	5.50
			CG	3.79	1.39	1.00	5.75
		T2	EHG	2.33	1.12	1.00	4.50
			CG	4.15	1.45	1.25	6.50
	Cognitive reappraisal	T0	EHG	4.99	1.19	2.20	6.80
			CG	4.53	1.46	1.40	6.20
		T1	EHG	5.11	1.09	3.40	7.00
			CG	4.59	1.79	1.00	7.00
		T2	EHG	5.43	1.43	2.20	7.00
			CG	4.88	1.24	2.80	7.00
FACT-B	Physical wellbeing	T0	EHG	24.40	2.56	19.00	27.00
			CG	21.43	6.76	8.00	28.00
		T1	EHG	22.07	4.57	11.00	28.00
			CG	22.71	4.53	13.00	28.00
		T2	EHG	21.92	3.55	17.00	27.00
			CG	19.82	6.03	12.00	28.00
	Social wellbeing	T0	EHG	18.73	5.08	8.00	26.00
			CG	16.21	2.55	12.00	19.00
		T1	EHG	17.93	3.63	12.00	24.00
			CG	15.71	4.07	11.00	25.00
		T2	EHG	18.62	2.96	13.00	22.00
			CG	17.55	4.97	5.00	24.00
	Emotional wellbeing	T0	EHG	17.60	3.48	10.00	22.00
			CG	16.43	5.45	4.00	23.00
		T1	EHG	17.13	3.11	9.00	21.00
			CG	16.71	4.55	8.00	23.00
		T2	EHG	19.54	2.90	14.00	24.00
			CG	16.82	5.04	9.00	23.00
	Functional wellbeing	T0	EHG	14.13	4.34	5.00	20.00
			CG	12.64	3.82	8.00	21.00
		T1	EHG	13.73	4.30	6.00	20.00
			CG	12.43	6.00	5.00	23.00
		T2	EHG	14.31	3.28	9.00	21.00
			CG	13.45	6.59	3.00	24.00
	FACT-B general	T0	EHG	74.87	10.36	51.00	88.00
			CG	66.71	13.86	40.00	88.00
		T1	EHG	70.87	9.78	48.00	83.00
			CG	67.57	12.75	46.00	89.00
		T2	EHG	74.38	9.11	60.00	91.00
			CG	67.64	17.18	32.00	89.00

Protocol Efficacy

We tested the efficacy of the e-health intervention on emotion regulation and well-being related to cancer. To do this, a series of repeated measures ANCOVAs was conducted, with the baseline (T0) measure of the different variables as covariate, the factor Time (with two levels: T1 and T2) as within subject variable, and the Factor Group (EHG vs. CG) as between subject variable (see **Table 2** for the ANCOVA statistical values).

Concerning the emotion regulation strategy, as measured by ERQ, the initial level of emotional suppression was significantly related to the level of emotional suppression in the post-treatment (T1) and in the follow-up (T2). Furthermore, after controlling for the effect of the initial level of emotional suppression, the interaction Time × Group was also significant. Looking at the marginal means estimated by the model (see **Figure 3**), it is evident that in the EHG the emotional suppression

TABLE 2 | Repeated measures ANCOVAS results.

			F	*df*	*p*	η^2
EQR	Emotional suppression (ES)	ES (T0)	22.25	1,19	0.003	0.38
		Group*Time	5.5	1,19	0.03*	0.23
	Cognitive reappraisal (CR)	CR (T0)	9.2	1,19	0.07	0.33
		Group*Time	0.01	1,19	0.92	0.001
FACT-B	Physical wellbeing (PWB)	PWB (T0)	15,18	1,21	0.001	0.42
		Group*Time	2.95	1,21	0.1	0.12
	Social wellbeing (SWB)	SWB (T0)	5.56	1,21	0.03	0.21
		Group*Time	1.11	1,21	0.3	0.05
	Emotional wellbeing (EWB)	EWB (T0)	52.86	1,21	0.000	0.72
		Group*Time	5.83	1,21	0.03*	0.22
	Functional wellbeing (FWB)	FWB (T0)	13.5	1,21	0.01	0.39
		Group*Time	0.64	1,21	0.43	0.03
	FACT-B general (FACT-G)	FACT-G (T0)	23.31	1,21	0.000	0.53
		Group*Time	0.99	1,21	0.33	0.05

* *Statistically significant.*

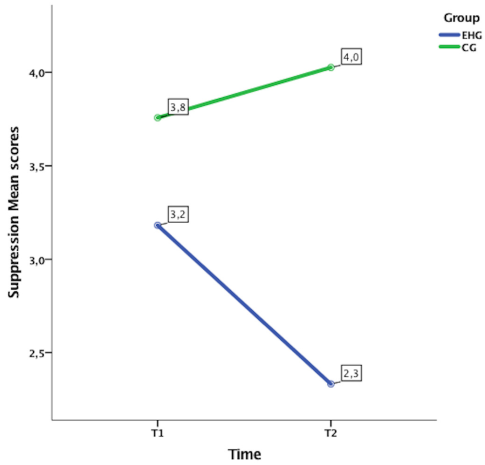

FIGURE 3 | Emotional Suppression significant interaction effect time × group from ANCOVA analysis.

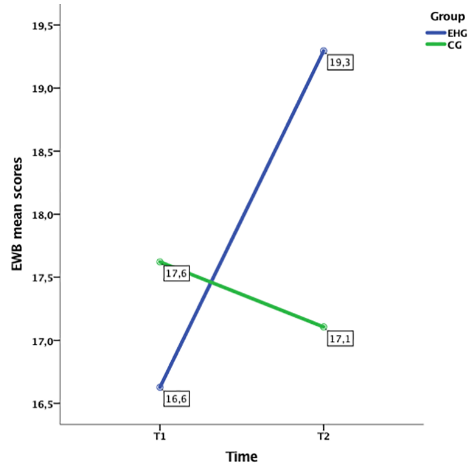

FIGURE 4 | Emotional Well-being significant interaction effect time × group from ANCOVA analysis.

decreased from T1 to T2 (T1 = 3.18; T2 = 2.33), whereas in the CG the scores were almost the same at the two time points (T1 = 3.76; T2 = 4.03). The initial scores of cognitive reappraisals were significantly related to the scores of the same variable in T1 and T2. Though, after controlling for the initial level of cognitive reappraisal, the interaction Time × Group was not significant, indicating that the two groups did not change differently from each other in that strategy over time.

The analyses of the FACT-B evidenced that all the covariates significantly affected the scores of the correspondent variables in T1 and T2. However, only the EWB scores appeared significantly different over time in the two groups, after controlling for the initial EWB score (see **Figure 4**). The marginal means estimated by the model revealed that the EHG reported an increase in emotional wellbeing in the follow-up compared to the post-treatment (T1 = 16.63; T2 = 19.3), whereas the CG did not report any notable difference at the two time points (T1 = 17.62; T2 = 17.11).

Emotional Changes and Intervention Acceptance

Changes in emotional states following the online intervention had been assessed by comparing VAS scores pre and post session, day by day (see **Figure 5**). Paired sample t-tests underlined a significant reduction of anxiety on days 1, 3, and 7 [respectively $t(10) = 3.516$, $p = 0.006$; $t(9) = 2.571$, $p = 0.030$; $t(11) = 3.362$, $p = 0.006$]. Furthermore, a significant increase of relaxation was reported on days 2, 4, 6, 7, 8, and 9 [respectively $t(12) = -2.944$, $p = 0.012$; $t(11) = -2.880$, $p = 0.015$; $t(10) = -2.472$, $p = 0.033$; $t(11) = -2.872$, $p = 0.015$; $t(10) = -2.292$, $p = 0.045$; $t(10) = -3.012$, $p = 0.013$]. No significant emotional changes were achieved in days 5 and 10 (respectively completed by 11 and 4 women).

The intervention acceptance was measured by averaging the scores of the five questions presented after completing the daily protocol, first across different days, and then across participants.

In relation to the skills acquisition and rehearsal phase (sessions 1–7), the pleasantness and usefulness of the video interviews were rated good (respectively, $M = 5.18$, $SD = 0.37$; $M = 5.29$, $SD = 0.44$) and also the pleasantness, usefulness and easiness of performing the exercises proposed within the video meditation and relaxation experience (respectively, $M = 5.12$, $SD = 0.29$; $M = 5.16$, $SD = 0.19$; $M = 5.37$, $SD = 0.12$). The same positive evaluation emerged in relation to the application and follow-through phase (sessions 8–10) from data assessing the pleasantness and the usefulness of the video interviews (respectively, $M = 5.16$, $SD = 0.31$; $M = 5.27$, $SD = 0.24$) and the pleasantness, usefulness and easiness of performing the exercises proposed within the video meditation and relaxation experience (respectively, $M = 5.47$, $SD = 0.18$; $M = 5.24$, $SD = 0.21$; $M = 5.47$, $SD = 0.12$).

DISCUSSION

Even if agreement about the experience of distress in breast cancer patients has not been found, some studies carried out in a similar cultural context – with an Italian sample – showed that, early on in the cancer trajectory, age can be considered one of the crucial precursor of patients' distress (Chirico et al., 2015) and emotional distress is recognized as one of the principal indicators of vulnerability to long-term distress (Cook et al., 2018).

Breast cancer patients of all ages are uncertain as to whether or not they will experience and be able to cope with potential treatment-related side-effects such as severe nausea, vomiting, hair loss and tiredness. Thus, pre-chemotherapy counseling or education should help patients to increase their knowledge and develop active strategies to cope with the upcoming event. Coherent with this need and taking advantage of the opportunities offered by online intervention for these patients (McAlpine et al., 2015), this study developed and tested the efficacy of a 2 weeks ehealth intervention based on SIT

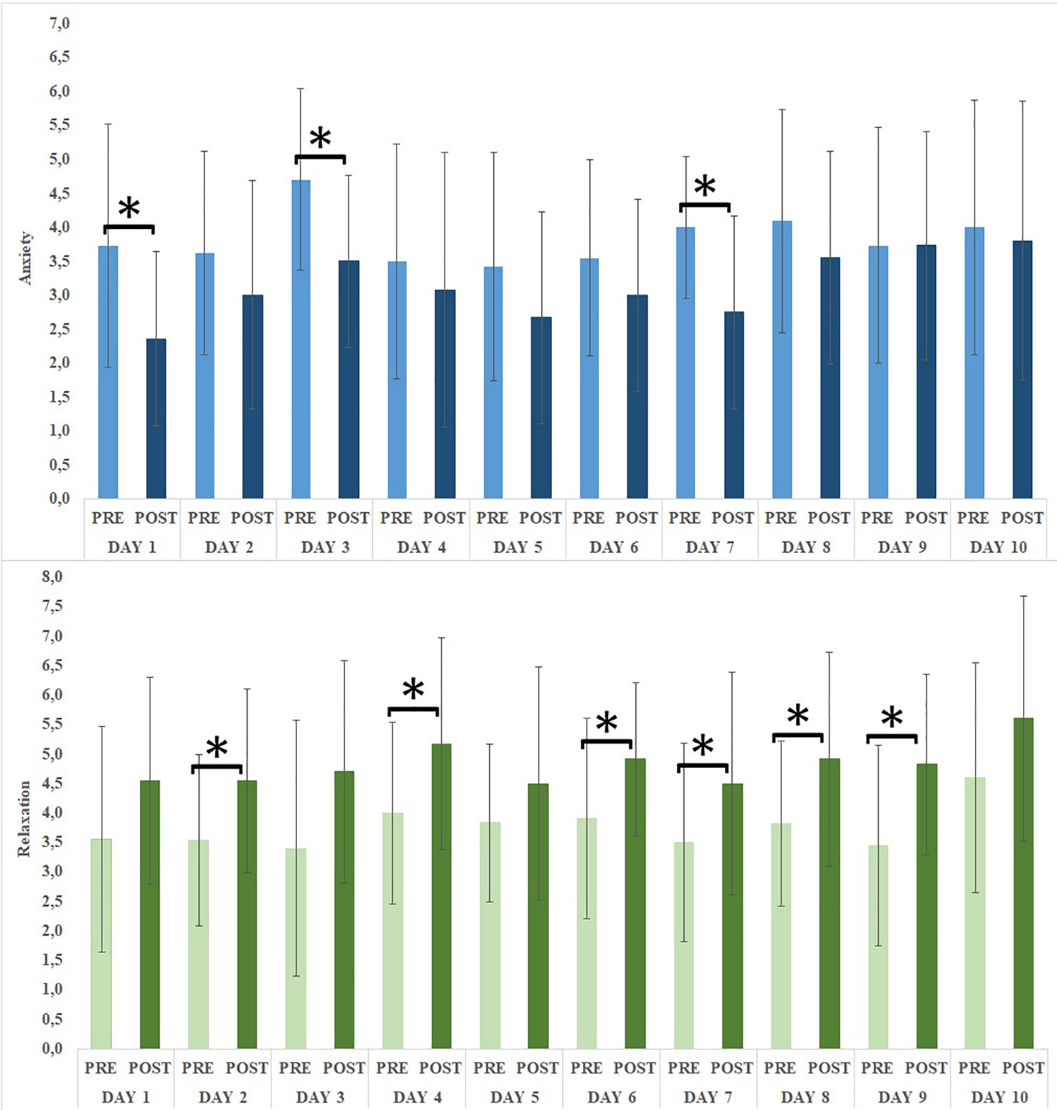

FIGURE 5 | Emotional changes (anxiety and relaxation). Error bars: ±1 SD; * significant changes

(Meichenbaum, 1985) on emotion regulation and cancer-related well-being. This intervention was proposed after surgery and before chemotherapy and the ehealth group was compared with a control group without intervention.

To test protocol efficacy, self-report questionnaires were administered to all participants at baseline (T0), at the end of the 2 week intervention (T1), and 3 months after the end of the intervention (T2).

The ehealth group almost always completed the online sessions, with the exception of the last one (day 10). Results showed that after 2 weeks of ehealth intervention, patients did not achieve significant changes related to emotion regulation strategies, but they significantly reduced emotional suppression by 3 months after the end of the intervention. To understand these results, it is important to consider that, according to Gross and John (2003) 2 weeks is probably not enough time to modify patients' emotion regulation strategies, which are generally built up over time and become a stable response to stress. Even if individuals are able to modify or improve these strategies, the result would not be immediately visible. However, after a sufficient time to be aware of their own internal processes, and after the beginning of chemotherapy treatment, breast cancer patients felt encouraged to express their emotions. This is an important result, as even if occasionally suppression is the best or even the only option to cope with the acute situation, it is recognized that this strategy is not helpful in reducing the experience of negative emotion that remains unsolved in the long term (Gross and John, 2003). Thus, emotional suppression has been shown to have a negative impact on a patient's adjustment to cancer, whereas being able to express emotion can lessen distress and improve quality of life (Low et al., 2006). Furthermore, emotional expression can be seen as a proxy for obtaining social support; thus, it may engender positive social response. Specifically, Stanton and colleagues showed that women who coped through expressing emotions surrounding cancer had fewer medical appointments for cancer-related morbidities and decreased distress in the following three months, and those who perceived their social contexts as highly receptive reported an improvement in quality of life (Stanton et al., 2000).

The same trend has been found concerning cancer-related well-being. Specifically, the intervention significantly increased patients' emotional well-being by 3 months after the end of the intervention. Despite some studies suggesting that older patients place great emphasis on antecedent emotion regulation and report great motivation to down-regulate negative emotions, probably assuming that aging is associated with a greater awareness of the inevitability of death (Scheibe and Carstensen, 2010), our study did not confirm this view: in fact, the control group did not improve their emotional strategies as time passed. This highlights both the importance of considering individual differences in older women (Boyle et al., 2017) and the value of designing interventions that facilitate more expression of emotion, which will allow help the patient accept and adapt to the progression of the disease (Moorey and Greer, 2002).

Specifically, the ehealth SIT intervention encouraged at least three adaptive strategies broadly associated with psychological well-being: acceptance, that is acknowledging that there are real issues and being aware of the negative experiences to come; emotional processing, in which the patient actively learns to understand the nature of the emotional experience; and emotional expression, which helps the patient to communicate emotional feelings, both in words and actions (Marroquín et al., 2017).

The emotional experience of patients also was monitored at a distance through the online compilation of the anxiety and relaxation questions. Results appeared positive, as we found that the emotional change due to the exposure to the online sessions helped patients in both reducing their anxiety and increasing their relaxation at some level. Furthermore, as the *application and follow-through* phase included live-video interviews of breast cancer patients currently undergoing chemotherapy – both with and without wigs – which could generate stress (Villani et al., 2013), it was encouraging to see that these sessions, followed by relaxing and meditation mindfulness experiences, helped patients to feel less stressed. To understand this positive outcome, we have to consider that the purpose of mindfulness is not to prevent negative experiences or change emotions, but rather to reframe the experience in a way that allows acceptance. By observing thoughts and feelings as mental events, patients have retrained negative thought patterns and reduced reactivity, thus fostering their sense of calm and well-being (Feldman et al., 2010; Hoge et al., 2015).

Finally, it is important to highlight that patients in the experimental group reported a good level of acceptance of the ehealth intervention. Live-video interviews were assessed as useful and pleasant. Meditation experiences were primarily assessed as very easy to perform, and also useful and pleasant. This result appears consistent with other studies showing that brief mindfulness meditation protocols can be successfully integrated in self-help interventions supported by new technologies and mobile apps, leading to a beneficial impact on stress, anxiety, depression, and well-being (Carissoli et al., 2015; Chittaro and Vianello, 2016; Spijkerman et al., 2016). While some studies argue that longer interventions are required to obtain positive outcomes (Baer et al., 2012), recent studies have suggested that very short mindfulness interventions can improve psychological well-being (Creswell et al., 2014), even when performed through a mobile app (Economides et al., 2018).

This result is similar to finding in other studies suggesting that Internet acceptance has reached an older age group, probably because patients older than 60 years are currently more familiar with the Internet than reported in previous studies (Santana et al., 2011), and indicates that the use of the Internet for health-related questions appears to be feasible for most patients (Drewes et al., 2016). In future years, with the increase of Internet access and computer literacy in society, we expect a growing interest in therapy assistance via digital health platforms. This trend, together with costs and cancer prevalence that are likely to increase as the population ages and increases, creates more pressure to develop new, less expensive treatments aimed to enhance patients' self-management skills.

Before concluding, we have to underline some limitations of the study. First, the small sample size, related to the difficulties in recruiting elderly women undergoing chemotherapy, that did not include the patients' starting level of distress. This issue may have reduced the ability to identify benefits of the ehealth intervention and future studies are encouraged to replicate the study with a wider sample and to assess the level of distress and the need of intervention as inclusion criteria. Second, the lack of an active control group, which is difficult to include considering that psychological interventions are usually offered during the chemotherapy treatment and not before. Other studies have proposed using the waiting list group, but this methodology did not appear suitable for this case as patients started chemotherapy after the brief ehealth intervention. The integration of the first and second limitation did not allow us to draw the effectiveness of the ehealth intervention in a definitive way. Future studies could integrate a placebo group, to which to propose an Internet intervention with content not consistent with the disease, in order to verify the effectiveness of the this ehealth intervention. Third, another limitation was the short time period analyzed (from definitive diagnosis, after operation, to the first months of chemotherapy), leaving out important moments such as the end of treatment and follow-up.

CONCLUSION

To conclude, designing and developing eHealth interventions as part of regular care for breast cancer patients of all ages represents a challenge for future interventions. Specifically, immersive technology could be implemented in other phases of the treatment, such as during chemotherapy, to help women with breast cancer to facilitate a reduced time perception through distraction (Schneider et al., 2011) or to increase their knowledge and anxiety management (Jimenez et al., 2018). Furthermore, one possible way forward may be to view online interventions as an important step in universal psychosocial care within a tiered model of care. For example, distressed patients could be offered a low-cost self-managed online program such as this eSIT protocol and then transitioned to other more in-depth care models (such as psychotherapy treatment) if their distress remains unresolved (Chambers et al., 2018).

AUTHOR CONTRIBUTIONS

DV developed the study concept. CC was involved in the data collection. DV, CR, and SS performed the data analysis and interpretation, wrote the first draft of the manuscript. All authors were involved in the critical revision of the manuscript for important intellectual content, approved the final version of the manuscript for submission, and contributed to the study design.

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Exploring the Incorporation of a Positive Psychology Component in a Cognitive Behavioral Internet-Based Program for Depressive Symptoms. Results Throughout the Intervention Process

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Traditionally, evidence-based treatments for depression have focused on negative symptoms. Different authors describe the need to include positive affect as a major target of treatment. Positive psychology aims to fill this gap. Reaching everyone in need is also important, and Internet-based interventions can help in this task. The present study is a secondary analysis derived from a randomized controlled trial aimed to test the efficacy of an Internet-based intervention for patients with depressive symptoms. This intervention consisted of an 8-module Internet-based program that combined four modules based on cognitive-behavioral therapy strategies and four modules based on positive psychology strategies. The main goal of this secondary analysis is to report the data collected after each module from the participants who completed the intervention, explore the changes throughout the intervention process, and examine the changes observed in the different variables before versus after the introduction of the positive psychology component. A total of 103 patients completed the intervention. At pre-, post-intervention, and post-module evaluations, they completed positive and negative affect, depression, and anxiety measures. Negative affect and anxiety decreased significantly during the implementation of the cognitive-behavioral therapy and positive psychology modules. However, depression and positive affect improved only after the introduction of the positive psychology modules. This is the first study to explore, throughout the intervention process (module by module), the incorporation of a positive psychology component in an Internet-based program. Results suggest that positive psychology techniques might have an impact on clinical symptomatology, and they emphasize the need to include these techniques to achieve a more profound change in positive functioning measures.

Clinical Trial Registration: NCT02148354 (http://ClinicalTrials.gov/ct2/show/NCT02148354).

Keywords: depressive symptoms, positive psychology, internet-based Intervention, intervention process, post-module assessment

INTRODUCTION

Depression is one of the most common health problems worldwide. Its economic cost is quite high, and it disrupts the lives of millions of people each year (Haro et al., 2014). The increasing prevalence of this disease and its tendency toward chronicity suggest that its prevention and treatment should be a health priority (Ferrari et al., 2013; Haro et al., 2014).

Evidence-based psychological interventions for depression have been shown to be effective (Nathan and Gorman, 2015). However, these interventions are usually designed to reduce negative symptoms and deficits rather than building positive resources (Dunn, 2012). In this regard, the absence of mental illness does not necessarily imply the presence of well-being (Gotlib and Hammen, 2008; Keyes and Simoes, 2012). The literature emphasizes the role of both negative and positive affect in the initiation and maintenance of emotional disorders (Kessler et al., 2011; Barlow et al., 2013). Moreover, depressive symptoms often involve low levels of positive emotions, engagement, and purpose in life, but they are typically viewed as consequences or mere correlates of depression (Ruini, 2017). Thus, studies have shown that low levels of positive affect are more strongly linked to depression than to other emotional disorders (Watson and Naragon-Gainey, 2010). Therefore, different authors state that there is a need to include positive affect as a main target of treatment (Werner-Seidler et al., 2013).

Positive psychology (PP) aims to fill this gap by exploring the conditions and processes that contribute to the flourishing or optimal functioning of people, groups, and institutions (Gable and Haidt, 2005). Meta-analyses have shown that positive psychological interventions (PPIs) are effective in enhancing well-being and reducing depressive symptoms (Sin and Lyubomirsky, 2009; Bolier et al., 2013). Despite these findings, some authors claim that there has been an artificial separation between positive and clinical psychology, and they defend the need for an integration of these two approaches in order to diminish suffering and increase well-being, suggesting the term "Positive Clinical Psychology" (Johnson and Wood, 2015). However, few studies have tested the efficacy of treatments combining PPI and Cognitive Behavioral Therapy (CBT) components in clinical settings (Meyer et al., 2009; Bolier et al., 2013; Titov et al., 2013). Furthermore, although the importance of including assessments during the course of treatment is well known (Kazdin, 2007), the majority of studies report pre to post intervention changes, limiting the possibility of analyzing the impact of each specific component.

Another important issue in depression is reaching everyone in need. Internet interventions may be more affordable and accessible than face-to-face interventions (Richards and Richardson, 2012; Kazdin and Rabbitt, 2013; Kazdin, 2015). Furthermore, research results encourage the use of online questionnaires (Carlbring et al., 2007; Vallejo et al., 2007; Hedman et al., 2010) because they offer many advantages over traditional data collection methods. Missing data can be handled better, and scoring is easy and immediate, for example, when patients finish one psychological component (Carlbring et al., 2007), making it possible to discover the specific contribution of each component throughout the intervention process. In addition, online assessment allows users to receive feedback about their progress (Barak and English, 2002).

The combination of Internet and PP allows the emergence of self-help online PP interventions that may contribute to improving individuals' mental health by offering them a way to self-manage their well-being (Mitchell et al., 2010; Bolier et al., 2013). Therefore, PPIs in a self-help format may be an effective and suitable way to reach a large number of people (Mitchell et al., 2010). These programs can be considered "Positive Technology" interventions, that is, technology-based strategies to improve the quality of the personal experience, increase wellness, and generate strengths and resilience in individuals (Botella et al., 2012; Riva et al., 2012).

To our knowledge, no studies have explored the evolution of both clinical and positive variables throughout an Internet-based positive clinical psychology intervention, including post-module assessments.

The present study is a secondary analysis derived from a randomized controlled trial (RCT) designed to test the efficacy of a positive clinical psychology intervention implemented through positive technology for patients with depressive symptoms (Mira et al., 2017). This intervention consisted of an 8-module Internet-based program that combined 4 modules based on CBT strategies and 4 modules based on PP strategies. In the RCT, overall the results produced medium to large effect sizes compared to the control group, not only in anxiety, depression, and negative affect, but also in positive affect (Mira et al., 2017). However, the contribution of each module to the improvement of these variables is not known; nor is the specific contribution of the PP component because 4 of the 8 modules included PP strategies. Therefore, the main goal of this secondary analysis is to report the data collected after each module from the participants who completed the intervention, explore the changes in positive and negative affect and depression and anxiety symptoms throughout the intervention process, and examine the changes observed in these variables before and after the introduction of the PP component, in order to provide preliminary evidence about the specific contribution of each component. Furthermore, given that some findings point out that depression status moderates the effectiveness of PPIs (Sin and Lyubomirsky, 2009), a second goal of the present study is to explore whether the severity of the depressive symptoms is related to the benefits in positive affect obtained from the PP component.

MATERIALS AND METHODS

Research Design

This is a secondary analysis study derived from an RCT with three independent groups: (a) Internet-based intervention group with automated support (automated mobile phone messages, automated emails, and continued feedback through the program); (b) Internet-based intervention group with automated support plus human support (brief weekly support phone call without clinical content); and (c) Waiting list control group (participants completed the intervention program after the waiting time) (Mira et al., 2017; ClinicalTrials.gov ID: NCT02148354).

All the participants who completed the Internet-based intervention filled out the pre-treatment evaluation through the web platform. After completing each of the eight treatment modules, they filled out the post-module evaluation, also through the web system. At the end of treatment, they also completed the post-treatment evaluation through the web site. Regarding platform usage, participants progressed sequentially through the intervention program in a completely self-applied way over the Internet at their own pace. Participants were encouraged to complete about one module per week in order to obtain maximum benefits from the program. The participants had up to 12 weeks to complete the eight modules.

More details about the design, procedure, therapists, recruitment methods, and support offered to participants are included in the main outcome study (Mira et al., 2017).

Inclusion Criteria

Inclusion criteria were: age between 18 and 65 years, willingness to participate in the study, ability to use a computer and having an Internet connection at home, ability to understand and read Spanish, currently experiencing at least one stressful event in their lives that produces interference, and having minimal, mild, or moderate depressive symptoms [score of 28 or less on the Beck Depression Inventory-II (BDI-II)].

Participants

For this study, all the participants from the RCT who completed the Internet-based intervention were included, that is, participants from both intervention groups, with and without human support (no differences were found between them on any measure; Mira et al., 2017), and participants from the waiting list control group who completed the program after the wait time. As a result, 103 participants are included in these analyses.

The sample was composed mostly of women (68%). Regarding marital status, 53.4% of the participants were single, 39.8% married or with a partner, and 6.8% separated or divorced. Regarding the study level, most of the participants had higher education (69.9%), 25.2% had mid-level studies, and the rest had basic studies (4.9%). Ages ranged between 20 and 58 years, with a mean of 35 years (*SD* = 9.42). Regarding depression severity at baseline, the average on the Beck Depression Inventory-II (BDI-II) was 9.50 (*SD* = 7.08).

Intervention and Protocol Modules

We developed a manualized treatment protocol that included traditional therapeutic components of evidence-based treatments for depression (Motivation, Psychoeducation, Cognitive Therapy, and Behavioral Activation). The program also included a PP component, offering strategies to promote psychological strengths and enhance positive mood. We adapted the protocol to an Internet-based, multimedia interactive program. It is designed for optimal use on a PC, but it can also be used on a tablet.

The intervention protocol consists of eight interactive modules. Four of them are based on CBT, and the other four on PP psychology.

The main objectives of the 4 CBT modules: (1) "*Motivation for change*" (2) "*Understanding problems*" (3) "*Learning to move on*" and (4) "*Learning to be flexible*" are, respectively: (a) to analyze the advantages and disadvantages of obtaining a therapeutic change; (b) to provide information so that the user can understand the nature of emotional problems; (c) to teach the importance of "moving on" in order to acquire a proper level of activity and involvement in life; and (d) to teach a more flexible way of thinking.

Regarding the PP modules, designed to improve well-being and encourage psychological strengths and positive emotionality (see **Table 1**): (5) "*Learning to enjoy*" (6) "*Learning to live*" (7) "*Living and learning*" and (8) "*From now on, what else. . .?*", the main objectives, respectively, are: (a) To promote involvement

TABLE 1 | Description of the PP modules.

Module	Specific strategies	Empirical source
"Learning to enjoy"	The role of positive emotions in our lives The importance of the Duchenne smile The concept of "savoring" and the importance of "small things"	Ekman et al., 1990; Soussignan, 2002; Miles and Johnston, 2007; Bryant et al., 2011; Fredrickson, 2013
"Learning to live"	The importance of identifying the individual's own psychological strengths The concept and dimensions of well-being Select and record activities linked to values and significant areas and goals in life	Peterson and Seligman, 2004; Seligman et al., 2005; Ryff, 2014
"Living and learning"	Strategies to develop our strengths: Gratitude, Curiosity and Hope Identify episodes of wellbeing and maintain them	Fava, 1999; Lee Duckworth et al., 2005; Seligman et al., 2005; Sheldon and Lyubomirsky, 2006
"From now on, what else. . .?"	What have I learned? How do I want my future to be?: Following positive life mottos and my best possible self exercise	Sheldon and Lyubomirsky, 2006

in pleasant and significant activities, having contact with other people, enjoying positive experiences, and "savoring" positive aspects of life; (b) To understand the importance of identifying the individual's own psychological strengths and carrying out meaningful activities linked to values and goals in life; (c) To develop an action plan to boost the individual's psychological strengths and start working for life and the future; and (d) To learn that the end of the program is only the beginning of each person's path, inviting them to think about how they would like their future life to be, following the positive life mottos (e,g., *Every morning, a new day full of possibilities begins for you; The richest person is the one who knows how to enjoy the best pleasures without spending a penny*).

For more information about the specific content in each module, see Mira et al., 2017.

Measures

Severity of depression measure (at pre-treatment, via the Internet):

The BDI-II is a 21-item self-report scale of depressive symptoms (Beck et al., 1996). It has shown good psychometric properties in several studies (Storch et al., 2004). The Spanish version of the BDI-II was used (Sanz et al., 2005). It shows good reliability and validity data and provides a bifactorial solution that matches what was found in previous studies (Sanz et al., 2005). It has shown high internal consistency in both general (α = 0.87) and clinical populations (α = 0.89) (Sanz et al., 2005).

Self-assessment measures (at pre-treatment, post-treatment, and post module evaluation, via the Internet):

Primary outcome measure: Positive and Negative Affect Scale (PANAS) (Watson et al., 1988). It consists of 20 items that evaluate two independent dimensions: positive affect (PA) and negative affect (NA). The range for each scale (10 items on each) is from 10 to 50 (Watson et al., 1988). It is a brief, reliable, and valid self-report measure. It has shown excellent convergent and divergent validity (Watson et al., 1988). As in the original version, the validation of the Spanish PANAS revealed a robust and stable two-dimensional structure, and provided strong support for its validity and reliability (internal consistency: 0.89–0.91 for PA and NA in women and 0.87 for PA and 0.89 for NA in men) (Sandín et al., 1999).

Secondary outcome measures: Overall Anxiety Severity and Impairment Scale (OASIS) (Norman et al., 2006). It consists of 5 items that measure the frequency and severity of anxiety, as well as the level of avoidance, work/school/home interference, and social interference associated with anxiety. It was found to have excellent test–retest reliability, in addition to good convergent and discriminant validity and high internal consistency (α = 0.80) (Norman et al., 2006). The range for the scale is from 0 to 20. The validation data for the Spanish version confirmed the factorial structure and the reliability and validity data obtained by the original authors (Mira et al., 2015).

Overall Depression Severity and Impairment Scale (ODSIS) (Bentley et al., 2014). It is a self-report measure with 5 items that evaluate experiences related to depression. The ODSIS measures the frequency and severity of depression, as well as the level of avoidance, work/school/home interference, and social interference associated with depression. The range for the scale is from 0 to 20. It has shown good convergent and discriminant validity and excellent internal consistency (α = 0.94 in an outpatient sample, 0.91 in a student sample, and 0.92 in a community sample) (Bentley et al., 2014). The validation data for the Spanish version confirmed the factorial structure and the reliability and validity data obtained by the original authors (González-Robles et al., 2015).

Statistics and Data Analysis

In order to enhance the power of the results, intent-to-treat analyses were carried out to handle missing data. These analyses made it possible to use all the available data collected from the whole sample of participants across the different time points. The procedure was based on the guidelines suggested by Hair et al. (2014). First, the type of missing data was analyzed, concluding that these data were missing at the item level and eligible for imputation. Second, the quantity of missing data was explored, determining that the total amount of missing values was less than 10%. Third, the random pattern of missing data was explored through the Little MCAR test X2 (108) = 108.63, $p = 0.46$ (Little and Rubin, 1990), concluding that missing data were due to chance, and not to any other specific factor. Finally, missing values were imputed through maximum likelihood (ML) estimation procedures. Sensitivity analyses comparing the results of completers and the ITT sample were conducted, determining that both samples followed the same patterns, and concluding that there was no chance of making biased estimations.

In order to explore the change on the OASIS, ODSIS, and PANAS over time, a repeated-measures ANOVA including the 10 temporal assessments (8 modules plus pre- and post-treatment assessment) was conducted. Next, in order to explore the specific contribution of the CBT and PP components, another ANOVA was conducted with three temporal assessments: pre, post-module 4 (after CBT component), and post-treatment (after PP component). Sidak's *post hoc* analyses were conducted to explore pairwise comparisons. Finally, a univariant MANOVA with the whole sample was conducted with depression severity symptoms as independent variable and the change in positive affect after the presentation of the CBT component and the same change after the presentation of the PP component as outcomes. All statistical analyses were conducted by using IBM SPSS Statistics 20 (IBM Corporation, Armonk, NY, United States).

RESULTS

Changes in the Variables Throughout the Intervention Process: Positive and Negative Affect, Depression, and Anxiety

The means and standard deviations presented by the participants on each measure assessed throughout the intervention process are presented below in **Table 2**. Repeated-measures ANOVA analyses revealed a significant time effect on all measures: PANAS + [$F_{(1,102)} = 6.63$, $p < 0.001$], PANAS – [$F_{(1,102)} = 19.03$, $p < 0.001$]; OASIS [$F_{(1,102)} = 22.81$, $p < 0.001$] and ODSIS [$F_{(1,102)} = 12.43$, $p < 0.001$]. These results indicate that a

TABLE 2 | Means and standard deviations in each measure assessed throughout the intervention process.

Va.	Pre.		CBT therapy modules (M1–M4)								PP therapy modules (M5–M8)								Post	
			M1		M2		M3		M4		M5		M6		M7		M8			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
PA +	28.90	7.65	28.29	8.97	29.09	8.47	28.71	8.54	28.29	9.19	29.32	8.71	29.14	8.07	29.65	8.19	31.57	7.99	31.88	8.14
NA –	18.85	6.38	16.38	5.99	15.54	5.34	15.85	5.89	15.66	5.75	14.53	4.96	14.36	4.61	14.85	5.21	13.68	3.78	13.72	3.75
OA	4.29	3.56	4.01	3.37	2.93	2.99	2.79	2.97	2.86	2.94	2.32	2.74	2.28	2.82	2.36	2.79	1.57	2.21	1.40	1.97
OD	2.81	3.25	2.86	3.30	2.24	2.76	2.36	2.96	2.31	2.98	2.14	3.00	1.81	2.60	1.58	2.29	0.94	1.76	0.92	1.70

Va., variables; M, mean: SD, standard deviation; Pre, pre-treatment evaluation; Post, post-treatment evaluation; MX, post-module X evaluation (X = 1–8); PA$^+$, Positive Affect Scale; NA$^-$, Negative Affect Scale; OA, Overall Anxiety Severity and Impairment Scale; OD, Overall Depression Severity and Impairment Scale.

significant change over time was observed in the scores on the different measures.

Changes in the Variables Before Versus After the Introduction of the PP Modules: Positive and Negative Affect, Depression, and Anxiety

The analysis revealed a significant time effect on all measures: PANAS + [$F_{(1,102)} = 11.73, p < 0.001$], PANAS – [$F_{(1,102)} = 42.08, p < 0.001$]; OASIS [$F_{(1,102)} = 26.56, p < 0.001$] and ODSIS [$F_{(1,102)} = 19.31, p < 0.001$].

The results of the Sidak's *post hoc* tests are presented in the figures below (see **Figure 1**). **Figure 1** shows that in the case of the PANAS + and the ODSIS, there were significant improvements from the pre- to post-treatment evaluation and from the post-module four (after the CBT component) to post-treatment evaluation (after the PP component). In the case of the PANAS – and the OASIS, there were significant improvements from the pre-treatment evaluation to the post-treatment evaluation, from the pre-treatment evaluation to the post-module four evaluation, and from the post-module four evaluation to the post-treatment evaluation.

How Depression Severity at Pre-treatment Influences the Benefits of the PP Modules in Positive Affect

Depression severity was rated in terms of BDI-II cut-offs. In this regard, depressive symptoms were clustered into: (a) minimal depressive symptoms (patients with scores from 0 to 13; $N = 74$) and (b) mild-moderate depressive symptoms (patients with scores between 13 and 28; $N = 29$). Outcomes were considered the change in positive affect after the CBT component (M4 minus pre) and after the PP modules (Post minus M4). A MANOVA analysis was conducted with depression severity as independent variable and positive affect outcomes after the CBT modules and after the PP modules as dependent variables. Using Pillai's trace, there was a significant difference in the change in positive affect between patients with minimal depressive symptoms and those with mild-moderate depressive symptoms [$F_{(2,100)} = 9.86, p < 0.001$]. In this regard, separate univariate ANOVAs showed a non-significant change in positive affect between depression severity levels after the CBT modules [$F_{(1,101)} = 0.06, p = 0.80, \eta^2 p = 0.001$]. However, the change in positive affect after the PP modules was significantly greater for patients with mild-moderate depressive symptoms compared to patients with minimal symptoms [$F_{(2,100)} = 15.69, p < 0.001, \eta^2 p = 0.13$], with a large effect size (Cohen, 1992). These results are depicted in **Figure 2**.

DISCUSSION

The main objective of this study was to investigate the evolution of positive and negative functioning outcomes across the eight modules of an Internet-based intervention for depression, and explore the specific contribution of the PP component to

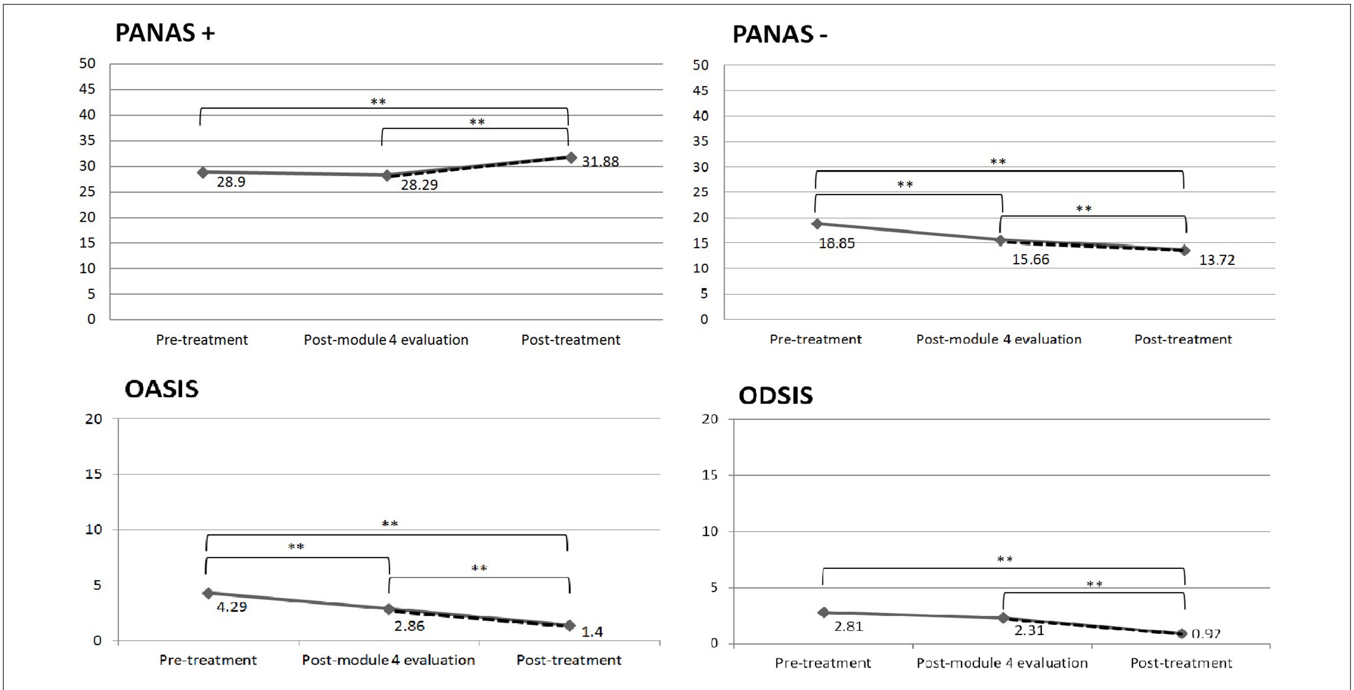

FIGURE 1 | Changes in the variables before versus after the introduction of the PP modules. The dashed line indicates the PP modules; $^{**}p < 0.01$.

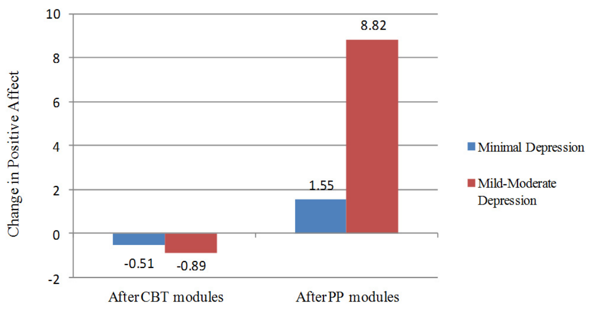

FIGURE 2 | Change in Positive Affect after the CBT modules (M1–M4) and after the PP modules (M5–M8), divided by the level of depressive symptoms. Number of participants with minimal depressive symptoms = 74; Number of participants with mild-moderate depressive symptoms = 29.

the outcomes. Results showed that participants significantly improved their anxiety, depression, and negative and positive affect scores throughout the intervention.

The exploration of the changes over time makes it possible to not only examine the pre-post change, but also to analyze the changes occurring during the intervention depending on the strategies learned throughout the intervention process. In this vein, the change in outcomes was examined before and after the introduction of one of the essential psychological components of the intervention program: the PP component. Results showed that negative functioning measures (ODSIS, OASIS, and PANAS-) decreased significantly during the implementation of the CBT modules, and also during the implementation of the PP modules, with the exception of depression (ODSIS), which only decreased significantly after the introduction of the PP modules. These results suggest that PP techniques might have an impact on the decline in clinical symptomatology, which is consistent with prior studies (Vázquez et al., 2006; Chaves et al., 2017). In the case of positive affect, results showed that there was no improvement after the implementation of the CBT components, but the improvement was significant after the introduction of the PP component. These results emphasize the need to include PP exercises and techniques in conventional treatments to directly address improvements in positive emotions and achieve a more profound change in positive functioning measures (Sin and Lyubomirsky, 2009; Bolier et al., 2013). In this regard, positive emotions can lead to positive behaviors and states of happiness that contribute significantly to robust health, mitigate the physiological and cognitive effects of negative emotions, and decrease reactivity to stress (Fredrickson and Branigan, 2005; Fredrickson, 2006; Bower et al., 2009). Thus, PP relies on the hypothesis that depression can be treated effectively, not only by reducing negative symptoms, but also by building positive emotions, character strengths, and meaning (Seligman et al., 2006). Therefore, it is important to include PP strategies to directly build up these positive resources in order to counteract negative symptoms and buffer against their future reoccurrence, as in the intervention presented here.

Our second goal was to explore whether more depressed patients would show greater improvements in positive affect, compared to those with less severe depressive symptoms. Results showed that participants did not improve positive affect after the CBT component, and no differences were found between the two groups. However, after the introduction of the PP component, patients with mild to moderate depressive symptoms had significantly larger improvements in positive affect, compared to those with minimal depression. Our results are consistent with the findings of a meta-analysis showing that depression severity moderates the effectiveness of PPIs (Sin and Lyubomirsky, 2009). These results could be explained by the fact that patients with mild to moderate depressive symptoms depart from lower levels of positive affect (floor effect) and have more room for improvement. In any case, as Sin and Lyubomirsky (2009) claimed in their meta-analysis, these findings challenge the notion that people with more severe depressive symptoms might benefit less from PPIs, because their affective, behavioral and cognitive characteristics keep them from taking full advantage of the relevant positive activities.

In this regard, the results obtained in the present study suggest that positive clinical psychology, that is, the combination of clinical and positive psychology approaches, can be an effective way to treat depression by reducing negative symptoms and increasing positive emotions (Wood and Tarrier, 2010). The results suggest that this protocol achieved the two goals considered essential in the treatment of patients with depressive symptoms, that is, reducing discomfort and negative emotions and promoting strengths and the increase in positive emotions (Vázquez and Hervás, 2008). An important strength of the present study is that it achieved these goals through an online intervention. The development of Internet-based interventions with a focus on both negative and positive aspects of human functioning will allow a more comprehensive psychotherapy (Rashid, 2009).

This study has limitations. First, the intervention was not compared to another intervention without the PP component, which keeps us from drawing firmer conclusions about the specific contribution of PP. Furthermore, bear in mind that these findings should be interpreted cautiously because a carry-over effect of the CBT component could explain the larger improvements in positive affect after the introduction of the PP component, although these effects are not observed in the other clinical measures. In future studies, we will take into account the importance of counter-balancing the order of the intervention and carrying out studies with dismantling designs in order to discover the specific contribution of the PP component. In this regard, we are currently conducting a research trial designed to dismantle the Internet-based positive clinical psychology program used in the present study, in order to discover the contribution of each specific component (ClinicalTrials.gov ID: NCT03159715). Moreover, it might be relevant to include other PP measures in the present study to investigate how the PP modules affect them. Future studies should also determine whether it is better for the PP component to be placed at the beginning or the end of an intervention. Furthermore, the low symptom severity should be included as one of the limitations because most of the sample were in the mild depressive range. It is important for further studies to explore the effect of PP strategies on severely depressed patients. Lastly, all the participants had to be facing a stressful event at baseline assessment in order to be included in the trial, but the presence of this event was not explored at post-assessment. Therefore, we cannot ensure that this stressor was absent after the intervention, which could potentially affect the results, although new stressful events could also arise.

CONCLUSION

In sum, this is the first study to explore the incorporation of a positive psychology component in an Internet-based program across each module. The negative clinical symptomatology decreased significantly during the implementation of both components, namely CBT and PP, with the exception of depression, which only improved during the implementation of the PP component. Likewise, positive affect increased only after the introduction of the PP modules. These results suggest that PP techniques might have an impact on clinical symptomatology, and they emphasize the need to include them to achieve a more profound change in positive functioning measures. Furthermore, the more depressed patients obtained greater improvements in positive affect during the PP strategies, compared to those with lower depressive symptoms. Overall, the present study provides further clinical and scientific support for the integration of positive and clinical psychology (Fava and Ruini, 2003; Rashid, 2009; Wood and Tarrier, 2010) using an Internet-based program. In addition, as more studies in this field emerge, these two approaches will become more unified. If these results are replicated, we speculate that future therapy for depression may combine talking about troubles with understanding and building positive emotions, engagement, and meaning.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Ethics Committee of Jaume I University with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of Jaume I University.

AUTHOR CONTRIBUTIONS

AM drafted the manuscript with important contributions from AE, JB-L, and CB. AM in collaboration with, JB-L and CB designed the study and participated in each of its phases. ÁE, DC, A-GP, and RB collaborated in the manuscript development and participated in each study phase. All authors participated in the review and revision of the manuscript and have approved the final manuscript to be published.

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Explicit Mental Health Messaging Promotes Serious Video Game Selection in Youth With Elevated Mental Health Symptoms

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Serious games aimed at promoting well-being in youth have promising effects and potential for far-reaching impact. Considering that most mental health disorders remain untreated in youth, therapeutic games may be most valuable when they are aimed at untreated youth with internalizing symptoms. However, when targeting youth outside of a clinical setting, the first impression of therapeutic video games may determine whether and how a game is played. Thus, understanding the influence of messaging used in the promotion of therapeutic games on game choice and experience is critical. The current study examined two alternatives in promoting mental health games: one included explicit mental health messaging (e.g., learn to manage stress) and the other was a stealth promotion that did not mention mental health but highlighted the entertainment value. Young adults with mild to severe internalizing mental health symptoms (i.e., depressive, anxiety, and stress symptoms) were shown two distinct trailer designs, with random assignment determining which design held which message. Participants (n = 129, M_{age} = 21.33, SD_{age} = 3.20), unaware that both trailers promoted the same commercial video game, were 3.71 times more likely to choose what they believed was the mental health game. Additionally, an unforeseen difference in the attractiveness of the two trailer designs resulted in participants being 5.65 times more likely to select the mental health game promoted in one trailer design over the other. Messaging did not influence game experience (i.e., gameplay duration, autonomy, competence, intrinsic motivation and affect). Exploratory analyses indicated that game experience, but not game choice, was influenced by symptom severity, symptom type and the interaction between symptom severity and messaging. The present study suggests that explicit mental health messages attract youth with mental health symptoms. Ultimately, youth may be empowered to seek out mental health games if they are promoted properly, allowing for far-reaching positive influences on well-being. Toward this aim, future research is needed on the game selection process, addressing underlying motivations, the balance between explicit health and entertainment messaging, and multiple interacting influences on game selection (e.g., promotion and peers).

Keywords: serious video games, mental health, messaging, affect, intrinsic motivation, depressive symptoms, anxiety symptoms, stress symptoms

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INTRODUCTION

Video games are immensely popular among youth (Lenhart et al., 2008; Entertainment Software Association, 2017). Consequently, the idea to capitalize on this popularity and to use games to teach youth skills is thriving (Wilkinson et al., 2008; Sardi et al., 2017; Dias et al., 2018). Serious games are designed to teach knowledge, skill or behavior change and may be used to promote mental well-being in youth (Lau et al., 2017). Mental health games can be offered as tools to supplement standard therapy or as a replacement of school-based prevention programs (e.g., Fernández-Aranda et al., 2012; Schoneveld et al., 2018). However, the potential for impact may be far greater. Mental health games may be used to promote overall well-being in the general population, to offer light interventions to people with mild mental health symptoms or to reach individuals with clinical disorders who are not seeking professional help. Whether or not serious games can reach such diverse populations may in part be determined by how games are presented. Therefore, the aim of the current study was to test how messaging used to promote therapeutic games affects the game choice of youth and their experience of gameplay outside of a therapeutic context. Our focus in the current study was on youth as they are both avid consumers of video games (Entertainment Software Association, 2017) and particularly vulnerable to the development of psychological disorders (Merikangas et al., 2010).

The idea to capitalize on the popularity of video games stems from the attraction and engagement of video games. The potential that using games for therapeutic purposes holds has researchers and therapists excited for several reasons. Specifically, games may: (1) get youth motivated to learn skills; (2) attract and retain youth in therapy programs; (3) help youth persevere throughout therapy's strenuous process, similar to persisting in a difficult game level; (4) help youth realistically practice and (5) facilitate internalization and generalization of new skills (see e.g., Granic et al., 2014; Buday, 2015; Fleming et al., 2017). Although immensely challenging, creating games in which the therapeutic aim and engagement of game design enhance each other has some precedence. One example is *MindLight*, an effective anxiety reduction game that successfully evokes anxiety during gameplay, trains regulation of these anxious feelings, and engages children to the level that they would recommend the game to others as much as they would recommend a commercial game (Schoneveld et al., 2016, 2018). With this engagement potential of therapeutic games, it would be a shame to have mental health games only be played as part of a therapy protocol rather than reaching billions of people who enjoy commercial video games (Meeker, 2017).

While the first target population for serious games may be youth already in therapy, for whom serious games could supplement a therapist-led intervention, serious games can also be aimed at youth not (currently) in therapy. Specifically, a particularly interesting target population for serious games are youth with mild mental health issues, because: (1) their symptoms may be mild enough to be alleviated through an intervention outside of a clinical setting and (2) prevention research has repeatedly shown larger effect sizes for prevention targeted at risk groups compared to universal prevention (Horowitz and Garber, 2006; Stockings et al., 2016).

Moreover, people with acute mental health problems who nevertheless do not seek help is a third target population for serious games. A wide range of studies demonstrates that professional help-seeking is low in youth, with only about a quarter to a third of youth seeking help for diagnosable mood and anxiety disorders (Alonso et al., 2004; Merikangas et al., 2011). Perceived stigma is one important barrier that prevents youth from seeking help (Clement et al., 2015). Youth tend to feel self-conscious and embarrassed about seeking help from professionals and are concerned about confidentiality (Gulliver et al., 2010). Serious games may relieve the most pressing distress of these youth and/or aim to encourage youth to seek professional help. Thus, although serious games may target a range of populations, they may be most valuable when targeting youth with light mental health problems as well as those with severe mental health problems who are not inclined to seek professional help.

Given the promise of serious games for mental health targeted at youth not (currently) in therapy, factors that increase motivation to engage with these games need to be addressed. It may be that promoting a serious game as a proven tool to enhance well-being could be effective. However, youth may not always be inclined to do something because it is 'good for them' and even if they do, their motivation may be lower than for a regular game. Another option may be a stealth approach which promotes mental health games as regular entertainment games.

The value of each approach will depend on how youth value addressing mental health concerns. On the one hand, youth who are actually seeking interventions may be more attentive to games with explicit mental health aims than to games using a stealth entertainment promotion. Games that are explicitly promoted for their mental health aims may be easier to locate (e.g., online game stores or platforms have health and well-being sections). Also, youth who are not actively seeking interventions but have mild symptoms may still be more attentive to information about mental health improvement as it is personally relevant for them.

On the other hand, the stealth approach may be very promising considering stigma and the reluctance of youth to seek treatment for mental health issues (Barney et al., 2006; Gulliver et al., 2010; Merikangas et al., 2011). Whereas explicitly promoted serious games may stand apart from 'normal games,' serious games may blend in with the available commercial games if they avoid explicit health messages both in their promotion and in the content of the game (e.g., not using psychoeducation; Buday, 2015). Additionally, youth who are (initially) resistant to the idea of treatment may avoid anything related to their mental health issues including a mental health game (e.g., out of embarrassment), while a stealth game is less likely to trigger resistance.

The current study examined the impact of explicit mental health and stealth entertainment promotion on game choice and game experience in young adults with elevated mental health symptoms. Hypotheses about the relative impact of these two approaches may be formed based on several theoretical models focused on media choice.

These models suggest that media selection can be based on a person's needs, motivations (Katz et al., 1973), mood (Zillmann, 1988), mood deteriorating costs from media (Perse, 1998; Fahr and Bocking, 2009), long term benefits of media (Oliver, 2009), and a person's desire to maintain their autonomy (Brehm, 1966; Burgoon et al., 2002). All of these models may indicate that explicit messaging would turn youth off to a mental health game. For example, reactance theory and the escape model suggest that health messages would drive youth to an alternative game, either because they perceive the message to threaten their choice freedom (Brehm, 1966; Hornik et al., 2008; Richards and Banas, 2015; Richards et al., 2017) or because they expect the game to induce negative emotions (e.g., an aim of stress management may imply confrontations with stress; Perse, 1998; Fahr and Bocking, 2009). However, many of these same theories may also be used to explain why youth may be attracted to explicit mental health games provided that youth have an interest in improving their well-being. For example, a wider definition of needs and costs from media suggests that youth would play an explicit mental health game to gain insight into personal issues and current negative emotions may be tolerated for long-term benefits (Oliver, 2009).

Next to media selection theories, the motivational theory of self-determination may predict youth's responses to messaging depending on their intrinsic values. Intrinsic motivation (i.e., motivation stemming from the activity itself, e.g., the activity interests you) is theorized to be supported by three psychological needs being fulfilled: autonomy (experiencing the freedom to make your own decisions), competence (experiencing that you are able to be successful given your skills) and relatedness (experiencing a connection to others; Ryan and Deci, 2000). Self-determination theory is particularly interesting as need fulfillment and intrinsic motivation have been associated with better outcomes, including therapeutic outcomes (Ryan and Deci, 2000; Zuroff et al., 2007, 2017; Ryan et al., 2011). Moreover, Ryan et al. (2006) showed that experiencing autonomy and competence during gameplay is associated with game enjoyment, continued gameplay and better mood after gameplay. Initially, youth's motivations (e.g., improving their mental health) and experienced need fulfillment (e.g., feeling autonomy is limited by the mental health message) may influence game choice. Thus, self-determination theory may be another theory that can explain youth's game choice, although again it allows both hypothesis in favor of mental health messaging and in favor of entertainment messaging. Moreover, during gameplay intrinsic motivation and need fulfillment are elements of the game experience (i.e., experiencing low or high competence during gameplay) influenced by gameplay and potentially messaging. Therefore, intrinsic motivation and psychological needs may be vital when we try to understand the impact of messaging on game experience.

Thus, theoretically it is hard to predict how youth will react to serious games with an explicit or stealth promotional approach. Moreover, there is hardly any empirical evidence that can guide our hypotheses. In one closely related previous study, we examined how a mental health or entertainment trailer preceding a commercial video game influenced the experience of this game (Poppelaars et al., 2018). This study showed that even though all participants played the same game, game experience was influenced by the trailer that participants viewed. Although intrinsic motivation and changes in affect were equal for participants regardless of the trailer message, participants who saw the mental health message experienced less autonomy in the game. Also, participants who reported more depressive symptoms and saw the mental health message experienced less competence. Additionally, participants with more depressive symptoms increased their positive affect after gameplay. This suggested that gameplay may at least temporarily improve the depressed mood of those at elevated risk for a depressive disorder. In contrast to daily life, however, participants had no influence on which game they played.

Therefore, the current study was designed to replicate the main findings as well as expand the scope of the previous study in three ways. First, to better approximate real-world media decisions, the current study allowed participants to *choose* between games promoted with a mental health or entertainment message. Second, as serious games may be most valuable if they target youth with some level of mental health problems, we selected participants with elevated mental health symptoms. Finally, the current study assessed stress and anxiety symptoms, in addition to depressive symptoms, to broaden the scope of our understanding and inform future prevention efforts.

Our primary aim was to test how entertainment versus mental health messaging influenced the choice and experience of a video game in young adults with elevated mental health symptoms. Participants chose a game to play after viewing two trailers, one for each type of messaging. We were able to directly link messaging to differences in choice and experience as both trailers portrayed the same game, unbeknownst to the participants. Following gameplay, game experience was assessed. This allowed us to examine the effect of entertainment and mental health messaging on eight dependent variables in the whole sample. We studied the effect of trailer message on three indicators of game appeal: (1) game choice; (2) perceived attractiveness and (3) perceived fun of the game. Additionally, the effect of game choice was examined on five prominent aspects of game experience, that is: (4) gameplay duration; (5) intrinsic motivation; (6) autonomy; (7) competence and (8) change in affect. Based on the theoretical literature and lack of previous empirical evidence, we made no predictions about how the messaging would influence game choice, preference for the games (i.e., perceived attractiveness and fun of the games from the trailers), the duration of gameplay nor about changes in affect. However, based on previous results (Poppelaars et al., 2018), we expected gameplay after either trailer selection to result in similar levels of intrinsic motivation and competence and to improve affect equally. Furthermore, we hypothesized that participants would experience equal levels of autonomy because all participants selected the game they played.

The secondary aim of this study was to explore how severity and type of mental health symptoms influence game choice and experience. Thus, we explored if symptom severity or symptom type (i.e., depression, anxiety, and stress) moderated the effects of messaging on the same eight variables named above. Although there currently is no consensus on the relation between symptom severity and professional help-seeking, most evidence suggests that more severe symptoms are related to seeking more professional help (e.g., Oliver et al., 2005; Merikangas et al., 2011; Sawyer et al., 2012). Therefore, we hypothesized that youth with severe symptoms would select the mental health game more often. As the personal relevance of the mental health game is higher for those with severe mental health symptoms compared to those with less severe symptoms, we hypothesized that this choice is more intrinsically motivated and related to higher levels of autonomy. Furthermore, based on previous results (Poppelaars et al., 2018), we expected elevated depressive symptoms to predict a greater increase in affect and to predict less competence in participants who select the mental health game over the entertainment game. For anxiety, stress and the remaining dependent variables for depressive symptoms and symptom severity, no hypotheses were formulated.

MATERIALS AND METHODS

Participants

In total 155 young adults (M_{age} = 21.48, SD_{age} = 3.36) participated in this study between March and November 2017. Participants were only included in the analyses if they were unaware of the study's aims and the fact that both trailers reflected the same game (n = 129).

Participants included in the analyses were between 18 and 31 years old, with a mean age of 21.33 years (SD = 3.20). The majority of the participants was female 73.6%. Almost all participants were enrolled in or had completed higher education (91.5%), while some were enrolled in or had completed a pre-university track (7.0%). Two participants had completed unsegregated secondary education (1.6%). The majority of participants currently enrolled in education were enrolled in a social science track (76.9%).

All participants were selected based on having at least mildly elevated mental health symptoms on at least one subscale of the Depression Anxiety Stress Scale (DASS-21; Lovibond and Lovibond, 1995). Participants showed mildly elevated symptoms on one (41.9%), two (27.9%) or three (30.2%) subscales. At least a mildly elevated score on depression, anxiety or stress were shown by, respectively, 64.3%, 67.4%, and 56.6% of participants. Of the sample 31.8% had severe or extremely severe scores on at least one DASS-21 subscale.

Although participants indicated that they were moderately positive about video games in general (M_{liking} = 4.50, SD = 1.75; on a 7-point scale with a higher score indicating a more positive attitude), 48.8% indicated not playing video games at all in an average week, with an additional 9.3% playing an hour or less per week. Almost a fifth of participants indicated playing video games more regularly (1–7 h a week; 18.6%) and almost a quarter of participants played more than 7 h a week (23.3%).

Procedure

Participants were recruited for the study on a university and higher vocational education campus in the Netherlands through flyers and the university's online research participation system. Young adults (n = 648), who provided informed consent, were invited to fill out a 15-min online screening questionnaire either voluntarily or for study credits. The online questionnaire was used to assess eligibility, as well as to gather information on demographics, video game behavior and additional questionnaires that are not part of the current study. The inclusion criteria were: (1) Being 18 years or older; (2) Having at least a mildly elevated score on the DASS-21; (3) Being unfamiliar with the game Monument Valley, meaning that the participant had not seen or heard anything about the game; and (4) Being willing and able to sign informed consent. Those who met the inclusion criteria (n = 264) were invited to participate in the lab experiment within 2 weeks from completing the screening questionnaire (range 1–20 days, M = 8.15, SD = 4.52). Of the 155 young adults participating in the lab experiment 9.0% participated between 2 and 3 weeks from screening, due to holiday periods and unavoidable delays (e.g., a participant being ill). Both the screening and experiment questionnaires were available in Dutch and English. For standardized questionnaires with no official translation, the Dutch translations of Poppelaars et al. (2018) were used (see article for further information).

During the lab experiment, participants were seated in a plain cubicle with a computer and a tablet. At the start of the experiment participants were given both verbal and written information on the study and gave informed consent. Participants were told that they would see two trailers of video games. The researcher requested the participants to choose the game they believed they would enjoy most, under the guise that the study's topic was gameplay of a game that participants may have played at home. To further encourage choosing the most appealing game, participants were informed that they had a chance to win their chosen game.

Next, participants received instructions on using the tablet. They were told they were free to play the chosen game as long as they liked, but that it was important that they could evaluate the game. In fact, although there was no minimum time limit, participants were told to continue with the questionnaires 50 min from the start of the experiment (approximately 40 min of gameplay), to ensure they did not exceed the 60 min set for the experiment.

Once the researcher left the cubicle, participants filled out an assessment of affect. Next, participants were shown, in a random order, two trailers of the video game Monument Valley. One trailer portrayed the game as an entertainment game and one trailer portrayed the game as beneficial for players' mental health. The trailers were designed to convince participants that two separate games were being promoted and the combination of trailer design and message was counterbalanced across participants. To achieve the latter, participants were randomized using a blocked randomization to receive trailer A including the entertainment message and trailer B including the mental health message or to see the same trailers with the messages interchanged. After viewing the trailers, participants were asked to select the game they would like most and were reminded that they could win that same game. After choosing a game, participants rated the attractiveness and fun of each game based on the trailer, before they were instructed to play Monument Valley 1 (Ustwo Games, 2014a).

Following gameplay, participants completed questionnaires on their affect, intrinsic motivation, autonomy and competence and questions about the manipulation check, trailer message and questionnaires not included in the current study. Participants were provided with study credits or a gift certificate worth €10. Once testing was completed in November 2017, debriefing was done through email and 10 participants were randomly selected to receive a reimbursement for purchasing Monument Valley 1 and 2 (Ustwo Games, 2014a, 2017). This study was approved by the ethical committee of the Faculty of Social Sciences at Radboud University (ECSW2017-3001-461).

Monument Valley and Messaging

The original Monument Valley game released in 2014 (Ustwo Games, 2014a) is an award winning commercial puzzle game with optical illusions inspired by the art of M. C. Escher and can be played on smartphones and tablets (**Figure 1**). This game was designed to create an optimal balance between difficulty and pleasure, as well as to allow all players to be able to complete all levels (Ustwo Games, 2014b) making it accessible for participants with various levels of gameplay experience. Although the game was not designed with a therapeutic aim, players may believe that it was when it is presented that way, because of the relaxed atmosphere and the way the game illustrates problem solving, an adaptive technique for coping with stress and negative emotions (i.e., the player finds solutions for the game's challenges by literally looking at the challenge from several angles). Indeed, participant comments following gameplay indicated that the mental health claim was credible (e.g., one participant recommended the mental health game to other participants because 'it will relax all stressed out students').

For this study, we created two distinguishable trailers of Monument Valley allowing us to attribute any differences in game choice or game experience to messaging while participants were unaware of this manipulation. Screenshots taken from the later levels and expansion levels of Monument Valley were used in the trailers to make it unlikely for participants to encounter these levels during the experiment. We differentiated the trailers on several aspects to create the impression that the trailers were portraying two separate games. Pilot studies were conducted to make sure that potential participants indeed believed that the two trailers advertised two different games. Information regarding pilot studies are available upon request. The trailers, which we will refer to as the *detailed* and the *abstract* trailer, were both approximately 1-min long and differed on the following aspects, respectively: (1) Showing game challenges that had a more *detailed* environment vs. game challenges that were *abstract* buildings floating in space (**Figure 2**); (2) Faster vs. slower music; (3) A warmer vs. a cooler color palette; (4) AR BONNIE vs. Gloucester MT font for the trailer text; and (5) An editing style focused on slowly moving across the pictures vs. zooming in or out of the pictures.

During the experiment, the messaging in each trailer design was counterbalanced and trailers were shown in a random order. This allowed us to assess the effects of messaging while controlling for trailer design. Approximately half of the participants saw the detailed trailer as the mental health trailer ($n = 66$) and the abstract trailer as the entertainment trailer, while the other half ($n = 63$) saw the abstract trailer as the mental health trailer and the detailed trailer as the entertainment trailer. Both messages consisted of five short phrases. For both messages the first sentence introduced the game as appealing, as one would expect from a promotional trailer. The next four phrases

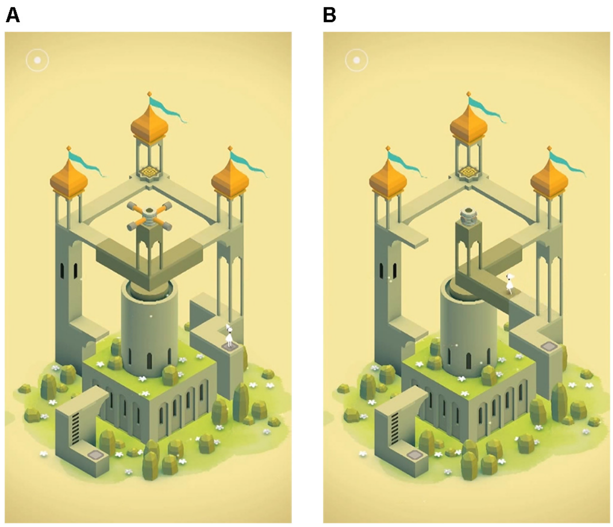

FIGURE 1 | Screenshots from the video game Monument Valley. **(A)** A building before the dark khaki section is rotated. The player's aim is to have the avatar in white reach the top of this building. **(B)** The same building after rotating the dark khaki section, allowing the player to find a new path upward. These images are reproduced from Monument Valley by Ustwo Games (2014a) with the permission of the copyright holder Ustwo Games.

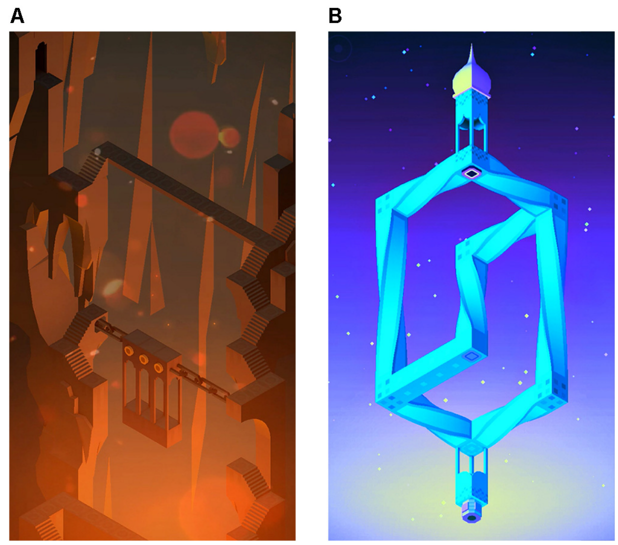

FIGURE 2 | Screenshots from the two trailers of Monument Valley. **(A)** A screenshot from the detailed trailer. **(B)** A screenshot from the abstract trailer. These images have been adapted from Monument Valley by Ustwo Games (2014a) with the permission of the copyright holder Ustwo Games.

focused on the mental health or the entertainment message (**Table 1**).

Instruments

Mental Health Symptoms

The DASS-21 (Lovibond and Lovibond, 1995) was used both in the original English version as well as in the Dutch translation by De Beurs (2010). All 21-items were scored on a 4-point scale (*Did not apply to me at all* = 0, *Applied to me to some degree, or some of the time* = 1, *Applied to me to a considerable degree, or a good part of the time* = 2, *Applied to me very much, or most of the time* = 3) with seven items for each of the subscales: depressive symptoms (e.g., 'I felt that I had nothing to look forward to.'; α = 0.83), anxiety symptoms (e.g., 'I felt scared without any good reason.'; α = 0.70) and stress symptoms (e.g., 'I found it difficult to relax.'; α = 0.79). Participants rated to what degree each statement applied to them over the past week. The summed score for each subscale indicated mild symptoms at or above a score of 5 for depression, 4 for anxiety, and 8 for stress. Thus, when we refer to elevated symptoms, we are referring to symptoms at or above the mild cut-off. Additionally, in the analyses all participants who scored at or above the severe cutoff (11 for depression, 8 for anxiety, and 13 for stress) for one or more of the subscales were compared to participants who had no symptoms within the severe or extremely severe range. As symptoms of the different subscales have different cutoffs (e.g., a score of 8 can indicate mild stress or severe anxiety) a continuous sum score cannot be used to indicate overall mental health. Thus, when referring to severe symptoms, we are referring to a score at or above the severe cut-off on one or more DASS-21 subscales.

Affect

The Self-Assessment Manikin (SAM; Bradley and Lang, 1994) for affect was used to asses current affect before and after gameplay. Participants were asked to indicate, on a 5-point manikin based scale, the manikin that reflected how they felt at that moment and were given a list of adjectives to indicate the extreme negative (e.g., *unhappy, annoyed, bored* = 1) and extreme positive (e.g., *happy, satisfied, hopeful* = 5) points of the scale. Each manikin was a simple line drawing of a person with an emotional facial expression, with the neutral facial expression in the middle of the scale (a score of 3).

Game Choice and Trailer Preference

After viewing the trailers, participants chose one of the games, referred to as game A and game B and accompanied by screenshots to ensure that participants could correctly identify each game. Although all participants played Monument Valley, the analyses were done from the perspective of the participant and focus on their choice for a game promoted with mental health or entertainment messaging. Directly after game selection, participants rated both games based on the trailers on attractiveness and fun using two separate 10-point scales (1–10), with higher scores indicating more perceived attractiveness and perceived fun, respectively.

TABLE 1 | Messages included in the mental health and entertainment trailers.

Mental health	Entertainment
Perfect for a single marathon playthrough	A game you must play
Learn to manage stress more efficiently	Think outside the box to solve intricate puzzles
Therapeutic insights for emotional mastery	9/10 Polygon 5/5 Touch Arcade
Both challenging and relaxing	Almost impossibly gorgeous
Recommended by games for mental health	IPad game of the year

Gameplay Duration

Gameplay duration was measured using two methods. First, the online questionnaire page that was open while participants played Monument Valley contained an invisible timer. Second, the game tablets were equipped with the program Funamo Parental Control (Funamo; Funamo Inc., 2016), which recorded how long Monument Valley was open for each participant.

Both measures were used to create a gameplay duration measure, as some participants did not close the game when they continued with the questionnaire (resulting in an incorrect gameplay duration in Funamo) and others continued to the next page in the questionnaire before finishing gameplay (resulting in an incorrect gameplay duration on the questionnaire timer). As Funamo directly records how long the game is opened it was the preferred measure. For participants who had an incorrect gameplay duration in Funamo (n = 9), we used the gameplay duration from the questionnaire corrected for the average time it took to open and close the game as well as to read the instruction on the questionnaire page. For one participant, no gameplay duration could be calculated as both the Funamo and questionnaire measures were incorrect.

Additionally, it was decided that a standard gameplay duration would be given to all participants who were stopped during gameplay to complete the questionnaire (n = 25) and participants who exceeded that standard duration without being stopped (n = 2). This was done because the maximum amount of time participants could play during the experiment was constrained by the duration of the experiment explanation and the time it took participants to fill out all questions prior to gameplay. Thus, the gameplay duration for all these participants was set at the mean gameplay duration correctly recorded for participants who were stopped, that is 40.38 min.

Intrinsic Motivation

Intrinsic motivation was measured with the interest/enjoyment subscale from the Intrinsic Motivation Inventory (Ryan, 1982; McAuley et al., 1989). Participants responded to seven statements (e.g., 'This game was fun to do.') about their experience with Monument Valley using a 7-point scale (*Not at all true* = 1, *Somewhat true* = 4, *Very true* = 7). Two items needed to be recoded to create a mean score where higher scores indicated more intrinsic motivation (α = 0.89).

Autonomy and Competence

Using the Player Experience of Need Satisfaction questionnaire (PENS; Ryan et al., 2006; Immersyve, 2007), the psychological needs autonomy and competence were measured. Both needs were assessed with three items, for example 'The game lets you do interesting things.' for autonomy (α = 0.78) and for example 'I feel very capable and effective when playing.' for competence (α = 0.83). Items were rated on a 7-point scale (*Strongly disagree* = 1, *Strongly agree* = 7) and a mean was calculated for each subscale with higher scores indicating a stronger experience of autonomy and competence, respectively. The psychological need for relatedness was not measured as Monument Valley provides no opportunity to interact with other players.

Manipulation Check

At the end of the experiment participants were asked (1) what they believed the study's aim was, (2) which game they would recommend to the next participant and why (i.e., *Game A, because . . ., Game B, because . . ., or I do not have a preference, because . . .*, with the last option prompting some participants to indicate that they believed there was only one game) and (3) to explain the difference between the messaging of the two trailers, if they had noticed a difference. The answers to these questions were checked for (1) awareness of the study's manipulation using one game rather than two games; (2) awareness of the study's aim to relate the mental health message in one of the trailers to game choice and (3) awareness of the study's aim to relate players mental health symptoms to game choice. Participants who were aware of at least one, were excluded from the analyses (n = 26).

Trailer Message Awareness

After the manipulation check, participants answered two last questions to identify if they had noticed the mental health message. The first question was 'Did you notice that the message of one of the two trailers was primarily focused on game enjoyment, while the other trailer contained the message that it could help people who feel stressed or have some mental health difficulties?' (*Yes* or *No*). Finally, participants selected a screenshot from one of the trailers to answer the question 'Which of the two trailers do you believe contained the message that this video game can help people who feel stressed or have some mental health difficulties?'

Statistical Analyses

All analyses were done in version 25 of SPSS (IBM Corp, 2017). First, randomization was checked by comparing the two conditions on several descriptive variables, mental health symptoms and awareness of messaging using t-tests and Chi-square. Additionally, a Chi-square test was used to compare the selection of the trailer designs and dependent t-tests were used to test if perceived attractiveness and perceived fun differed per trailer design. Also, t-tests were done to test if the trailer design of the chosen game was related to gameplay duration, intrinsic motivation, autonomy, competence, affect. Additionally, a Repeated Measures ANOVA (RM-ANOVA) was used to relate changes in affect to the trailer design of the chosen game.

Turning to the main research aim, a logistic regression was performed predicting game choice using trailer design as a predictor to understand how the effects of trailer design and trailer message interact. Furthermore, t-tests were used to test if game choice was related to gameplay duration, intrinsic motivation, autonomy, competence, and affect before and after gameplay. Moreover, for perceived attractiveness and fun RM-ANOVAs were used to compare the scores for the mental health and the entertainment trailer provided by each participant. Another RM-ANOVA was used to relate changes in affect to game choice.

Finally, these analyses were repeated to address the second research aim to distinguish effects of mental health symptom severity and type of mental health symptoms. First, in logistic regressions game choice was predicted using trailer design, symptoms and the interaction between symptoms and trailer design. Next, one-way ANOVAs were used to relate symptoms and the interaction between symptoms and game choice to gameplay duration, intrinsic motivation, autonomy, competence, and affect before and after gameplay. Again, RM-ANOVAs were used for attractiveness, fun and affect. Thus, the analyses were repeated comparing those with and without severe symptoms, those with or without elevated depressive symptoms, those with or without elevated anxiety symptoms and those with or without elevated stress symptoms. For all significant interaction effects *post hoc* analyses were performed with a Bonferroni correction.

RESULTS

Descriptive Statistics

The descriptive statistics for the entire sample and per condition are provided in **Table 2**. Randomization was successful as there were no differences between conditions on age, gender, birth country, general video game liking, weekly hours of video gameplay, depressive symptoms, anxiety symptoms, stress symptoms or severe symptoms. Participants played Monument Valley for a mean of 28.48 min (SD = 8.85), with a range of 12.77–40.38 min.

Moreover, we tested if the mental health message was clear in both trailer designs. Of the whole sample 88.4% indicated that they noticed that one of the trailers contained a mental health message and 82.2% was able to correctly identify this trailer. There was no difference between conditions in correctly identifying the trailer containing the mental health message (**Table 2**). Furthermore, there was no difference in awareness of the mental health message between those who decided to play the mental health game versus those who decided to play the entertainment game (81.8% vs. 82.7% correctly identified the mental health trailer, respectively; X^2 (1, n = 129) = 0.02, p = 0.90).

Trailer Design

Before testing the effect of the trailer message, we tested if trailer designs were selected equally and if trailer design affected preference (**Table 3**). Participants were significantly more likely to select the detailed trailer than the abstract trailer. Similarly, participants perceived the game in the detailed trailer as more attractive and more fun than the abstract trailer. Therefore, trailer design was controlled for in all further analyses on game choice, perceived attractiveness and perceived fun.

TABLE 2 | Descriptives (means and standard deviations or percentages) for the total sample and per condition including chi-square tests and *t*-tests comparing conditions.

	Total (*SD*)		Detailed trailer with mental health (*SD*)		Abstract trailer with mental health (*SD*)		X^2/t	*df*	*p*
Age	21.33	(3.20)	21.56	(3.06)	21.10	(3.35)	0.83	127	0.41
Gender							0.06	1	0.81
Female	73.6%		72.7%		74.6%				
Male	26.4%		27.3%		25.4%				
Birth country							1.77	2	0.41
Dutch	49.6%		53.0%		46.0%				
German	29.5%		24.2%		34.9%				
Other	20.9%		22.7%		19.0%				
Video game liking	4.50	(1.75)	4.55	(1.85)	4.46	(1.64)	0.28	127	0.78
Weekly video gameplay	4.25	(6.77)	4.83	(7.52)	3.63	(5.87)	1.01	122.20	0.31
Depressive symptoms	6.02	(3.92)	6.30	(4.16)	5.71	(3.67)	0.85	127	0.40
Anxiety symptoms	5.12	(3.41)	5.52	(3.75)	4.70	(3.00)	1.36	127	0.18
Stress symptoms	8.24	(3.85)	8.35	(4.04)	8.13	(3.67)	0.33	127	0.75
Severe symptoms							<0.01	1	0.99
Yes	31.8%		31.8%		31.7%				
No	68.2%		68.2%		68.3%				
Elevated depressive symptoms							0.29	1	0.59
Yes	64.3%		62.1%		66.7%				
No	35.7%		37.9%		33.3%				
Elevated anxiety symptoms							0.88	1	0.35
Yes	67.4%		71.2%		63.5%				
No	32.6%		28.8%		36.5%				
Elevated stress symptoms							0.70	1	0.40
Yes	56.6%		53.0%		60.3%				
No	43.4%		47.0%		39.7%				
Messaging identified							0.32	1	0.57
Yes	82.2%		80.3%		84.1%				
No	17.8%		19.7%		15.9%				

TABLE 3 | Descriptives (means and standard deviations or percentages) for the detailed and abstract trailers including chi-square and *t*-tests comparing trailers.

	Detailed trailer (*SD*)		Abstract trailer (*SD*)		X^2/t	*df*	*p*
Game choice	69.8%		30.2%		20.16	1	<0.001
Attractive	6.50	(1.60)	5.53	(1.83)	−6.07	128	<0.001
Fun	6.25	(1.62)	5.47	(1.81)	−5.25	128	<0.001
Affect before	3.73	(0.73)	3.67	(0.81)	−0.46	127	0.65
Affect after	3.89	(0.67)	3.87	(0.67)	−0.14	124	0.89
Duration play	28.32	(8.91)	28.86	(8.82)	0.32	126	0.75
Motivation	5.25	(1.04)	5.38	(0.97)	0.67	127	0.51
Autonomy	4.75	(1.20)	4.95	(1.03)	0.89	127	0.37
Competence	4.98	(1.11)	5.10	(1.19)	0.56	127	0.58

Next, we tested whether the trailer design of the chosen game was related to game experience. We found that affect increased over time with a small effect size [$F(1, 124) = 6.45$, $p < 0.05$, $\eta_p^2 = 0.05$], however, the trailer design of the chosen game was not related to change of affect over time [$F(1, 124) = 0.01$, $p = 0.92$, $\eta_p^2 < 0.01$]. In addition, results show that trailer design was not related to affect before gameplay, affect after gameplay, duration of gameplay or the experience of intrinsic motivation, autonomy or competence (**Table 3**). Thus, participants who played Monument Valley after selecting the detailed trailer did not play longer and did not experience more intrinsic motivation, autonomy or competence than participants who played the game after selecting the abstract trailer.

Main Analyses

To address the first research aim, we first compared the effects of trailer message on game choice and preference. A logistic regression predicting game choice using the trailer design as a predictor showed that the odds of choosing the mental health game were 3.71 times higher than the odds of choosing the entertainment game [X^2 (1, n = 129) = 18.99, $p < 0.001$]. However, the odds of choosing the mental health message when it was portrayed in the detailed trailer were 5.65 times higher than the odds of choosing the mental health message when it was portrayed in the abstract trailer [X^2 (1, n = 129) = 19.09, $p < 0.001$]. The complete model was able to correctly predict 69.8% of the game choices [X^2 (1, n = 129) = 21.11, $p < 0.001$]. **Figure 3** shows how the four combinations of trailer design and trailer message were chosen at different rates by the participants. Specifically, the figure shows both a favoring of the detailed trailer and the trailer with the mental health message.

Although mental health messaging made it more likely for participants to choose a game, participants did not perceive the game promoted with the mental health message as more attractive or more fun than the game promoted with the entertainment message (**Table 4**). However, there was a significant interaction for perceived attractiveness of trailer message × trailer design [$F(1, 127) = 36.60$, $p < 0.001$, $\eta^2_p = 0.22$], indicating that there was a significant difference between the trailer designs in perceived attractiveness when they contained the mental health message [$M_{abstract} = 5.40$, $SE_{abstract} = 0.21$; $M_{detailed} = 6.79$, $SE_{detailed} = 0.20$; $F(1, 127) = 22.89$, $p < 0.001$, $\eta^2_p = 0.15$], but not when the trailer designs contained the entertainment message [$M_{abstract} = 5.65$, $SE_{abstract} = 0.22$; $M_{detailed} = 6.21$, $SE_{detailed} = 0.22$; $F(1, 127) = 3.16$, $p = 0.08$, $\eta^2_p = 0.02$]. Similarly, there was a significant interaction for perceived fun of trailer message × trailer design [$F(1, 127) = 27.23$, $p < 0.001$, $\eta^2_p = 0.18$], indicating that there was a significant difference between the trailer designs in perceived fun when they contained the mental health message [$M_{abstract} = 5.37$, $SE_{abstract} = 0.21$; $M_{detailed} = 6.41$, $SE_{detailed} = 0.21$; $F(1, 127) = 12.51$, $p < 0.001$, $\eta^2_p = 0.09$] and not when they contained the entertainment message [$M_{abstract} = 5.58$, $SE_{abstract} = 0.22$; $M_{detailed} = 6.08$, $SE_{detailed} = 0.22$; $F(1, 127) = 2.64$, $p = 0.11$, $\eta^2_p = 0.02$]. Thus, participants believed the game to be significantly more fun and attractive if the mental health message was included in the detailed trailer than if they received the mental health message in the abstract trailer. However, when trailers contained the entertainment message the abstract and the detailed trailer were perceived as equally fun and attractive (**Figure 4**).

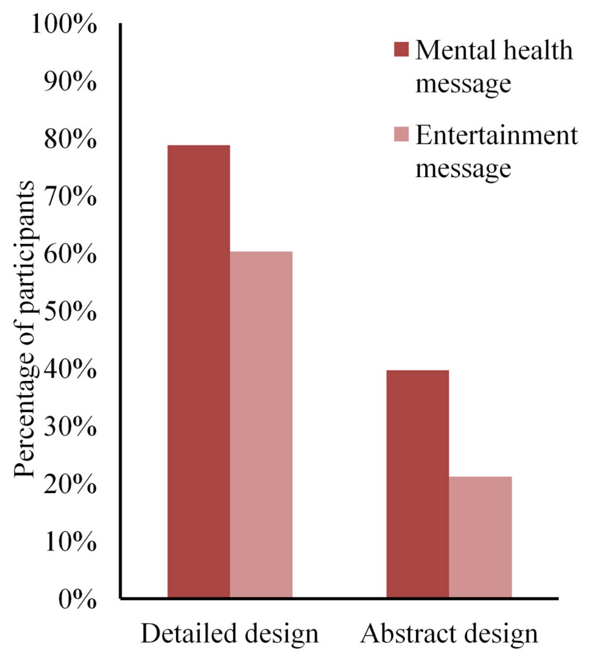

FIGURE 3 | The percentage of game selection. Participants were given the choice between (1) the detailed trailer with the mental health message (78.8%) and the abstract trailer with the entertainment message (21.2%) or (2) the detailed trailer with the entertainment message (60.3%) and the abstract trailer with the mental health message (39.7%). Despite the detailed design being preferred over the abstract design, both designs were chosen more often when presented with the mental health message.

Furthermore, we tested if game choice predicted game experience (**Table 4**). T-tests showed no differences in gameplay duration, intrinsic motivation, autonomy and competence. Thus, playing a game promoted for entertainment or mental health did not change the duration of gameplay, nor how much intrinsic motivation, autonomy and competence players experienced.

Next, we tested change in affect. As shown previously there was a significant improvement in affect over time [$F(1, 124) = 7.18$, $p < 0.01$, $\eta^2_p = 0.06$], however, there was no effect of game choice on the change in affect [$F(1, 124) < 0.01$, $p = 0.98$, $\eta^2_p < 0.01$]. This indicates that participants experienced more positive affect after gameplay regardless of playing a game promoted for entertainment or mental health.

Exploratory Analyses

In order to address the second research aim, we explored the effects of mental health symptom severity and type on all dependent variables. For all groups, we first tried to predict game choice with a logistic regression using symptoms and the interaction between symptoms and trailer design. Next, the remaining dependent variables were predicted using symptoms and the interaction between symptoms and game choice as predictors. All descriptives and statistics can be found in **Table 5**, with the exception of the three-way interactions for fun and attractiveness and the RM-ANOVAs for change in affect.

Symptom Severity

For game choice, symptom severity was not found to be related either directly [X^2 (1, n = 129) = 0.86, $p = 0.35$] or in interaction with trailer design [X^2 (1, n = 129) = 0.51, $p = 0.48$]. Thus, participants without severe symptoms were equally likely to select the mental health game (58.0%) as participants with severe symptoms (63.4%).

However, further analyses did show effects of symptom severity on competence and autonomy. A direct effect was found for competence, demonstrating that participants with severe symptoms experienced more competence in the game than participants without severe symptoms regardless of game choice. Additionally, both a direct and an interaction effect

TABLE 4 | Descriptives (means and standard deviations or percentages) for the mental health and entertainment trailers including tests comparing trailers: chi-square, RM-ANOVA and *t*-tests.

	Mental health trailer (*SD*)		**Entertainment trailer (*SD*)**		**$X^2/t/F$**	***df***	***p***
Game choice	59.7%		40.3%		4.85	1	< 0.05
Attractive	6.11	(1.79)	5.92	(1.79)	1.03	1, 127	0.31
Fun	5.90	(1.75)	5.82	(1.77)	0.16	1, 127	0.69
Affect before	3.78	(0.77)	3.62	(0.72)	1.22	127	0.23
Affect after	3.95	(0.57)	3.79	(0.78)	1.25	88.28	0.16
Duration play	28.74	(8.87)	28.10	(8.90)	0.40	126	0.69
Motivation	5.31	(1.03)	5.26	(1.01)	0.27	127	0.79
Autonomy	4.81	(1.15)	4.81	(1.16)	–0.02	127	0.98
Competence	4.99	(1.16)	5.06	(1.10)	–0.38	127	0.71

The Chi-square test for game choice was not controlled for trailer design.

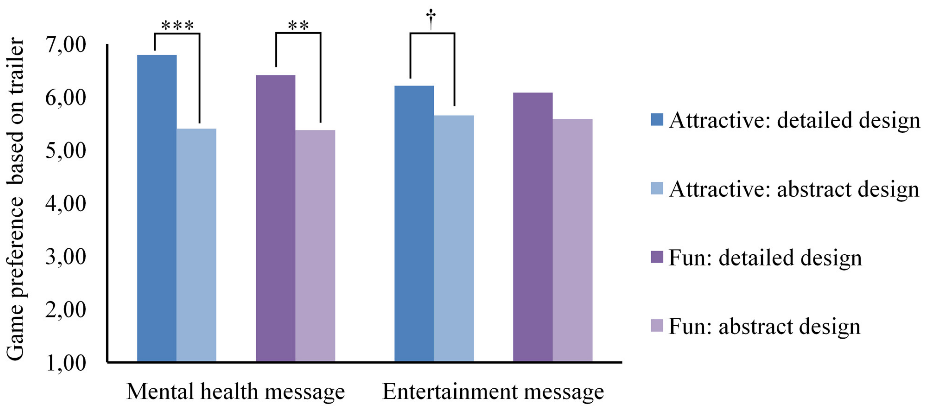

FIGURE 4 | Perceived attractiveness and fun of the game for each design and message combination. Significant effects are indicated as follows: †$p < 0.10$, *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

was found for autonomy. Together these effects show that for those who selected the entertainment game, no difference was found on autonomy for participants with or without severe symptoms [$F(1, 125) = 0.02$, $p = 0.90$, $\eta_p^2 < 0.01$]. However, when participants selected the mental health game, participants with severe symptoms experienced more autonomy in the game than participants without severe symptoms [$F(1, 125) = 11.43$, $p < 0.001$, $\eta_p^2 = 0.08$].

Moreover, we observed that affect was lower prior to, but not after, gameplay in participants with severe symptoms than in participants without severe symptoms. Further analyses showed an interaction of time × symptom severity [$F(1, 122) = 4.16$, $p < 0.05$, $\eta_p^2 = 0.03$], but no three-way interaction: time × game choice × symptom severity [$F(1, 122) = 0.83$, $p = 0.36$, $\eta_p^2 = 0.01$]. *Post hoc* tests suggested that there was an increase in affect for participants with severe symptoms [$F(1, 122) = 10.30$, $p < 0.01$, $\eta_p^2 = 0.08$], but affect did not change for participants without severe symptoms [$F(1, 122) = 1.29$, $p = 0.26$, $\eta_p^2 = 0.01$]. In sum, participants with more severe symptoms experienced less positive affect prior to gameplay, but showed an increase in positive affect, resulting in equal positive affect for participants with more and less severe symptoms after gameplay. Symptom severity had no further effects on the dependent variables.

Depressive Symptoms

Elevated depressive symptoms did not influence game choice either directly [X^2 (1, $n = 129$) = 2.69, $p = 0.10$] or in interaction with trailer design [X^2 (1, $n = 129$) = 1.22, $p = 0.27$], which indicates that there was no difference in the odds for participants with and without elevated depressive symptoms to select the mental health game (62.7% and 54.3%, respectively).

Also, depressive symptoms did not predict dependent variables except for affect. Elevated depressive symptoms were related to less positive affect both before and after gameplay. Further analyses showed that there was an interaction for time × elevated depressive symptoms on affect [$F(1, 122) = 4.40$, $p < 0.05$, $\eta_p^2 = 0.04$], indicating that affect became more positive for participants with elevated depressive symptoms [$F(1, 122) = 12.45$, $p < 0.001$, $\eta_p^2 = 0.09$], while affect did not change for participants without elevated depressive symptoms [$F(1, 122) = 0.01$, $p = 0.94$, $\eta_p^2 < 0.01$]. There was no three-way interaction: time × game choice × elevated depressive symptoms [$F(1, 122) = 3.68$, $p = 0.06$, $\eta_p^2 = 0.03$]. This effect replicates what we previously saw for severe symptoms.

Anxiety Symptoms

We found no direct effect of anxiety symptoms [X^2 (1, $n = 129$) = 0.46, $p = 0.50$], nor an interaction effect of anxiety

TABLE 5 | Descriptives (means and standard deviations) and ANOVA results: main effect of symptoms and interaction with messaging.

	Total				Mental health		Entertainment			
	Non-elevated *M (SD)*	**Elevated *M (SD)***	***F***	η_p^2	**Non-elevated *M (SD)***	**Elevated *M (SD)***	**Non-elevated *M (SD)***	**Elevated *M (SD)***	***F***	η_p^2
Symptom severity										
Attractive	5.98 (1.54)	6.10 (1.28)	0.21[a]	<0.01	6.17 (1.84)	5.98 (1.68)	5.78 (1.86)	6.22 (1.60)	3.39[a†]	0.03
Fun	5.78 (1.56)	6.04 (1.35)	0.82[a]	<0.01	5.89 (1.79)	5.93 (1.68)	5.67 (1.84)	6.15 (1.59)	1.99[a]	0.02
Affect before	3.83 (0.71)	3.45 (0.78)	**6.66[c*]**	0.05	3.92 (0.67)	3.48 (0.87)	3.70 (0.74)	3.40 (0.63)	0.22[c]	<0.01
Affect after	3.92 (0.71)	3.80 (0.56)	0.44[c]	< 0.01	4.04 (0.54)	3.76 (0.60)	3.76 (0.86)	3.87 (0.52)	2.28[c]	0.02
Duration play	28.31 (9.27)	28.84 (8.01)	0.02[b]	< 0.01	28.27 (9.46)	29.66 (7.72)	28.36 (9.14)	27.44 (8.56)	0.44[b]	<0.01
Motivation	5.19 (1.07)	5.52 (0.87)	2.97[a†]	0.02	5.21 (1.06)	5.50 (0.96)	5.15 (1.09)	5.54 (0.70)	0.08[a]	<0.01
Autonomy	4.63 (1.21)	5.20 (0.89)	**4.80[a*]**	0.04	4.50 (1.19)	5.41 (0.79)	4.80 (1.24)	4.84 (0.97)	**3.97[a*]**	0.03
Competence	4.87 (1.20)	5.34 (0.91)	**5.13[a*]**	0.04	4.84 (1.24)	5.27 (0.95)	4.90 (1.16)	5.47 (0.85)	0.10[a]	<0.01
Depressive symptoms										
Attractive	6.12 (1.63)	5.96 (1.36)	0.23[a]	< 0.01	6.22 (1.92)	6.05 (1.72)	6.02 (1.97)	5.87 (1.69)	0.03[a]	<0.01
Fun	5.77 (1.60)	5.91 (1.45)	0.31[a]	< 0.01	5.85 (1.83)	5.93 (1.72)	5.70 (1.91)	5.89 (1.70)	0.05[a]	<0.01
Affect before	4.02 (0.61)	3.52 (0.76)	**16.43[c***]**	0.12	4.00 (0.71)	3.65 (0.78)	4.05 (0.50)	3.32 (0.70)	2.04[c]	0.02
Affect after	4.04 (0.60)	3.79 (0.69)	**4.47[c*]**	0.04	4.16 (0.47)	3.84 (0.59)	3.90 (0.70)	3.71 (0.82)	0.27[c]	<0.01
Duration play	27.00 (9.10)	29.31 (8.66)	1.23[b]	0.01	25.42 (8.59)	30.37 (8.63)	28.88 (9.53)	27.56 (8.57)	3.66[b†]	0.03
Motivation	5.11 (1.16)	5.39 (0.92)	2.54[a]	0.02	5.19 (1.20)	5.37 (0.95)	5.01 (1.14)	5.43 (0.88)	0.42[a]	<0.01
Autonomy	4.63 (1.28)	4.91 (1.07)	1.44[a]	0.01	4.52 (1.36)	4.95 (1.02)	4.76 (1.19)	4.85 (1.16)	0.63[a]	<0.01
Competence	4.93 (1.17)	5.06 (1.12)	0.30[a]	<0.01	4.81 (1.33)	5.07 (1.08)	5.08 (0.95)	5.05 (1.21)	0.44[a]	<0.01
Anxiety symptoms										
Attractive	6.35 (1.18)	5.86 (1.56)	3.73[a†]	0.03	6.48 (1.45)	5.93 (1.91)	6.21 (1.76)	5.78 (1.79)	0.70[a]	0.01
Fun	6.30 (1.18)	5.65 (1.59)	**6.09[a*]**	0.05	6.36 (1.45)	5.68 (1.85)	6.24 (1.53)	5.62 (1.85)	0.38[a]	<0.01
Affect before	3.54 (0.81)	3.79 (0.71)	2.93[c†]	0.02	3.58 (0.83)	3.86 (0.73)	3.47 (0.80)	3.69 (0.68)	0.05[c]	<0.01
Affect after	3.80 (0.68)	3.92 (0.66)	0.47[c]	<0.01	3.79 (0.59)	4.02 (0.55)	3.82 (0.81)	3.77 (0.77)	1.20[c]	0.01
Duration play	30.87 (8.48)	27.31 (8.84)	3.60[b†]	0.03	32.22 (7.60)	27.04 (9.02)	28.88 (9.53)	27.71 (8.70)	1.44[b]	0.01
Motivation	5.44 (1.03)	5.22 (1.01)	1.12[a]	0.01	5.51 (0.92)	5.21 (1.08)	5.34 (1.19)	5.22 (0.92)	0.24[a]	<0.01
Autonomy	4.86 (1.15)	4.79 (1.15)	0.07[a]	<0.01	4.88 (1.14)	4.78 (1.16)	4.82 (1.21)	4.81 (1.16)	0.04[a]	<0.01
Competence	5.08 (1.25)	4.99 (1.08)	0.15[a]	0.01	5.07 (1.34)	4.95 (1.07)	5.10 (1.13)	5.05 (1.11)	0.02[a]	<0.01
Stress symptoms										
Attractive	5.98 (1.37)	6.04 (1.53)	0.13[a]	<0.01	6.21 (1.68)	6.03 (1.87)	5.75 (1.70)	6.05 (1.86)	1.16[a]	0.01
Fun	5.74 (1.56)	5.95 (1.45)	0.77[a]	0.01	5.91 (1.75)	5.89 (1.76)	5.57 (1.80)	6.01 (1.74)	1.39[a]	0.01
Affect before	3.72 (0.71)	3.69 (0.78)	0.04[c]	<0.01	3.78 (0.71)	3.76 (0.82)	3.64 (0.73)	3.60 (0.72)	<0.01[c]	<0.01
Affect after	3.91 (0.65)	3.86 (0.68)	0.08[c]	<0.01	4.00 (0.51)	3.90 (0.62)	3.77 (0.81)	3.80 (0.76)	0.25[c]	<0.01
Duration play	28.65 (9.31)	28.36 (8.56)	<0.01[b]	<0.01	29.54 (9.23)	28.13 (8.65)	27.30 (9.50)	28.68 (8.55)	0.74[b]	0.01
Motivation	5.20 (1.10)	5.36 (0.95)	0.94[a]	0.01	5.27 (1.20)	5.34 (0.89)	5.09 (0.93)	5.39 (1.05)	0.38[a]	<0.01
Autonomy	4.66 (1.30)	4.93 (1.02)	1.49[a]	0.01	4.64 (1.31)	4.95 (0.99)	4.70 (1.30)	4.90 (1.06)	0.06[a]	<0.01
Competence	5.11 (1.11)	4.95 (1.15)	0.79[a]	0.01	5.02 (1.27)	4.96 (1.08)	5.24 (0.82)	4.93 (1.27)	0.37[a]	<0.01

*[a] df = (1,125), [b] df = (1,124), [c] df = (1,122), [†]p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001, significant effects are printed in bold.*

symptoms × trailer design on game choice [X^2 (1, n = 129) = 0.34, p = 0.56]. Thus, anxiety symptoms did not predict how often the mental health trailer was selected (non-elevated symptoms: 59.5%; elevated symptoms: 59.8%).

Moreover, no main or interaction effects of anxiety symptoms with game choice were found on gameplay duration, intrinsic motivation, autonomy, competence, attractiveness, or affect before and after gameplay. However, there was a significant effect of anxiety symptoms on perceived fun of the trailers, showing that participants with elevated anxiety symptoms rated the games as less fun than participants without these symptoms based on the trailers. Further analyses did not show an interaction of time × anxiety symptoms [$F(1, 122) = 1.29$, $p = 0.26$, $\eta_p^2 = 0.01$] or a three-way interaction of time × game choice × anxiety symptoms [$F(1, 122) = 0.62$, $p = 0.43$, $\eta_p^2 = 0.01$] on affect. Thus, anxiety symptoms did not influence the change in affect after gameplay.

Stress Symptoms

Finally, elevated stress symptoms did not influence the odds of selecting the mental health or the entertainment trailer directly [X^2 (1, n = 129) = 2.07, p = 0.15], nor in interaction with trailer design [X^2 (1, n = 129) = 3.25, p = 0.07]. Therefore, it appears participants with elevated stress symptoms were no more likely to select the mental health trailer than participants without elevated stress symptoms (58.9% and 60.7%, respectively).

Furthermore, no significant direct or interaction effects of stress symptoms were found on gameplay duration, intrinsic motivation, autonomy, competence, perceived attractiveness, fun, or affect before and after gameplay. Moreover, there was no interaction of time × stress symptoms [$F(1, 122) < 0.01$, $p = 0.96$, $\eta_p^2 < 0.01$] nor a three-way interaction of time × game choice × stress symptoms [$F(1, 122) = 0.28$, $p = 0.60$, $\eta_p^2 < 0.01$] for affect. Thus, participants with elevated stress symptoms did not react differently to the game than participants without elevated stress symptoms.

Affect

As previous analyses showed that affect only improves in participants with severe symptoms and participants with elevated depressive symptoms, but not in other participants, we examined if severe depressive symptoms are driving the effect. Therefore, we performed RM-ANOVAs for change in affect using only severe symptoms within each type of mental health symptoms as a predictor. These analyses showed that only those with severe depressive symptoms increased in affect [$F(1, 122) = 5.65$, $p < 0.05$, $\eta_p^2 = 0.04$], in contrast to those with severe anxiety [$F(1, 122) = 0.82$, $p = 0.37$, $\eta_p^2 = 0.01$] or severe stress symptoms [$F(1, 122) = 0.06$, $p = 0.82$, $\eta_p^2 < 0.01$]. This significant interaction is also reflected by the fact that participants with severe depressive symptoms only scored lower than participants without severe depressive symptoms before gameplay [$M_{severe} = 3.30$, $SE_{severe} = 0.18$; $M_{non-severe} = 3.76$, $SE_{non-severe} = 0.07$; $F(1, 122) = 5.62$, $p < 0.05$, $\eta_p^2 = 0.04$] and not after gameplay [$M_{severe} = 3.86$, $SE_{severe} = 0.17$; $M_{non-severe} = 3.87$, $SE_{non-severe} = 0.06$; $F(1, 122) < 0.01$, $p = 0.96$, $\eta_p^2 < 0.01$].

DISCUSSION

The current study examines an important, rarely addressed, factor in the potential success of therapeutic games: how we present and promote therapeutic games. With the number of interactive media interventions for mental health growing rapidly, it is vital to understand how these interventions are going to be accepted outside of research and clinical settings.

Messaging and Game Choice

Our findings show that young adults with mild to severe mental health symptoms were almost four times more likely to select a game when it was explicitly promoted as beneficial for mental health compared to when it was promoted as entertaining. The most important conclusion we can draw from these results is that explicit mental health messaging did not deter young adults with mild to severe mental health symptoms from selecting a game, but in fact made the game more appealing to select. Overall, nearly 60% of participants selected the game they believed to be a mental health game. Given that regular professional help is sought by only approximately a quarter to a third of people with a diagnosable disorder (Alonso et al., 2004; Merikangas et al., 2011), it is encouraging that in a sample with elevated mental health symptoms three in five young adults showed interest in playing a game that purported to benefit their mental health.

Additionally, the results show that participants were almost six times more likely to select the game promoted with the mental health message in the detailed trailer as they were to select the mental health message in the abstract trailer. In our attempt to create two distinguishable trailers for the same video game we unintentionally created a version that was perceived as more attractive and fun. Although not manipulated as such, this incidental finding may suggest that both trailer messaging and trailer design are important factors in game choice. Accordingly, mental health games will likely be more successful if their trailer design is equally as appealing or even more appealing than the design of commercial videogames.

Furthermore, exploratory results show that symptom type did not predict game choice, suggesting that results are not specific to disorders and apply to internalizing issues in general. Interestingly, the same is found for symptom severity. Thus, youth with more severe symptoms were not more likely to turn to a mental health game, while most other studies indicate that people with severe symptoms are more likely to seek professional help (Merikangas et al., 2011; Sawyer et al., 2012). However, our result is in line with other studies that have shown that severity of depressive symptoms had no influence on help-seeking (Merikangas et al., 2011; Chin et al., 2015). Yet, considering that severe depressive symptoms have been found to decrease informal help-seeking (Sawyer et al., 2012; Chin et al., 2015), another explanation for our finding may lie in the undefined nature of mental health games. Mental health games may be interpreted as formal, informal or a separate category of help. This may have resulted in participants reacting to the therapeutic video game differently based on their interpretation. However, it is also possible that for mental health games, severity counteracts existing differences in help-seeking between those with more and less severe symptoms by decreasing barriers for help (Granic et al., 2014).

Moreover, exploratory analyses showed that the attractiveness and fun young adults expected of the games based on the trailers was not predicted by symptom severity or symptom type with the exception of anxiety symptoms. Participants with elevated anxiety symptoms rated both the entertainment and the mental health game as less fun based on the trailers than participants without anxiety symptoms. This may indicate that individuals more prone to anxiety are apprehensive of video games. Alternatively, a third variable (e.g., intolerance of uncertainty), which influences both the perceived fun of video games and the level of anxiety symptoms, may explain why participants with elevated anxiety symptoms expected the games to be less fun irrespective of messaging.

Thus, besides the influence of the trailer design the analyses provided no indication of why messaging differentially influenced participants. As two in five participants chose the entertainment game over the mental health game it is meaningful to explore why they may have made this decision and what may enhance the success of mental health messaging. First, participants may have experienced reactance or perceived stigma in response to the mental health trailer (e.g., one participant indicated that the mental health game suggested that there was 'something wrong with me') and therefore may have chosen the entertainment game instead. Previous research has shown that reactance may be limited both by warning people ahead of the persuasive intent of a health message (Richards and Banas, 2015) as well as by restoring their sense of autonomy after the message (Bessarabova et al., 2013). Yet, stigma is a broader societal problem, and evoking a sense of stigma cannot easily be avoided within an explicit mental health message.

Alternatively, participants may have selected the entertainment game to improve their mood in line with the mood management model (Zillmann, 1988) or to avoid potential mood damaging effects of the mental health game in line with the escape model (Perse, 1998; Oliver, 2009). Both motivations appear plausible. One participant explained her choice for the entertainment game indicating 'If everybody likes it, it is very likely I will like it too' supporting a mood management perspective. Whereas another participant argued the mental health game 'looks frustrating and more complicated' supporting an escape perspective. This suggests that explicit mental health games emphasizing positive game experiences would be even more attractive.

Finally, self-determination theory (Ryan and Deci, 2000) suggests participants may have chosen the entertainment game as the mental health game was not in line with their intrinsic motivations (e.g., one participant explained 'I did not feel stressed or bad at the moment'). Though for some individuals beliefs about personal relevance may depend on their current state, suggesting that the mental health game may be selected at another point in time, others may never identify reducing stress as an intrinsic need. Thus, proclaiming to meet multiple needs may increase the chances of mental health games matching individual needs. Moreover, it will be valuable to further study motivations for mental health or entertainment game selection to inform strategies to attract even more young adults to mental health games.

Game Experience

Besides testing the influence of messaging on game choice, the current study also looks at how the selected message influenced game experience. Young adults played Monument Valley for approximately 28 min regardless of game choice, mental health symptom severity or type. Additionally, as hypothesized, young adults who selected the mental health game experienced similar intrinsic motivation, autonomy and competence compared to those who selected the entertainment trailer. In contrast, exploratory analyses showed that although young adults who selected the entertainment message experienced similar autonomy, participants with severe symptoms who selected the mental health message felt more autonomous compared to participants without severe symptoms, confirming our expectation. In a similar vein but contrary to our expectations, participants with severe symptoms felt more competent than participants without severe symptoms, regardless of whether they believed the game was an entertainment or mental health game.

Finally, as expected, the current study shows that overall participants improved in affect over time, regardless of the message they selected. However, exploratory results suggest that this effect was driven by participants with severe depressive symptoms rather than those with no to moderate depressive symptoms or other severe symptoms. Thus, although we had expected participants with elevated depressive symptoms to experience more positive affect, the game increased positive affect only for those youth who reported severe depressive symptoms.

The current results replicate several of the findings from a previous study in which a mostly healthy sample of young adults were exposed to either a mental health or an entertainment-focused introduction message (Poppelaars et al., 2018). Both studies show that mental health messaging does not influence intrinsic motivation and affect. Both studies also show that positive affect increased for those with (severe) depressive symptoms, while there was no change in affect for those without (severe) depressive symptoms (i.e., using SAM). Perhaps most importantly, the current findings extend the previous one by indicating that these effects are particularly relevant for youth with severe depressive symptoms.

It is promising that those who are most affected by depressive symptoms show at least a short-term boost in positive affect. In general people with depressive symptoms report fewer positive experiences in their daily life (Peeters et al., 2003; Bylsma et al., 2011) and also have been shown to react with less positive affect to positive experiences in experimental settings (Bylsma et al., 2008). However, naturalistic studies show a mood-brightening effect in people with depressive symptoms, indicating that they may in fact be more sensitive to positive experiences in daily life and respond with more positive and less negative affect (Peeters et al., 2003; Bylsma et al., 2011). Thus, our results are in line with the mood-brightening effect in young adults with (severe) depressive symptoms. Temporary positive affect may partially explain why casual commercial games have been shown to reduce depressive symptoms (Russoniello et al., 2013). That is, according to the broaden-and-built theory, momentary positive emotions can create an upward spiral, broadening one's perspective thus allowing one to seek out positive experiences, leading to more opportunities for positive emotions (Fredrickson, 2001). This upward spiral could eventually reduce depressive symptoms as depressed mood is replaced by a more positive mood.

Just like for mood, messaging had no effect on competence. However, exploratory analyses indicated that participants with more severe symptoms experienced enhanced competence following gameplay. This may reflect that youth with severe symptoms selected either the entertainment or the mental health game based on their capacity to deal with their issues and felt competent in the selection they made. Moreover, Nezlek and Gable (2001) propose that mental health issues are associated with unstable self-worth which increases sensitivity to daily events that may reflect on self-worth. As Monument Valley is designed for successful completion and triumphs are more visible (i.e., the avatar's path becomes visible) than failures, participants with more severe symptoms may experience more pronounced competence after playing Monument Valley compared to participants with less symptoms and more stable self-worth.

The current study revealed no negative effect of mental health messaging on autonomy. These results may indicate that the ability to actively choose a game with a mental health message reduces the potential reactance evoked by the messaging. In fact, reactance to persuasive messages can be limited by providing a text confirming the choice freedom of individuals (Bessarabova et al., 2013), and the actual behavioral choice provided here may be even more successful in reestablishing a sense of choice freedom. Alternatively, we may hypothesize that the participants who felt that the mental health message was controlling and who would have therefore experienced less autonomy in the game, selected the entertainment game and so avoided experiencing less autonomy. Additionally, both explanations could work in unison.

Moreover, exploratory analyses indicated that when the mental health game was selected, participants with severe mental health symptoms experienced more autonomy than participants without severe symptoms. Thus, suggesting that mental health messaging can stimulate a sense of autonomy. Possibly, participants with severe mental health symptoms felt the mental health aim to be especially in line with their own values and motivations, thus leading to an enhanced sense of autonomy when choosing this option. However, this did not result in the expected accompanying increase in intrinsic motivation.

Strengths, Limitations, and Future Directions

Besides focusing on a societally relevant research question, the current study has some additional strengths. First, our design is an important strength to highlight. We provided participants with a controlled choice between an explicit mental health and a stealth entertainment message that in reality promoted the same game. Participants were able to freely choose and play the game for as long as they liked (within the study's time-constraints) creating a genuine game experience and an objective measure of engagement, avoiding self-report biases that come with post-game questionnaires. Second, the counterbalanced presentation of the two trailer designs in which the messages were shown allowed us to separate the effects of messaging from the perceived attractiveness of the trailers. Third, we could relate any differences in game play experiences to messaging because all players played the same commercial game and because there was no contamination of any in-game mental health content, as would be the case with most existing therapeutic games. Finally, the current study included at-risk participants with elevated mental health symptoms, arguably the most relevant target audience for therapeutic games. Thus, our sample is likely representative of the audience who would be seeking such games and serious game designers with mental health targets would benefit from incorporating our messaging results.

Naturally, the study also has a number of limitations. The sample overrepresented highly educated young adults, females, and social science students due to our recruitment strategy. Highly educated social science students may be more open to and curious about innovative mental health interventions, which may have inflated the interest for the mental health game. Similarly, women may potentially be more attracted to mental health games than men, as a recent review indicates that gender influences gaming motives and behavior (Veltri et al., 2014), which could have skewed our results. Thus, it is advisable for future research to include men and women equally, to target a more diverse group of young adults, as well as to target other age groups as children may react differently to messaging.

Another limitation to consider is the experimental setting in which participants selected and played the game. First, the length of the experiment limited gameplay to a single session under 45 min. Vital differences in gameplay patterns between mental health and entertainment games may only become visible when repeated gameplay is possible and sessions are not artificially limited. Therefore, future research is needed that observes naturalistic gameplay over a matter of weeks or even months.

Second, participants may still have selected a different game than they would have outside the lab due to several experimental factors. The choice within the experiment was limited to two games, rather than the reality of almost unlimited video game choice, in which one mental health game may not even attract enough attention to be considered as an option. Moreover, participants may have behaved in a socially desirable way when choosing a game, knowing that their choice was recorded. On the one hand, participants may have assumed that selecting the mental health game (i.e., an uncommon game type) was preferred by the experiment leader. On the other hand, participants may have felt that selecting the mental health game indicated needing a therapeutic intervention and therefore selected the more normative entertainment game. A final way the experimental setting may limit the generalizability of this study is the fact that the experimental environment may have encouraged participants to make a more thoughtful choice, potentially anticipating that they would have to explain their choice. In everyday situations, game choice may be a more instinctive choice (i.e., based on unconscious decision processes) as well as a more implicit choice (i.e., multiple games may be played and selecting game X does not rule out playing game Y).

Consequently, future research exploring more promotion channels for therapeutic games and the relative success of explicit and stealth messaging will be valuable. Youth can be recommended video games through a myriad of sources such as friends, blogs, forums, online video game stores (e.g., Steam), video game news and review sites and popular video game players who demonstrate games online (e.g., on YouTube or Twitch). Research on any of these sources of recommendations can help clarify if messaging may need to be adapted per situation. Additionally, alternative messaging may be explored. For example, messaging may combine entertainment and mental health messaging in various proportions or alternatively explicit messaging may describe causes of mental health issues rather than the effects of the game. A recent study shows that young adults believed a mental health app to be more useful and had higher intentions to use it if a prior message emphasized internal causes of depression (Khan and Peña, 2017).

Furthermore, in real-life youth may only play a video game after receiving recommendations from multiple sources (e.g., a friend, review site and popular gamer recommending the same game) and future research may study this complexity (see Konijn et al., 2013 for methods to use YouTube for research purposes). In order to enhance the generalizability of the research results further, researchers may provide more choice to youth. Certainly, if youth are presented with an entire webpage of video games, which may easily contain 50 video games, the chances of them selecting a single mental health game will be lower than the almost 60% found in the present study. However, given the fact that youth would not necessarily only play one game recommended on such a page, it will be critical to see if youth will consider mental health games in such a scenario and what aspects influence the likelihood for youth to play therapeutic games.

In addition to messaging, individual characteristics besides symptoms may also influence game choice and experience. The current study did not assess if participants were diagnosed with a mental health disorder nor if they themselves believed that they had a mental health disorder. Participants who are aware of a mental disorder may be more likely to select a mental health game as they feel that is meant for them in comparison to participants who do not identify their symptoms as a coherent mental issue. Additionally, game choice is likely affected by personal motivational factors, the individual's believes concerning the value of video games and their beliefs about mental health disorders. For example, someone who considers video games violent and a waste of time may be much less likely to find a mental health game credible than someone who believes video games can be educational and foster social connections. Similarly, the stigma that one experiences surrounding mental health or the extent to which one believes mental disorders cannot effectively be treated can limit the effectiveness of mental health messages. Thus, future research may examine which individual factors influence the choice between explicit and stealth messaging.

Finally, future research will need to study the effects of messaging on game effectiveness. Naturally, games that are not played cannot be effective. However, while maintaining the attractiveness of the game, the promotion may also aim to enhance effectiveness. Intrinsic motivation for playing a game may enhance its effectiveness. Furthermore, explicit mental health messaging promising health benefits may enhance the effectiveness of therapeutic games through the positive expectations of the player (Enck et al., 2013).

CONCLUSION

Therapeutic games, other serious games (e.g., educational games) and other self-administered interventions will have the biggest impact if they are widely available and can motivate people to seek out and stay engaged in these interventions. Thus, it is critical to consider how messaging in the promotion of therapeutic games can attract youth and support an immersive game experience. The current study indicates that once effective therapeutic games targeting youth outside of a clinical setting are developed, these games may indeed be attractive to youth, especially when promoted in an engaging trailer that includes an explicit mental health message.

This study has several implications for the design of games that target a wide range of mental health issues and the messaging used in these games. First, as youth with the most severe symptoms in our study were found to have a better game experience in terms of autonomy, competence, and affect, special attention needs to be paid to youth with mild to moderate symptoms. When designing therapeutic games for youth with mild to moderate symptoms, supporting autonomy and competence either in game design or in promotional messaging is especially important, given that these factors predict a more positive game experience (Ryan et al., 2006). Second, designers of therapeutic games may search for ways to improve mood for youth without severe depressive symptoms to enhance engagement. This is especially important if the game's effectiveness relies partially on short-term increases in mood. Finally, this study indicates that elevated anxiety symptoms were related to expecting less fun from video games. Thus, it may valuable for those developing anxiety reducing therapeutic games to study if promoting these games in a different way makes them appear more fun and so allows youth to take the initiative to play therapeutic games.

Many research questions remain regarding the promotion of therapeutic games, but so far the results support the idea that explicitly marketing games as beneficial to mental health may not turn youth away from these games. Instead, they may provide youth with the opportunity to improve their well-being in an autonomous and engaging manner.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Code of Ethics for Research in the Social and Behavioural Sciences Involving Human Participants, the ethical committee of the Faculty of Social Sciences at

Radboud University. The protocol was approved by the ethical committee of the Faculty of Social Sciences at Radboud University (ECSW2017-3001-461). All subjects gave written informed consent in accordance with the Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

MP, AW, AL-A, and IG contributed to the conception and design of the study and discussed the interpretation of the results. MP developed the trailer design and messaging with feedback from AW, AL-A, and IG. MP and AW organized and performed the data collection and responsible for data management. AW coordinated the data collection. AL-A and IG supervised the project. MP performed the statistical analyses and wrote the first draft of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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OPINION
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Preventing Technostress Through Positive Technology

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INTRODUCTION

Over the past decade, the workplace has experienced significant changes as a result of Information and Communication Technologies (ICTs) and the subsequent digital transformation (Mcafee, 2006; Matt et al., 2015). Such technological, cultural, and organizational changes have redefined business models and competition. As evidenced by the shift from the Enterprise 1.0 to the Enterprise 2.0 business models, ICTs offer companies increased productivity and efficiency (Bilbao-Osorio et al., 2013). At the same time, introduction of ICTs can pose a threat to both a company and its employees through misuse, abuse, and overuse, resulting in technostress (Gaudioso et al., 2017). This emerging risk seems to have become more evident in the past 10 years, as a consequence of the 2008 economic crisis. This difficult and challenging economic context was demonstrated to have negatively impacted workers' mental health on its own, due to the workers' perception of the crisis, lack of social support, and increased job stress (Giorgi et al., 2015; Mucci et al., 2016). The economic crisis has had two paradoxical effects that indirectly may have contributed to the raise of technostress. On the one hand, the crisis reduced the number of total worked hours, reducing the resources needed. On the other hand, at the same time, it increased the pressure on the workers: corporations reduced available personnel—and thus increased tasks and activities on those remaining—and introduced new technologies to support their employees, who are required to deal with a higher work load and with managing new and more complex flows of information. This article aims to present the technostress construct, and propose how Positive Technologies (Riva et al., 2012) can help prevent technostress, and promote positive work experiences and general well-being through an effective organizational safety culture (Galimberti, 2014; Galimberti et al., 2016).

TECHNOSTRESS

Technostress was first conceptualized in the early 1980s as "a modern disease of adaptation caused by the inability to cope with new technologies in a healthy manner" (Brod, 1984), which can result into non-acceptance of ICTs or excessive identification with the new technologies, resulting in both anxiety and stress. Today, technostress is considered to be multidimensional, and it is defined as "a negative psychological state associated with the use or the "threat" to use new technologies," which leads to "anxiety, mental fatigue, skepticism, and sense of ineffectiveness" (Salanova et al., 2007). The fundamental dimensions to technostress include:

- Techno-anxiety: the use of computers or ICTs that generates fear, apprehension, and agitation in the user; it includes feelings of uncertainty resulting when a person is required to carry out an action using a ICT (e.g., pressing a button), and the related fear of losing information (Salanova et al., 2013).

- Techno-addiction: related to workaholism, it appears when an individual is unable to disconnect from work-related ICTs (e.g., phone, computer, etc.), therefore continuing to, often compulsively, perform work-related functions outside of normal business hours (Schaufeli et al., 2008); it can cause disconnection anxiety—the fear of being detached from the ICT device and information it provides (Elhai et al., 2016). It also manifests itself in an individual's behavioral patterns, such as constant anticipation of notifications, lack of control and/or difficulty in refraining from using ICTs, conflicts with other activities or tasks, and negative reactions to interrupted ICT use (Salanova et al., 2013).
- Techno-strain: perceived stress experience resulting from the use of new information technologies (Salanova et al., 2013).

Research shows that many factors contribute to technostress (Ragu-Nathan et al., 2008), including techno-invasion, techno-overload, techno-complexity, techno-insecurity, and techno-uncertainty. These stressors may have impact both at private and organizational levels. Techno-invasion, for example, is defined as constant connectivity, without boundaries of space and time, which maintains that employees are continuously available to work requests (Tarafdar et al., 2007; Ragu-Nathan et al., 2008; Gaudioso et al., 2017). Together with techno-addiction, techno-invasion entails that work-related tasks may spill into the worker's private life, endangering their work-life balance. At organizational levels, communication information overload (or techno-overload) results from employees' receipt of information from multiple channels simultaneously. This information can be difficult to manage, as it may be unclear how to prioritize or best use the information received (Tarafdar et al., 2007; Gaudioso et al., 2017). Another contributing factor is techno-complexity, the unpleasant feeling that the new ICTs are multifaceted and require tremendous effort to understand. Techno-insecurity is the perception that ICTs and the constant need to remain up-to-date can threaten an individual's job (Tarafdar et al., 2007). Lastly, techno-uncertainty causes perceived instability, due to the evolving nature of the work, and associated processes as well as constant introduction of new ICTs (Tarafdar et al., 2007).

Other contributing factors include: lack of support during testing, implementation, and use of the ICTs adopted by the company; discomfort and fatigue resulting from multitasking, as ICTs allow for completion of more tasks in a lesser amount of time (Ragu-Nathan et al., 2008); frequent interruption of assigned tasks due to the ongoing stream of communication (Mark et al., 2008). These stressors, together with a lack of personal coping mechanisms, create technostress in the work environment, placing both physiological and psychological consequences on employees. Proven physiological symptoms of technostress include fatigue (Salanova et al., 2007), irritability, insomnia (Porter and Kakabadse, 2006); psychological symptoms include frustration and perceived increased level of mental load and time pressure (Mark et al., 2008), skepticism, sense of ineffectiveness (Salanova et al., 2007), and reduction in job satisfaction and employee commitment, productivity, and work-life balance (Tarafdar et al., 2007). Technical and organizational support (Nelson, 1990), employees' involvement in the ICT implementation phase (Brod, 1984), and appropriate communication management (Galimberti, 2014; Galimberti et al., 2016) allow for decreased technostress emergence in organizations, as well as encourage greater well-being and productivity.

ORGANIZATIONAL SAFETY CULTURE

Because technological development and advancement are common in a multitude of organizations, companies must take technostress into consideration to care for their employees and thus their performance. Organizational culture refers to a set of processes, professional practices, explicit, and implicit rules, regulation, conventions, and shared ways of thinking within an organization. When these elements are linked to risk and safety in the workplace, they contribute to define a specific organizational safety culture (Galimberti, 2014). More specifically, von Thaden and Gibbons (2008) define safety culture as

"the enduring value and prioritization of worker and public safety by each member of each group and in every level of an organization. It refers to the extent to which individuals and groups will commit to personal responsibility for safety; act to preserve, enhance and communicate safety information; strive to actively learn, adapt and modify (both individual and organizational) behavior based on lessons learned from mistakes; and be held accountable or strive to be honored in association with these values."

Establishing exceptional organizational safety culture is vital, as it directly affects performance and profit (Butler, 2016). These criteria emphasize that organizational safety culture is not only laws and regulations to be followed, but also an overall dynamic that concerns the well-being and productivity of individuals and groups. Safety culture therefore needs appropriate flows of information that allows all employees to be up-to-date and be part of a shared culture of safety. Safety culture does not only include the transmission of information, but also creation of information and values through exchanges amongst organization members. Communication is necessary for safety culture to properly exist. If communication is the mechanism through which safety is transmitted and created, then all the individuals who communicate with the organization are key to the organization's creation of its own safety culture, which ultimately influences employees' behaviors.

Technostress is a manifestation of a lack of safety culture. It is evident that any intervention to prevent or minimize technostress begins with the recognition that it is a factor which affects performance within the organization. Following recognition of technostress, it is possible to focus on work, technological, and communicative processes involved in this emerging risk.

A PROPOSAL: POSITIVE TECHNOLOGY FOR TECHNOSTRESS PREVENTION AND MANAGEMENT

While there have been several attempts in organizations to counteract techno-stressors (Dello Iacovo, 2012; Tarquini, 2014), previous attempts were neither anchored in any theoretical framework nor preventive. Rather, such attempts were compensative, and their effectiveness was highly anecdotal. A scientific approach proven to be highly effective in producing positive change is Positive Psychology (Seligman and Csikszentmihalyi, 2000; Seligman, 2002), with its derivative Positive Technology (Calvo and Peters, 2012; Riva et al., 2012, 2014). Positive Psychology postulates that personal experiences can be leveraged to foster well-being and personal growth. Similarly, Positive Technology is "the scientific and applied approach to the use of technology for improving the quality of our personal experience" (Riva et al., 2012, pp. 70). Perceived quality of personal experience occurs at three different domains: hedonic (technology is used to generate positive experiences); eudaimonic (technology is designed to support individuals in reaching "engaging and self-actualizing experiences"); and social/interpersonal (technology helps improve connectedness between individuals or groups).

At the bottom of **Figure 1**, Positive Technology domains are shown, as designed by Riva et al. (2012) (bottom part of the figure). At the top of **Figure 1**, the corresponding action of organizational culture safety are shown. These actions can generate positive experiences in companies and minimize technostress. It is possible to note that organizational cultural actions mediate between organizational outcome and the use of technologies. All three domains of personal experience affected by Positive Technology are as follows:

- Hedonic: at the individual level, positive emotions can be induced if the technologies are well designed and compatible to the employee's role within the company. An organization that employs this approach to technologies and work processes may develop a Positive Technology-based culture that prevents technostress. Employees using positive technologies could experience a reduction of techno-anxiety—as the ICTs are build according to their specifications, abilities, and needs—and perceive the work requests as fitting their role and way of working, therefore avoiding techno-overload, that is the amount of information received by the employees is appropriate to their roles and work processes. Reduced levels of anxiety and having more role-appropriate tasks may positively affect work performances.
- Eudaimonic: a technology within a work setting can generate an effect at this level if it is designed correctly, and employee training is performed accordingly. The key for a eudemonic experience is balancing employees' abilities with the technology that supports the task to be completed. If complex ICTs take into consideration the workers and their needs, their design and implementation will be less traumatic and require less employee training and adjustments. Even the most complex ICT can be perceived as easy-to-use with sufficient training. If the task and the technology are more complex than the employee's training and abilities, the technology will be perceived as an extraneous imposition, and then techno-complexity (perceived effort required to understand technology), techno-insecurity (perceived threat of not being up-to-date with the ICTs required for the job), and techno-uncertainty (perceived instability in work processes) can occur, ultimately resulting in technostress. The transition to the Enterprise 2.0 model entails slowly leaving work processes related to Web 1.0 tools, such as email, and adopting 2.0 tools (such as social media, blogs, wikis). Such change can be the opportunity to assess current ICTs and related work processes to develop and optimize new ways of working and relative technologies. On the contrary, collaboratively designed, Positive Psychology-based work processes and technologies make the employees' job easier, more satisfying, and less stressful. Consequently, employees may take more active part to collaborative work processes. Well-designed processes and ICTs will not require extra time and effort from the employees, thus preserving their work-life balance, avoiding techno-invasion, techno-strain, and techno-addiction.
- Social/interpersonal: many organizations are moving toward systems that exploit collaborative intelligence processes (Lee and Lan, 2007), requiring their employees to communicate with each other to generate a competitive advantage. A well-designed positive technology and work processes must support social presence, that is, the perception that others are present in the same digital environment and have a specific intention or task (Triberti et al., 2018), and intersubjectivity, that is the process to reach mutual comprehension (Galimberti, 2011). At this level, it is important that individuals share the same set of rules and regulations about how, when, and what is appropriate to communicate. This type of rules makes up part of the organizational safety culture, as they define boundaries for proper ways of communicating, setting appropriate time and space for using the ICT (reducing techno-invasion), and type of information and effort required (reducing techno-overload), overall limiting techno-strain (perceived stress due to the use of technology). When designing positive work ICTs and their work processes, it is therefore paramount that they have an embedded communication management system (e.g., system do not forward emails to employee after the end of business hours) that respects and contributes to the developing of this organizational safety culture, and helps prevent technostress.

All the suggestions made above may be applied both in a preventive and a corrective way. Literature shows that the Positive Technology approach rarely has been applied preventively, but the preventive perspective may prove to have more impactful and lasting effects, both on employees and organizations, as it can be easily included in an organization's safety culture. Bacchini (2014) states that organizational safety culture should become the general corporate organizational culture, as it respects the employees, it abides to laws and regulations, and it improves business performance, all the while promoting health and safety. As technology is essential to any

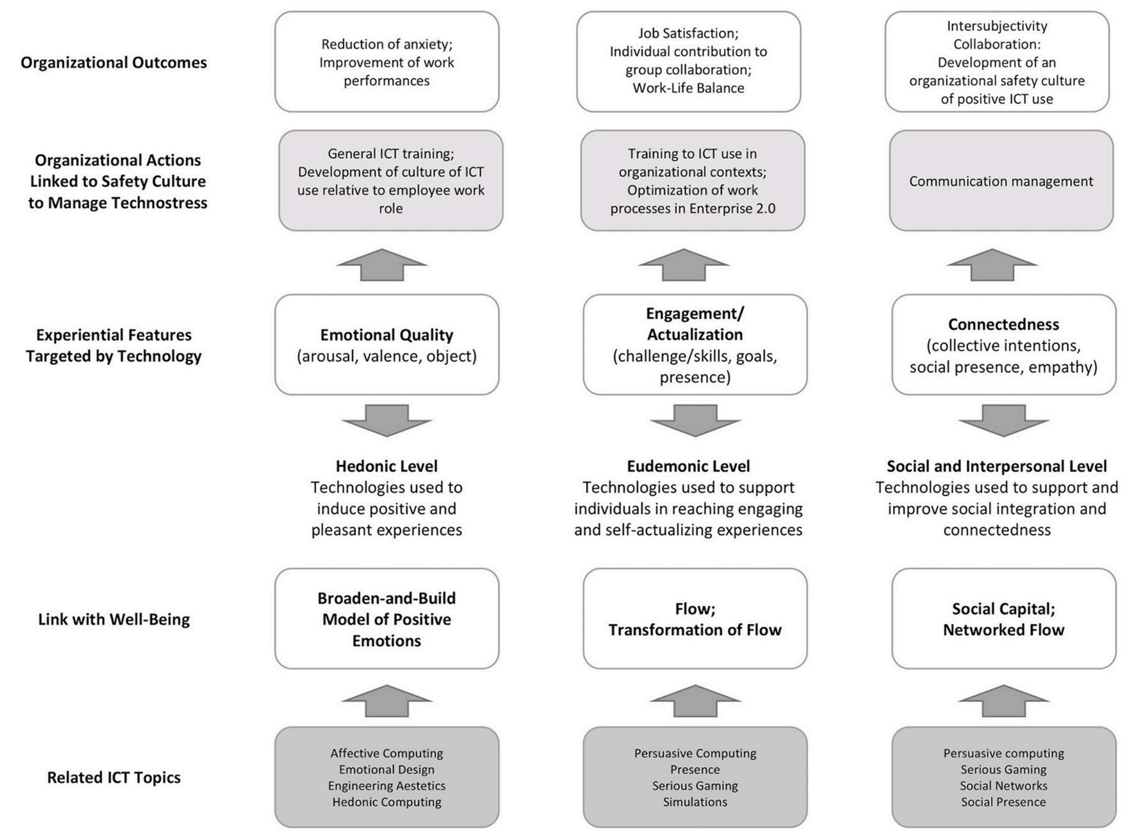

FIGURE 1 | Positive Technology domains and their application to organizational safety culture (adapted from Riva et al., 2012).

company nowadays, adopting a Positive Technology perspective in designing not just the technologies themselves, but also the work processes, is the first step to prevent technostress and its related techno-stressors, and enduring happy, healthy, and satisfied employees, and an efficient and productive organization.

CONCLUSION

This article was an opinion piece aimed to present technostress as a new field for the Positive Technology approach, which has only recently been applied to real-world contexts. Positive Technology can be considered as a proactive solution for organizations and companies who seek to increase their employees' well-being and prevent technostress. In particular, Positive Technology-designed solutions highlights how the three main dimensions of techno-stress and its other stressors may be reduced, or even eliminated, if this approach is used as a thinking framework for the organization.

This perspective is not without limitations, as some ICTs found within companies cannot be designed to stimulate the hedonic, eudemonic, and social/interpersonal levels of personal experience separately. All the levels contribute to employees' well-being and other organizational outcomes, as well as to prevent technostress. Positive Technology experts can contribute to the design of such technologies and related work processes, and interventions directed toward preventing and managing technostress. Another limitation is that this framework currently remains theoretical and requires implementation and observation in the field. Field research is possible, but may pose challenges, such as the time constrains demanded by design and implementation within an organization, which may not completely support the research requirements.

Conditions necessary for this approach to work is for companies, their employees, and Positive Technology experts to work together in designing new ICTs or modifying existing systems to include work processes that support such technologies. Without appropriate collaboration, technologies will induce technostress, rather than preventing it. As for any technology or process introduced within an organization, Positive Technology must be designed according to the organizational safety culture to which it will belong and contribute.

AUTHOR CONTRIBUTIONS

EB, FG, and CG conceived the presented ideas and participated to the literature review search. EB and CG wrote the manuscript; FG, IV, CRM, CR, and AS helped with the literature search and revised the first draft of the manuscript. EB acted as corresponding author.

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New Technologies for the Understanding, Assessment, and Intervention of Emotion Regulation

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In the last decades, emotion regulation (ER) received increasing attention and became one of the most studied topics within the psychological field. Nevertheless, this construct has not been fully updated with the latest technological advancements. In this perspective, we will show how diverse technologies, such as virtual reality (VR), wearable biosensors, smartphones, or biofeedback techniques, can be applied to the understanding, assessment, and intervention of ER. After providing a brief overview of the currently available technological developments, we will discuss the benefits of incorporating new technologies in ER field, including ecological validity, intervention personalization, and the integration of understudied facets of ER, such as the implicit and interpersonal dimension.

Keywords: emotion regulation, virtual reality, biofeedback, internet interventions, smartphones, serious games

INTRODUCTION

Mental health, understood as "*a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community*" (World Health Organization, 2004), is witnessing a revolution due to the incorporation of new digital technologies. Although its real impact is difficult to foresee, it is a matter of fact that profound changes are already taking place at multiple levels. In this direction, different technologies have already been applied to the mental health realm. Illustrative examples are internet-based interventions (Andersson, 2016), mobile health (Firth et al., 2017; Grist et al., 2017), or the emerging field of mixed realities (MR) (Baus and Bouchard, 2014), serious games (Fleming et al., 2017), and biofeedback techniques (Schoenberg and David, 2014). ER is not the exception to the rule, and new technologies are called to transform our understanding of the field, and thus to positively impact on its assessment and intervention.

In the last years, ER emerged as one of the most studied constructs in the psychological field (Fernández-Álvarez et al., 2018a). ER is a dynamic process that every person implements with the aim of downregulating or upregulating positive and negative emotions in order to reach desirable states (Gross, 1998, 2015a). ER is always addressed to accomplish a certain goal (Tamir, 2016), either hedonic (i.e., maximize pleasure and/or minimize pain in the short term) or instrumental (i.e., maximize pleasure and/or minimize pain in the long term), by means of strategies (Gross and Jazaieri, 2014) that can be implemented before or after emotions' occurrence (Gross, 1998). ER can be deployed both intrapersonally or interpersonally (Zaki and Craig Williams, 2013): people may try to regulate emotions in solitude, for instance, by reappraising a situation, but they can also modulate emotions interpersonally, for example, by seeking support from an intimate partner. Furthermore, ER can be explicit or implicit, as well as controlled or automatic (Braunstein et al., 2017). On one hand, ER is explicit when significant goals are deliberately pursued, and it is implicit when regulatory mechanisms are automatically activated by unconscious goals. On the other hand, automatic ER is a nonconscious attempt to regulate emotions, whether controlled ER involves top-down control mechanisms.

ER entails cognitive, behavioral, and physiological processes. From a *cognitive* point of view, among the most studied ER strategies, there are rumination, cognitive reappraisal, suppression, acceptance, savoring, and dampening (Naragon-Gainey et al., 2017). The generation of emotions is also intimately related to *behaviors*, which are indeed driven by our emotional states: people tend to engage in mood-increasing activities when feeling upset and join useful rather than pleasant activities when in a good mood (Taquet et al., 2016). Finally, a long tradition of research focused on the *psychophysiological* dimension of ER processes, both at a peripheral and neural level. The bed nucleus, the habenula, the striatum and the amygdala are the central cortical areas, while the prefrontal cortex (PFC), in particular, dorsolateral PFC, ventrolateral PFC, and ventromedial regions (vmPFC), and the anterior cingulate cortex constitute key subcortical regions (Ochsner et al., 2012; Lopez et al., 2018). Meanwhile, the autonomous system has also been extensively studied. A central process within this research line is the ECG activity, through which heart rate variability (HRV) can be calculated. In particular, the high frequency domain, related to the respiratory sinus arrhythmia, is considered to be an index of the vagal activity which in turn is a key for stress patterns and emotion regulation processes (Balzarotti et al., 2017).

Traditionally, ER has been measured by means of self-report questionnaires that consider ER as a stable trait of a person. Clear examples are the Emotion Regulation Questionnaire (ERQ), a 10-items self-report to assess the use of cognitive reappraisal and expressive suppression to regulate emotions (Gross and John, 2003), or the Difficulties in Emotion Regulation Questionnaire (DERS), which explores six different ER dimensions of emotion dysregulation (Gratz and Roemer, 2004). More recently, state questionnaires have been developed that can be applied to explore the adoption of single (Ganor et al., 2018; Marchetti et al., 2018) or multiple strategies (Katz et al., 2017; Lavender et al., 2017) in specific situations.

In the last years, emotion dysregulation has been shown to be a transdiagnostic factor (Kring and Sloan, 2009; Aldao et al., 2016; Fernandez et al., 2016; Fernández-Álvarez et al., 2018a,b). Ample evidence has suggested that poor regulatory skills constitute a vulnerability and maintenance feature among a wide range of mental disorders (Rottenberg et al., 2005; Mennin and Farach, 2007; Nolen-Hoeksema et al., 2008). The constant deployment of nonadaptive strategies to regulate emotions would elicit negative psychological health outcomes (Aldao et al., 2010; Sheppes et al., 2015; Urzúa et al., 2016). This lack of adaptiveness should not be understood as the utilization of specific strategies, but rather as an inflexible pattern in which the deployed strategies are incorrectly selected, inaccurately deployed, or unsuccessfully monitored (Gross, 2015b). Accordingly, the action control perspective states that emotion dysregulation is the result of failures in identifying when to regulate, how to do it, and how to deploy the selected strategy (Webb et al., 2012). Beyond psychopathology, the ability to adopt a wide repertoire of strategies with high variability across different situations (i.e., ER flexibility) (Aldao et al., 2015) has been shown to play a key role for mental well-being (Aldao and Nolen-Hoeksema, 2012; Bonanno and Burton, 2013).

ASSESSING AND CAPTURING EMOTION REGULATION THROUGH NEW DIGITAL TECHNOLOGIES

The value of using new technologies for the understanding and assessment of ER relies undoubtedly on the possibility of increasing ecological validity and exploring this process in real-life, thus overcoming the barriers of traditional laboratory/clinical settings and leading to the exploration of new facets of this process. In the next paragraphs, we will briefly discuss the current state-of-the-art of smartphones, smartphone-embedded sensors, and wearable biosensors application within the field, showing the potentialities of these tools to assess ER and to understand its temporal dynamics in daily life as well as the role of contextual and momentary factors. Furthermore, we will suggest virtual reality (VR) as an innovative approach to understand and assess ER that gives researchers the opportunity to develop realistic scenarios in which to elicit emotions and explore the way, ER is deployed.

Ecological Momentary Assessment

In the last decade, an increasing number of Ecological Momentary Assessment (EMA) (Csikszentmihalyi and Larson, 1987; Shiffman et al., 2008) has been developed for the investigation and understanding of ER. By means of portable devices like Personal Digital Assistants (PDAs) and smartphones, EMA gave researchers the opportunity to observe and repeatedly assess people in daily life by providing prompted self-reports directly on electronic devices.

Altogether, the use of EMA through mobile devices significantly increased the knowledge about ER, shedding new light on the complexity of this process and on aspects that were still understudied. ER is indeed a dynamic process affected by situational, contextual, and momentary factors (Aldao, 2013; Doré et al., 2016), and strategy implementation in daily life only moderately correlates with ER trait measures (Brockman et al., 2017). This suggests that ER cannot be completely grasped and understood in traditional laboratory experiments. In that sense, EMA has been proposed as an innovative approach to explore ER (Bylsma and Rottenberg, 2011) in order to capture the temporal deployment of strategies and their impact on subsequent mood (Heiy and Cheavens, 2014; Catterson et al., 2017; Richardson, 2017), as well as the role of momentary affect (Brockman et al., 2017; Li et al., 2017b) and environmental factors (Heiy and Cheavens, 2014; English et al., 2017) in implementing certain strategies.

EMA could constitute a powerful tool not only for the understanding, but also for the assessment of ER. So far, many questionnaires have been developed, which measure strategies deployment, considering ER as a stable trait of a person, and thus underestimating the role of contextual and momentary factors. EMA could instead substitute or integrate classical paper-and-pencil, retrospective questionnaires by assessing ER directly in daily life. In turn, this would help clinicians to identify strategies that are to be targeted in the therapeutic process, as well as recognizing triggers and/or consequences of maladaptive strategies implementation on patients' life (see, for example Anestis et al., 2010; Czyz et al., 2018). Nevertheless, the available literature on EMA and ER is limited to the research field, and we are not aware of studies applying EMA to assess ER in real clinical practice.

There are still many challenges ahead for EMAs. First of all, most of the studies assessing ER with EMA only rely on self-reports, assuming people to be perfectly able to recognize how they regulate emotions. Furthermore, standardized and *ad hoc* items to be implemented in mobile devices for the assessment of ER are currently not available, making it difficult to compare results across studies or to apply this approach in clinical practice, as well as specific guidelines for EMA designs to increase users' adherence and reduce dropout rates (Colombo et al., 2018). Even if still not validated, a set of 20 self-regulation items specific for EMA are currently being developed (Eisenberg et al., 2017). Starting from 594 self-regulation survey items, Eisenberg and colleagues used the item response theory to choose a smaller set of items to specifically assess momentary self-regulation processes through EMA. To the best of our knowledge, this is the first attempt in this direction, leading the way to the possibility of developing standardized, specific items for the assessment of ER by means of EMA.

Sensors and Wearable Biosensors

Ideally, an accurate understanding and assessment of ER should not be based only on self-report questionnaires but also on the associated behavioral and physiological mechanisms that could be provided by sensors (Harari et al., 2016) and biosensors (**Figure 1**; Marzano et al., 2015).

Different studies used mobile phone-embedded sensors data to infer and predict users' mood (see for example, Ma et al., 2013). Nevertheless, no attempt to integrate self-reports with sensors information has been done in the field of EMA for ER. As a matter of fact, little is known yet about the behavioral consequences or antecedents of adopting certain strategies in daily life and the available limited literature is only based on EMA assessing behaviors through self-reports. Undoubtedly, the behavioral aspect of ER could be further deepened through

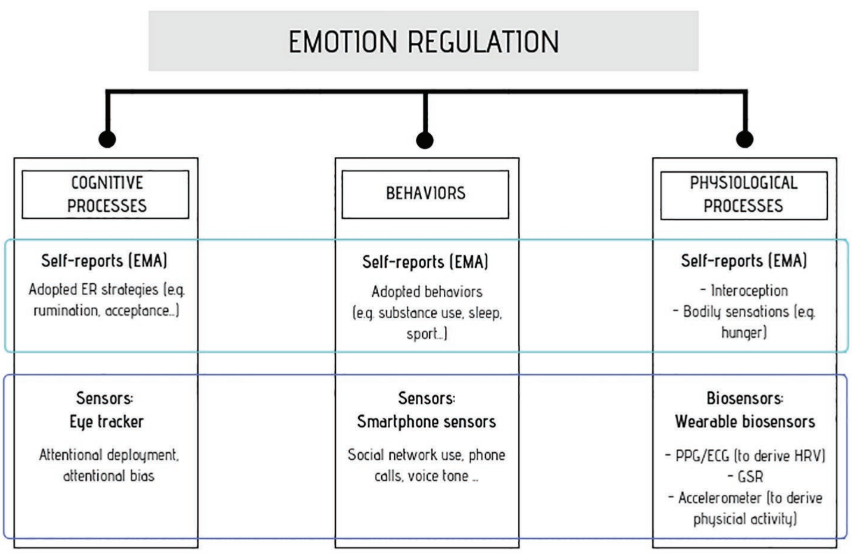

FIGURE 1 | ER is composed of different facets: Cognitive mechanisms, behavioral aspects and physiological processes. The integration of different technologies could grasp all these facets, leading to a more comprehensive understanding of ER. On the one hand, the use of self-reports by means of EMA could assess the three dimensions, i.e., by asking people to report them on a mobile device. On the other hand, the use of embedded-sensors and biosensors could further increase the quantity and objectivity of this information. Cognitive processes, such as attentional deployment or attentional bias, could be investigated using an eye-tracker or other implicit measures like Go/No Go Tasks. Behaviours could be assessed using data gathered from embedded sensors, like number of calls/messages or use of social networks. Finally, the underlying physiological processes could be grasped thanks to wearable biosensors, such as wrist-watches that monitor HRV or GSR parameters. ER, emotion regulation; EMA, ecological momentary assessment; PPG, photoplethysmography; ECG, electrocardiogram; HRV, heart rate variability; GSR, galvanic skin response.

the use of sensors such as accelerometer, Global Positioning System (GPS), or microphone, which can give us important behavioral information, and that in turn could be very informative of the behavioral antecedents or consequences of the ER strategies (Wampold, 2001). Beyond behaviors, ER-associated cognitive processes could also be grasped by means of the eye-tracker, a tool that allows to measure eyes and gaze movements and, therefore, conscious and/or unconscious attentional deployment. Notably, eye-trackers are nowadays available in portable solutions such as wearable glasses (MacInnes et al., 2018) or smartphone application (Krafka et al., 2016).

Beyond sensors, new breakthrough tools like wristband-like devices or wearable chest straps were created, enabling a noninvasive continuous physiological monitoring outside laboratory settings (Paradiso et al., 2011; Palix et al., 2017). This integration could foster the early detection of dysfunctional patterns. As for the behavioral component, the physiological correlates in daily life are still an understudied aspect of ER. A huge body of studies focused on the physiological markers of ER (Balzarotti et al., 2017), but mainly in laboratory settings, while just few studies investigated these mechanisms in daily life by means of wearable biosensors. In that sense, the combined use of EMA self-reports with daily physiological monitoring already showed its potential in the field of rumination and perseverative negative thinking (Ottaviani et al., 2016), highlighting the association between this strategy and heightened activation of the hypothalamic pituitary adrenal axis (HPAA) and decreased heart rate variability (HRV) during waking, which is considered a robust predictor of maladaptive ER. Although available wearables are still not perfectly accurate for the assessment of physiology in the wild, there are already available options to hurdle this obstacle (for a review of existing wearables, see Peake et al., 2018).

Virtual Reality

The incorporation of developed VR- and augmented reality (AR)-based tools both for research and practice in different branches of psychology has emerged 20 years ago but steadily increased its preponderance in the last years (Cipresso et al., 2018).

With regard to ER, the assessment by means of VR and AR has an undoubted potentiality although scant research has been conducted yet. VR allows to generate real-life simulated scenarios that may provide a contextualized situation to measure a certain construct through significant environments, though in a controlled way (Riva, 1997, 2009; Riva et al., 2018). This may be the case for ER, given that it would help substantially if a complementary process to the traditional self-report assessment could be carried out by means of the deployment of certain behaviors for which the person involved could spontaneously, and therefore ecologically implement ER strategies that usually are utilized. This may be also of paramount importance to gauge the complexity and diversity that defines the process of ER. Although there are available studies using VR to enhance psychological assessment (Chicchi Giglioli et al., 2015; Cipresso and Riva, 2016; Alcañiz et al., 2018), to the best of our knowledge, just one VR system was specifically developed for ER assessment: The Gameteen System (GT-System). The GT-System is a VR-based serious game to induce negative emotion and train ER strategies in adolescents (Rodriguez et al., 2015). More specifically, negative emotion induction is performed through a "whack a mole" VR-game, which is expressively developed in order to be scarcely accurate and induce frustration. Preliminary results showed that participants' performance levels were highly correlated with DERS scores, suggesting this game as a possible VR tool to assess ER.

INTERVENING IN EMOTION REGULATION THROUGH NEW DIGITAL TECHNOLOGIES

Interventions targeting ER can be greatly benefited by means of the incorporation of new digital technologies. Among those advantages, a greater dissemination of treatments (Fairburn and Patel, 2017) and the customization of self-help treatments by means of novel statistical procedures are some of the most important (Perna et al., 2018). As for the previous paragraph, we will here provide an overview of current technological applications in the ER field, including mobile applications, internet-based interventions, virtual reality, and biofeedback techniques, showing the advantages of each technology for the research and clinical fields.

Ecological Momentary Interventions and Health Applications

Ecological Momentary Interventions (EMIs) (Heron and Smyth, 2010) and mental health (mHealth) applications (Naslund et al., 2015) are innovative approaches to provide psychological support through mobile devices in everyday life, without necessarily involving the presence of a real therapist or a face-to-face clinical setting. Among all, the real innovative aspect relies on the possibility of providing personalized and just-in-moment interventions, based on the current needs and affective state of the user.

Many mHealth applications for ER training were developed, mainly focused on cognitive change (Beck, 2017), mindfulness (Plaza et al., 2013), or more generally, on cognitive behavioral therapy (CBT) principles (Rathbone et al., 2017). Nevertheless, most of them do not have a scientific validation or evidence supporting its efficacy (Plaza et al., 2013). Furthermore, the available applications mainly rely on self-reports and do not try to integrate the different dimensions of ER. An innovative recent attempt is represented by Calm Mom, a mobile application that specifically aims at enhancing ER through the integration of data from self-reports and electrodermal activity (Leonard et al., 2018). Due to the continuous EDA monitoring, the application triggers alert when a high level of stress is detected, providing users with a consistent customized ER support (i.e., motivational messages or behavioral strategies).

Internet-Based Interventions

Under the umbrella of Internet-based Interventions (IBT), a vast array of recent developments are comprised, including computerized and bibliotherapy interventions (Botella et al., 2004; Andersson, 2016). The advantages are many, such as the possibility to reach a great number of people in need that otherwise would not have any kind of access to psychological treatment. Apart from dissemination, internet-based interventions are supposed to increase the cost-effectiveness in comparison with other active treatment (Beecham et al., 2019), although existent literature shows inconclusive results in this regard (Kolovos et al., 2018).

Internet interventions are generally an adaption of classical face-to-face protocols in which emotion regulation plays a relevant role. In this line, different initiatives were carried out taking an already validated protocol and translating the content for an Internet delivery format, many of which entail one or more components to train emotion regulation. The Unified Protocol, one of the first transdiagnostic treatments developed for emotional disorders, which has ER as one of the principal therapeutic targets, constitutes an illustrative example of this (Barlow et al., 2004) and different IBTs have been developed following this model. The first IBT in this line was called Smiling is Fun. A randomized control trial (RCT) with 124 participants showed its effectiveness in reducing depressive symptomatology through the enhancement of ER strategies (Mira et al., 2017). Furthermore, two other RCTs are being conducted. One aims to analyze the effectiveness of a transdiagnostic IBT compared to treatment as usual (González-Robles et al., 2015). The other one studies the differential efficacy of the same transdiagnostic IBT but compared to a transdiagnostic IBT with additional components of positive affect enhancement (Díaz-García et al., 2017).

Virtual Reality and Serious Games

Despite the potentiality described for the assessment, MR have initially emerged in the psychological realm as a powerful intervention tool for facilitating exposure therapy for specific phobias (Rothbaum et al., 1995; Botella et al., 1998; Riva et al., 1999). From the 90s on, a significant amount of research has yielded evidence on the efficacy of MR, particularly VR, for several clinical conditions (Opriş et al., 2012; Turner and Casey, 2014). With the emergence of low-cost devices as well as massive commercial products, VR has become a more feasible tool to be implemented in clinical contexts (Lindner et al., 2017).

Overall, VR can be of paramount importance for the intervention of ER. Illustratively, VR can be an effective tool for emotions' induction, and therefore, an innovative and more experiential way to train ER strategies in controlled environments. An illustrative example in this direction was developed by Bosse et al. (2012, 2013), who created a virtual scenario that could provide real-time feedbacks of users' coping skills based on a ER computational model and on the monitoring of behaviors and physiological parameters. Another interesting study targeted ER skills through VR with the aim of preventing adolescents risk behaviors, and although VR did not turn to be more effective that the non-VR condition, adolescents did attend more sessions and incremented their self-efficacy (Hadley et al., 2018). As previously mentioned, the GT-System is another example of a VR-based serious game to assess but also train ER strategies in adolescents through respiration and attention strategy games, which have been shown to significantly reduce frustration levels (Rodriguez et al., 2015).

Furthermore, novel 360° cameras can easily create immersive 360° videos that can be explored from all angles of recording. These videos can be integrated and manipulated by means of software like InstaVR or Google toolkit creator in order to elaborate *ad hoc* scenarios in which to simulate eliciting situations and improve, for example, ER strategies. However, there are also 360° videos in different web platforms that can be downloaded for free. Notably, Li et al. validated a public set of 360° videos for valence and arousal dimensions that can be easily used to experimentally induce emotions (Li et al., 2017a).

Finally, the incorporation of gamified features in the context of treatments can be of tremendous help, not only for the increase of engagement (Looyestyn et al., 2017) but also for the use, both at an experimental and intervention level. A recent systematic review has synthesized the evidence of studies exploring the connection between videogames and ER, showing that there are 23 studies that have explored this in the context of commercial and bespoke games (Villani et al., 2018). Although the review grasps a broad concept of ER, including emotional and mood regulation and even stress responses, it is a first approximation to better understand how such an ecological stimulus for young, adolescents, and event adults may be incorporated in the current perspective of ER assessment and intervention.

Biofeedback

Biofeedback constitutes an effective and noninvasive procedure, whose basic operating principle is the conscious registration of normally unconscious body procedures (e.g., brain activity, electrocardiogram, electromyography, or skin conductance) (Gaume et al., 2016) that are represented by a visual, haptic, or audio signal. As aforementioned, there is a large body of evidence showing the strong relation of ER with physiological processes such as HRV (Appelhans and Luecken, 2006; Balzarotti et al., 2017). Precisely, HRV biofeedback has shown to be effective for stress and anxiety (Goessl et al., 2017), conditions that have shown to be greatly explained by emotion regulation (Barlow et al., 2004). Besides, the neural activity, in particular, the activity of the amygdala, which constitutes a key area for emotion activity and regulation, has shown to be successfully regulated through neurofeedback procedures (Johnston et al., 2010; Zotev et al., 2013; Zich et al., 2018).

Finally, the integration of biofeedback with VR constitutes a very powerful research line. It would permit to provide users with engaging interfaces of the physiological targeted stimuli, which could in turn positively impact on the therapeutic outcomes. As an example, Lorenzetti and colleagues (Lorenzetti et al., 2018) implemented a real-time functional magnetic resonance imaging neurofeedback protocol to enhance emotional states in healthy subjects.

FUTURE PERSPECTIVES IN THE INCORPORATION OF NEW TECHNOLOGIES FOR EMOTION REGULATION

All the described developments show that new digital technologies not only constitute a potentiality but also an already current way to improve our knowledge of ER. Specifically, the following aspects are the most relevant to take into consideration for the further developments within the field.

Ecological Validity

In ER research field, many smartphone-based EMAs have been adopted in order to ecologically investigate ER in daily life, showing the potentialities of this approach to grasp emotion dynamics in real-life settings. However, few studies integrated self-reports with data gathered from embedded-sensors or wearable biosensors, which could instead bring new insights into ER daily processes in terms of determinants and consequences as well as contextual factors affecting ER. Notably, no EMA for ER assessment has been developed so far with the aim of being applied to clinical practice, where retrospective self-reports are still the most used method. We suggest that EMA could increase assessment accuracy by considering ER as a situated process, in which momentary and contextual factors play a key role. This would, in turn, help clinicians identify the strategies to be addressed by the therapy as well as the potential triggers of maladaptive strategies. Similarly, VR could constitute a powerful tool to develop realistic scenarios in which to elicit emotions and explore/assess ER deployment as well as train ER strategies. Nevertheless, this field is still completely understudied.

Individual Differences

In line with the first point, the potentiality of utilizing embedded sensors and wearable biosensors along with complex machine learning techniques is still undeveloped in the specific case of EMI for ER. Its progress could lead to the development of aware systems able to more accurately explore and predict users' emotion and affect regulation and provide support in specific moment of the day (Kuppens, 2015). Furthermore, VR could also be a powerful tool to increase intervention personalization. The possibility of manipulating VR scenarios could indeed represent a new way of intervening in ER, where it would be possible to adapt environments to the needs and characteristics of each individual.

Overcoming a Schematic Study of Single Emotion Regulation Strategies

Instead, the previously cited possibility of gathering large amount of data may allow grasping the complex interplay of the different strategies. In this way, the commonly used classification of adaptive or maladaptive strategies may be left aside in order to incorporate a context-based perspective. An integration of implicit, automatic, and interpersonal ER processes could also be achieved through an articulated study of cognitive, behavioral, experiential, and psychophysiological dimensions by means of the incorporation of all the described technologies.

Integrated Knowledge of ER

An integrated understanding of ER (i.e., implicit, automatic, and interpersonal dimensions) could be achieved through an articulated study of cognitive, behavioral, experiential, and psychophysiological dimensions by means of the incorporation of all the described technologies. For instance, a wide range of technologies such as VR-based avatars could embrace an embodied cognition perspective (Bailey et al., 2016), which is also an essential aspect within the emotion regulation field (Koole and Veenstra, 2015).

For the aforementioned reasons, the pursuit of integrated prototypes of technologies could lead to a successful understanding, assessment, and training of ER (**Figure 2**). All these advancements should be conducted in a multidisciplinary way, i.e., in active collaboration with the latest Human Computer Interaction and Biomedical Engineering findings. Ongoing examples of integrated technologies are already occurring, like the development of an interpersonal VR-based biofeedback called "DYNECOM" (Salminen et al., 2018). DYNECOM is

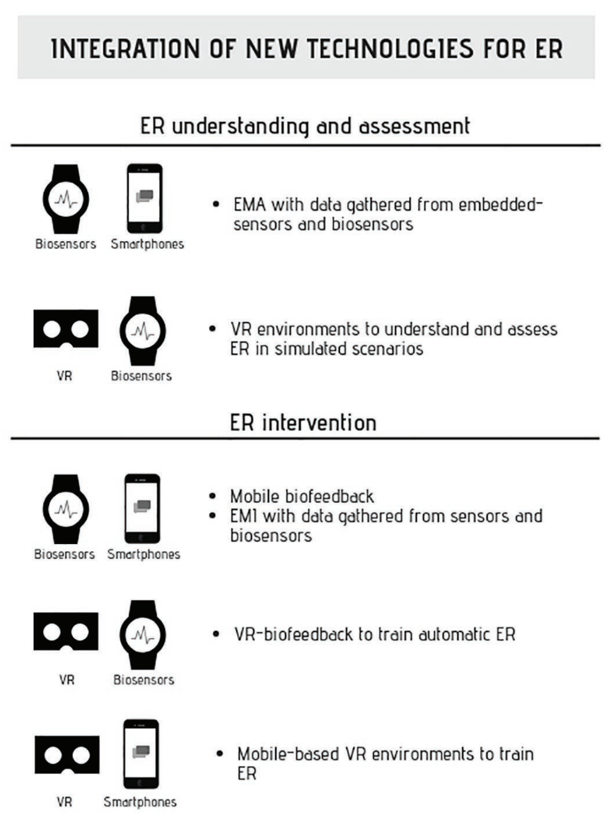

FIGURE 2 | Examples of the complementary and integrative role f new technologies for the understanding assessment and intervention of ER. ER, emotion regulation; EMA, ecological momentary assessment; VR, virtual reality; EMI, ecological momentary intervention.

an immersive VR system for the practice of empathy-evoking compassion meditation by dyads (Salminen et al., 2018). Within the virtual environment, real-time EEG and breath rate visual feedbacks are provided, as well as a visual representation of the signals synchronization between participants. According to preliminary results, this innovative couple biofeedback is able to increase the perceived affective interdependence between the dyad, suggesting the potentiality of this device to improve implicit ER. Other examples are VR-based intrapersonal biofeedback (Gaggioli et al., 2014), a mobile biofeedback with serious games (Dillon et al., 2016), gamified virtual reality (Miloff et al., 2016), or fMRI neurofeedback in virtual environments (Lorenzetti et al., 2018). If this integration is further developed, a powerful path for the upcoming years can be expected, resulting in the enhancement of the field of emotion regulation.

AUTHOR CONTRIBUTIONS

JF-Á and DC developed the idea for this perspective and equally contributed to the conceptualization and writing—original and subsequent drafts until last version. PC, AGP, CB, and GR contributed to writing—review, conceptualization, editing, and supervision.

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Positive Effects of Videogame Use on Visuospatial Competencies: The Impact of Visualization Style in Preadolescents and Adolescents

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Use of videogames (VGs) is almost ubiquitous in preadolescents' and adolescents' everyday life. One of the most intriguing research topics about positive effects of VG use is about the domain of visuospatial competencies. Previous research show that training with videogames enables children and adolescents to improve their scores in visuospatial tests (such as mental rotation of shapes and cubes), and that such training could overcome gender differences in these domains. Our study aimed at (1) verifying the positive effects of videogame use in the visuospatial domain both for male and female adolescents and preadolescents and (2) verifying whether the visualization style (2D or isometric 3D) of the VG has an influence about the positive effects of gaming. Six measures of visuospatial competency were administered to 318 preadolescents (mean of age = 13.94 years, range 10–18) prior and after a 3-day training with 2D and 3D Tetris. Results indicate that (1) gaming on the whole has slight positive effects both for males and females in enhancing visuospatial competencies, at least in the short term, and (2) it seems that participants who used the videogame with 2D graphics obtained greater improvements in the mental rotation domain while the participants who used the videogame with 3D graphics obtained greater improvements in the spatial visualization domain. However, a general learning effect between T1 and T2 was measured, which was found regardless of Experimental condition, indicating that the effect of training with videogames can be less relevant than expected.

Keywords: videogames, spatial cognition, preadolescence, adolescence, visuospatial abilities

INTRODUCTION

Visuospatial competencies are that realm of cognitive ability definable as: "[...] skills in representing, transforming, generating, and recalling symbolic, non-linguistic information" (Linn and Petersen, 1985, p. 1482). In general terms, visuospatial competencies can be described as the ability to imagine the appearance of a figure (regular or irregular) when it is rotated in space, and to perceive the spatial relations between objects. Halpern (2000) distinguishes several subdomains in visuospatial competencies: spatial perception, mental rotation, spatial visualization, and spatio-temporal ability. They can be defined as follows:

- Spatial perception – the ability to correctly assess and perceive spatial relationships;
- Mental rotation – the ability to mentally rotate (either 2D or 3D) spatial objects to see how they would look from a different angle or perspective;
- Spatial visualization – the ability to perform multiple mental manipulations of spatial information in order to reach a different configuration of the visual stimulus;
- Spatio-temporal ability –the ability to make accurate judgments regarding the timing and the movement of objects through space.

Visuospatial competencies are a domain that is susceptible to improvement via formal (e.g., school, specific exercise) and informal training (e.g., performing day-by-day activities like driving). As children progress in their development, these skills are very important for understanding and mastering material in the physical sciences, engineering, architecture, medicine, etc., In fact, visuo-spatial skills are central in many everyday tasks (e.g., navigating through 2D and 3D maps, using tools, operating machineries, and driving cars, etc.) and are closely related to academic achievement in STEM (science, technology, engineering, and mathematics) disciplines (cf. Holmes et al., 2008; Wai et al., 2009).

Visuospatial Competencies and Videogames

Videogames (VGs) are a very common cultural artifact among children and pre-adolescents: while on average gamers are 35 years old, over 27% of players are under 18 years of age Entertainment Software Association [Esa] (2016). As regards prevalence of video gaming in youth, two thirds of 6–17 year old Italians (AESVI – ISPO, 2010) and of 16–19 year old Europeans regularly play videogames (ISFE, 2010).

Videogames often represent the first introduction to information technologies for the new generations. In the developmental psychology literature, videogames have been linked to potential negative effects such as increased aggression due to violent contents (Milani et al., 2015) and risk of addiction (Petry et al., 2014; Milani et al., 2018).

However, since the Eighties and Nineties many authors have started to study the "bright side" of videogames, highlighting positive effects of their use. In this light, early studies about visuospatial competencies and VG use have shown how training with *ad hoc* videogames leads to an improvement in performance on pencil and paper visuospatial tests (Gagnon, 1985; McClurg and Chaillè, 1987; Okagaki and Frensch, 1994; Subrahmanyam and Greenfield, 1994), and possibly lessens gender differences (Halpern, 2000; Ferguson et al., 2008).

Moving from these preliminary results, researchers tried to maximize the ecological validity of the studies by leaving the lab setting and focusing on the effects of training with VGs in more naturalistic settings, using off-the shelf videogames as a training tool. Terlecki et al. (2008) specifically used the computer game Tetris to train undergraduate students in spatial cognition and found that the improvement lasted for months and generalized to other spatial tasks. They found that that the growth of visuospatial skills during long-term training with Tetris was continuous for a whole semester (albeit the growth curve flattened after 12 weeks of training) and that these improvements remained detectable some months after the cessation of the training. De Lisi and Wolford (2002) found similar results in third-graders, also using Tetris as a training videogame. Feng et al. (2007) showed that a 10 h training with (action and non-action) videogames significantly enhanced field-of-view of participants.

A meta-analysis by Ferguson (2007) highlights how the most significant effect detectable in the continued use of videogames (VGs) is improvement in visuospatial competencies both in males and females. As regards the amount of training needed to obtain any improvement, Cherney (2008) has found that even 4 h in total led to significant results.

Ferguson et al. (2008) verified how also habits in videogame use (and not only specific training) are strongly correlated with better visuospatial competencies. In fact, children who habitually use videogames (especially action ones) show better performance in visual memory tasks, independently of gender.

Oei and Patterson (2013) showed that such positive effects extend to adulthood and a large array of VGs (action games, non-action games, puzzles, and strategic games), on multiple devices (handheld, home-based), and that the transfer of cognitive enhancement is more likely to take place when game activities are closely matched with real-world tasks. Regarding the positive effects of gaming with VGs, Green and Bavelier (2012) argue that playing videogames may not only enhance cognitive and attentive performance, but also – to a greater extent –facilitate the learning of new tasks via flexible interaction with a highly motivating environment (such as the one in action videogames). In particular, effects of action videogames can be found in different domains of visuo-spatial competencies (cf. *ibidem*, pp. R202–R204): selective attention in space (i.e., the ability to focus attention on a target and ignore distracting information); selective attention in time (i.e., the ability to select relevant information over time); selective attention to objects (i.e., the ability to track many independently moving objects); attentional control (i.e., the ability to flexibly allocate attentional resources); and sustained attention and impulsivity (i.e., the ability to maintain attention active and focused attention while refraining from impulsive reactions).

Granic et al. (2014) argue that playing videogames is beneficial in at least four domains, fostering cognitive, motivational, emotional, and social benefits. As regards the cognitive domain, which is of interest for our paper, Granic et al. argue that spatial skills improvements obtained via commercial videogame play could be comparable to the effects of formal education targeted to the same set of skills, as also reported in the meta-analysis by Uttal et al. (2013). However, not all games are equally effective in this domain, as the action/shooter genre seems to convey the most beneficial effects due to their very dense and complex visual representation, while more visually sparse videogames (as adventures) seem to be less effective. The research from Shute et al. (2015) showed that a mixed action/puzzle commercial videogame such as Portal 2 (which provides compelling puzzles to be solved in order to progress in a first-person complex three-dimensional environment) was more effective in improving visuospatial abilities than a commercial cognitive training program ("Lumosity").

Beneficial cognitive effects of training with VGs are not limited to the "typical" population but are thought to extend to some atypical populations such as children with learning disabilities. In this area, Franceschini et al. (2013) showed that training with action videogames can improve attention skills, which in turn can improve the reading skills of children with dyslexia. They argue that videogames can represent "low-resource-demanding early prevention programs that could drastically reduce the incidence of reading disorders" (*ibid*, p. 465).

Finally, in terms of "real-world" applications of the potential benefits of training with VGs, one of the most intriguing lines of research deals with the effect of gaming expertise and/or training on trainees in surgery. The seminal work from Rosser et al. (2007) showed that surgeon trainees that never played videogames were the least performant in a laparoscopic training course, while surgeons that played 0–3 h a week were more able than the former, while surgeons that played more than 3 h a week were the most proficient with the laparoscope (scoring 42% better than the non-player group). Following up these correlational results with an experimental setting, Adams et al. (2012) found that a training with an action videogame with a traditional console (Xbox) led to a remarkable improvement in laparoscopic abilities of surgeon residents, while the training on the same videogame on a handheld device (Nintendo DS) led to more modest improvements. The residents that used the usual laparoscopic training box showed the least improvement of the three groups. Kennedy et al. (2011), however, showed that the higher proficiency in laparoscopic ability by those surgeon trainees that were gamers, compared to non-gamers trainees, was due more to psychomotor skills than to visuo-spatial competencies. Khatri et al. (2014) also found that previous experience with videogames was not related to higher performance with a VR simulator of orthopedic procedures. Thus, the contribution of expertise and training in videogames to proficiency in medical procedures requiring visuospatial abilities seems to have been established for some specific procedures such as laparoscopy, but not fully supported for other branches of medicine.

To sum up, the literature seem to have established a fairly robust correlation between practice with videogames and enhancement of visuospatial skills. Given the paradigmatic shift seen in the last 20 years in the videogame industry (i.e., the introduction of complex and real-time three-dimensional graphics), assessing the effects of different types of visualization is of some importance. This holds even truer when thinking about the learning potential embedded in videogames: choosing the "right" balance between scenario complexity, ease of use and sense of engagement in the VG could be very important in order to design videogames for learning purposes. At the moment, to our knowledge, no research has contrasted the potential positive effect on visuospatial competencies of 2D vs. 3D graphics, using the same videogame as a training. Moving from these assumptions, our exploratory research has specific one hypothesis (H1) and a general research question (RQ1):

(H1) Given the positive effects of videogame use in the increase in visuospatial competencies discussed in previous research, we hypothesize that participants in the Experimental groups (2D and 3D Tetris) will show a significant increase in visuospatial scores compared to participants in the control group.

(RQ1) We are interested in assessing whether the graphics of the videogame used (2D or 3D) tap different sub-components of visuospatial competencies and thus affects visuospatial competencies in a different manner. The following RQ is thus posited: Do the graphics (2D vs. 3D) affect visuospatial competencies differently?

MATERIALS AND METHODS

Participants

A total of 318 pre-adolescents and adolescents aged 10–18 years old (mean = 13.94 years old, *SD* = 2.21) were recruited from secondary schools in the Province of Milan. A hundred and sixty participants were male (mean age = 14.09 years, *SD* = 2.29) and 139 were female (mean age = 13.76 years, *SD* = 2.11). In terms of socio-economic status (SES), all participants were middle class. Mean age was not different across gender (t = 1.32; n.s.).

Participants were randomly assigned to three experimental conditions: training with a 2D videogame (N = 116), training with a 3D videogame (N = 119) and control (N = 83). The experimental conditions were balanced for gender (χ^2 = 0.04; df = 2; n.s.) and for mean age (F = 2.91; n.s.).

Procedure

Principals of the schools approved the schools' participation in the research project, agreed to the collection of data and informed the parents about the research. The day before the data were collected, the researchers explained the research to the students in the classroom and gave them an envelope to give to their parents. The envelope included a description of the research and its aims and a consent form to be signed by both parents prior to the administration of the instruments. The following day, the experimenters collected signed informed consent forms and administered the first survey only to students whose parents signed the informed consent. The research was organized into three phases:

T1 – we administered a battery of visuospatial paper tests to the adolescents, together with a specific questionnaire to measure videogame use habits. The questionnaire regarding gaming habits included 20 items with different response formats (9-point Likert scales, open-ended questions, and closed questions). Six subscales of the "Kit of Factor Referenced Cognitive Tests" (Ekstrom et al., 1976) were employed as visuospatial tests. Each of the six subscales consisted of a different visuospatial time-limited task. The time allowed for the completion of the tests ranged from one to 3 min according to the instructions provided in the Manual of the test. The administration of the instruments took place in the classes.

Training Phase – at the end of the administration of the visuospatial tests, 2D and 3D versions of Tetris were distributed via *Dropbox* access codes. The videogames used were "Tetrix2000" for the 2D version of the game and "3DBlocks" for the three-dimensional version. The games were free-distribution games that could run on almost any PC configuration due to low hardware requirements. Moreover, the blocks were the same shape and color in both 2D and 3D versions. The participants were asked to play the videogame at home for 45 min per day on the three following days. The participants were specifically asked not to use any videogame except the one provided by experimenters. Participants in the control sample were asked not to use any videogame for the 3 days. In order to maximize compliance with the instructions, we asked participants to collect a brief diary of their sessions in terms of points achieved for each game and number of games played per session. We opted for a short distributed training setting rather than a single session of mass training, as it seems to be effective and yield durable results (cf. Eichenbaum et al., 2014).

Tetris was selected for different reasons: first of all, it provides a challenging environment, mixing features from puzzle and action VGs; secondly it does not convey any violence nor aggressive content, and – finally – the Tetris learning curve is easy while maintaining a good challenge due to the constant increase in the speed of falling of the bricks. Spence and Feng (2010) assess "puzzle" videogames as having a "medium" effect on visuospatial competencies (albeit inferior to action videogames).

T2 – at the end of the 3 days, we administered an alternative version of the same visuospatial test battery to all participants, in order to hinder any recognition of the correct answers and partially control for learning effects. At the end of the experiment, all participants were granted free access to both versions of Tetris.

Instruments

The test used to measure visuospatial competencies was composed of six subscales of the "Kit of Factor Referenced Cognitive Tests" (Ekstrom et al., 1976), which covers some of the domains of visuospatial competence highlighted by Halpern (2000). The subscales' scores were computed as the total number of correct answers for each task, except for Rotation of figures (S-1) and Rotation of cubes (S-2), where scores were corrected against guessing by subtracting the number of errors from the number of correct answers, following Manual guidelines.

The tests were administered to all participants in the following order:

- Dot matrix (CF-3): the task consists in copying a geometrical configuration using a matrix of dots as reference. It measures the capacity to preserve a visual configuration mentally and thus covers Halpern's spatial perception. Scores could range from 0 to 32.
- Recognition of identical figures (P-3): the task requires recognition of which of the five symbols presented is identical to the one supplied as a model. It measures speed in perceiving and comparing visual stimuli, thus covering Halpern's spatial perception. Scores could range from 0 to 24.
- Reconstruction of images (CS-1): the task consists of guessing the identity of an object shown incompletely. It measures the capacity to perceive a gestalt from partial data (this covers Halpern's spatial visualization). Scores could range from 0 to 10.
- Labyrinth (SS-1): the task requires drawing a trail through a labyrinth with many dead-end paths. It also covers the capacity for spatial perception. Scores could range from 0 to 24.
- Rotation of figures (S-1): the task requires deciding whether the figures presented as stimuli are rotations of the model figure. It measures speed in perceiving bi-dimensional spatial relations, thus covering Halpern's mental rotation. Scores could range from −80 to 80.
- Rotation of cubes (S-2): the task consists of deciding whether the pairs of cubes presented as stimuli are the same cube rotated or different cubes. It measures speed in perceiving tri-dimensional spatial relations, also covering Halpern's mental rotation. Scores could range from −21 to 21.

Cronbach's Alpha for the tests (each was considered as an item) was 0.63.

Data Analysis Strategy

We performed firstly a set of descriptive analyses. Then multilevel modeling was run by means of Generalized Linear Mixed Models (GLMM) nesting Time measurements (Level 1) within participants (Level 2).

A linear model with identity as a link function was selected. Experimental condition (control, 2D, 3D), Time (Time 1, Time 2), and their interaction were included in the model as fixed factors, while Participant was included as a random effect to control for variance due to differences among participants. Bonferroni adjusted pairwise comparisons were employed to analyze differences among conditions. Gender and age were included as covariates. We performed tests of six models, one for each of the visuospatial tests administered.

RESULTS

Descriptive Results

Regarding the data derived from the questionnaire on videogame use habits, 98.1% of the participants declared that they played videogames habitually, and the mean of hours per week of videogame play was 5.88. Regarding videogame play, gender differences emerged: while males on average played videogames for 7.97 h a week, females played videogames for only 3.51 h ($t = 7.99$; $p < 0.001$). Mean scores obtained in the six visuospatial subscales administered were compared on the basis of gender. Contrary to the usual findings in the literature, no gender differences were found except in the labyrinth test (males mean = 11.82, female mean = 10.86; $t = 2.33$; $p < 0.05$). On the basis of previous literature and this result, gender was inserted as a covariate in the subsequent analyses.

TABLE 1 | Means and Standard Deviations of scores in the six scales of visuospatial competence by three experimental conditions.

	Experimental condition					
	2D		3D		Control	
	T1	T2	T1	T2	T1	T2
Dot matrix (CF-3)	15.57 (5.87)	18.97 (6.58)	15.08 (7.30)	19.03 (7.72)	13.20 (6.76)	15.39 (7.17)
Recognition of identical figures (P-3)	35.95 (7.56)	38.13 (7.09)	33.93 (9.00)	38.39 (7.95)	30.83 (10.29)	34.62 (9.43)
Reconstruction of images (CS-1)	6.79 (1.77)	6.57 (2.11)	6.77 (1.72)	6.44 (2.25)	6.65 (1.36)	6.12 (2.04)
Labyrinth (SS-1)	11.93 (3.80)	15.29 (3.97)	11.45 (3.50)	15.86 (4.24)	10.51 (3.69)	14.24 (3.80)
Rotation of figures (S-1)	38.19 (17.93)	44.76 (18.60)	34.24 (21.59)	38.48 (22.67)	30.72 (21.11)	34.01 (22.92)
Rotation of cubes (S-2)	5.46 (3.90)	4.49 (5.40)	4.95 (5.16)	4.67 (5.29)	4.27 (4.87)	3.34 (5.42)

TABLE 2 | Linear mixed model: Parameter estimates for the six measures of visuospatial competences.

	Dot matrix (CF-3)	Recognition of identical figures (P-3)	Reconstruction of images (CS-1)	Labyrinth (SS-1)	Rotation of figures (S-1)	Rotation of cubes (S-2)
Measure/Parameter	Est (SE)	Est (SE)	Est (SE)	Est (SE)	Est (SE)	Est (SE)
Fixed effects						
Intercept	14.33*** (0.635)	31.98*** (0.923)	6.93*** (0.171)	11.50*** (0.374)	33.61*** (2.35)	5.33*** (0.502)
Exp. condition (2D)	0.870 (0.767)	2.62* (1.12)	−0.114 (0.208)	0.823 (0.450)	5.16 (2.83)	0.440 (0.606)
Exp. condition (3D)	0.469 (0.753)	1.77 (1.10)	−0.167 (0.204)	0.279 (0.441)	1.24 (2.78)	0.048 (0.595)
Time of measurement	2.25*** (0.479)	3.78*** (0.677)	−0.597** (0.208)	3.65*** (0.318)	3.23* (1.30)	−1.04* (0.535)
Time × exp. cond. (2D)	1.55* (0.628)	−0.320 (0.888)	0.386 (0.271)	−0.267 (0.417)	4.40** (1.71)	0.277 (0.691)
Time × exp. cond. (3D)	1.63** (0.620)	0.689 (0.875)	0.262 (0.267)	0.771~ (0.411)	1.97 (1.68)	0.818 (0.680)
Gender	0.491 (0.568)	0.393 (0.786)	−0.073 (0.148)	−0.818* (0.341)	−2.57 (2.13)	−0.960* (0.412)
Age	2.03*** (0.130)	1.88*** (0.179)	0.452 (0.033)	0.910*** (0.077)	3.13 (0.487)	1.20*** (0.093)
Variance components						
Residual (T1)	6.03*** (1.31)	18.65*** (2.85)	0.898*** (0.155)	1.53** (0.498)	46.42*** (12.96)	8.04*** (1.15)
Residual (T2)	11.44** (1.53)	16.34*** (2.76)	2.28*** (0.234)	6.16*** (0.701)	82.97*** (14.22)	12.16*** (1.38)
Random effect						
Subject	19.85*** (2.04)	36.91*** (3.83)	0.963*** (0.156)	7.36*** (0.774)	307.34*** (28.21)	7.42*** (1.11)

*Note: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; ~$p < 0.06$. The estimates reported in this table were obtained using Control and Time 1 as reference conditions for Experimental Condition and Time of measurement, respectively.*

Mean scores on the six visuospatial tests are presented in **Table 1**.

Effects of the Use of the Videogame on Visuospatial Competencies

Results of the Generalized Linear Mixed Models are presented in **Table 2**, while **Table 3** presents confidence intervals.

Dot Matrix (CF-3)

By looking at estimates, it appears that 2D condition ameliorates control group mean score by 1.55 points while 3D condition edges control group scores by 1.63 points. Confidence intervals range from 0.31 to 2.78 and from 0.41 to 2.84, respectively. Thus, it appears that the training obtained a moderate effect if compared to control group trend from T1 to T2.

Recognition of Identical Figures (P-3)

Participants in the 2D condition showed a worse performance than participants in the control group by 0.32 points, while 3D condition means are higher than those of control group by 0.68 points. Confidence intervals range from −2.06 to 1.42 and from −1.03 to 2.40, respectively. As regards this specific subscale, it appears that the training with the videogame was not effective from T1 to T2. Results also show high dispersion within experimental conditions, showing that any difference is likely to be related to learning effects from T1 to T2.

Reconstruction of Images (CS-1)

Participants' scores in 2D condition were 0.38 points higher than scores of participants in control condition. Scores in 3D condition were 0.26 points higher than controls. Confidence intervals range from −0.14 to 0.91 and from −0.26 to 0.78, respectively. As for P-3, it appears that the training with the videogame was not effective in improving visuo-spatial abilities in this specific subscale.

Labyrinth (SS-1)

By looking at estimates, it appears that 2D condition scores are lower than scores of control group by 0.27 points, while 3D

TABLE 3 | Linear mixed model: Confidence intervals (95%).

	Dot matrix (CF-3)	Recognition of identical figures (P-3)	Reconstruction of images (CS-1)	Labyrinth (SS-1)	Rotation of figures (S-1)	Rotation of cubes (S-2)
Fixed effects						
Intercept	13.08, 15.58	30.16, 33.79	6.60, 7.27	10.76, 12.23	28.98, 38.24	4.34, 6.32
Exp. condition (2D)	−0.63, 2.37	0.42, 4.83	−0.52, 0.29	−0.06, 1.70	−0.40, 10.77	−0.75, 1.63
Exp. condition (3D)	−1.01, 1.94	−0.38, 3.94	−0.56, 0.23	−0.55, 1.14	−4.23, 6.71	−1.12, 1.21
Time of measurement	1.30, 3.19	2.44, 5.11	−1.00, −0.18	3.03, 4.28	0.67, 5.79	−2.09, 0.00
Time × exp. cond. (2D)	0.31, 2.78	−2.06, 1.42	−0.14, 0.91	−1.08, 0.55	1.04, 7.71	−1.08, 1.63
Time × exp. cond. (3D)	0.41, 2.84	−1.03, 2.40	−0.26, 0.78	−0.03, 1.58	−1.33, 5.28	−0.51, 2.15
Gender	−0.62, 1.60	−1.15, 1.93	−0.36, 0.22	−1.48, −0.14	−6.76, 1.63	−1.77, −0.15
Age	1.77, 2.28	1.53, 2.23	0.38, 0.51	0.75, 1.06	2.17, 4.09	1.01, 1.38
Variance components						
Residual (T1)	3.92, 9.24	13.82, 25.17	0.64, 1.26	0.81, 2.89	26.86, 80.25	6.07, 10.66
Residual (T2)	8.80, 14.87	11.73, 22.77	1.87, 2.79	4.93, 7.70	52.29, 116.09	9.73, 15.19
Random effect						
Subject	16.22, 24.27	30.11, 45.25	0.70, 1.32	5.99, 9.04	256.74, 367.92	5.52, 9.97

condition edges control group scores by 0.77 points. Confidence intervals range from −1.08 to 0.55 and from −0.03 to 1.58, respectively. These lead to ascribe a negligible effect of the 3D training and to categorize 2D training as ineffective.

Rotation of Figures (S-1)

Participants' scores in 2D condition were 4.40 points higher than scores of participants in control condition. Scores in 3D condition were 1.97 points higher than controls. These parameters lead us to categorize the training with the videogame as effective, especially in the 2D condition. However, confidence intervals range from 1.04 to 7.71 and from −1.33 to 5.28, respectively. This cautions against ascribing the improvement from T1 to T2 to training effects alone, as some learning may be happened between measurements.

Rotation of Cubes (S-2)

Estimates show that 2D condition scores are higher than scores of control group by 0.27 points, while 3D condition edges control group scores by 0.81 points. Confidence intervals range from −1.08 to 1.63 and from −0.51 to 2.15, respectively. These lead to ascribe a negligible effect of the 3D training and to categorize 2D training as ineffective.

DISCUSSION

Results of this exploratory research indicate, first of all, that participants performances increased between T1 and T2 in many of measures administered, regardless of Experimental condition. In particular, participants performances were better at T2 in the following subscales: Dot Matrix (CF-3), Recognition of identical figures (P-3), Labyrinth (SS-1) and Rotation of figures (S-1). This indicates a very likely effect of learning occurring between T1 and T2, implying the need for a prudent approach about the effects of training with videogames on visuospatial competencies. Literature shows that learning effect is a common artifact in cognitive testing (cf. Bartels et al., 2010).

For two of the tests (Reconstruction of images [CS-1] and Rotation of cubes [S-2]), participants showed worse performance at T2 than at T1. In our opinion, this could be due to a) the nature of the task of reconstructing images, which is not likely to be affected by learning since the figures in the T2 task were different than those in T1, and b) the intrinsic difficulty of the task relating to rotation of cubes. As regards the latter, in particular, the task is more suitable for older children and young adults than younger children, since it requires deciding whether the rotated test cube matches the model cube by evaluating whether the symbols on the faces of the cube can be compatible given the rotation.

As regards the main RQs of our study, we can conclude that for some of the subscales administered, the use of the videogame was seemingly effective for enhancing visuospatial competencies, at least in the short term. The participants that played Tetris slightly improved their performance compared to those in the control condition. Training with the videogame, according to our data, seems to be marginally effective in enhancing visuospatial abilities in some of the tests administered (H1). In particular, participants in the 2D Experimental condition obtained better scores than participants in the control condition in the Dot matrix (CF-3) and Rotation of figures (S-1) tests, while participants in the 3D Experimental condition showed higher scores in the Dot matrix (CF-3), Labyrinth (SS-1) and Rotation of Cubes (S-2) tests than participants in the control condition. On the whole, these results are likely to indicate that even a brief training on VGs can likely tap into Halpern's spatial perception and mental rotation visuospatial subskills. However, spatial visualization was not affected by the training.

We attribute these results to the fact that Tetris seem to match specifically both spatial perception – in terms of perceiving and assessing spatial relations between the shapes and their relative position according to the boundaries of the "well" – and mental rotation – in terms of quickly assessing the (either 2D or 3D) rotation needed to fit the pieces together. These results mirror previous research that found similar differential effects (Terlecki and Newcombe, 2005; Terlecki et al., 2008). On the contrary, spatial visualization seemed to be relatively unaffected by the training. We attribute this result to the mismatch between visuospatial operations performed in Tetris and the specific visuospatial task (CS-1), which required guessing figures of well-known objects (e.g., a ship) from an incomplete model figure.

As regards age, the results seem to indicate that in four of the tests older participants outperformed younger participants; in particular: Dot matrix (CF-3), Reconstruction of images (CS-1), Labyrinth (SS-1) and Rotation of cubes (S-2). Previous research reports that age is related to better visuospatial skills (Del Giudice et al., 2000; Rosselli and Ardila, 2003), so this is a non-surprising result. Moreover, since age was inserted as a covariate in all the models tested, we can be confident that any effect of VG practice detected in our study can be thought of as occurring independently of age. Also Gender was found to potentially influence some of the tests: Labyrinth (SS-1) and Rotation of cubes (S-2). As in the case of age, some research highlighted gender differences in visuospatial skills (cf. Halpern, 2000, for a review), so we believe this result is quite expected. Having inserted Gender as a potential covariate, we believe that any effect of VG practice on visuospatial competencies can be considered to be independent of gender.

In terms of visualization differences (cf. RQ1), it seems that participants who used the videogame with 2D graphics obtained greater improvements than those who used the videogame with 3D graphics in the domain of mental rotation of figures (S-1). On the contrary, participants who used the videogame with 3D graphics did not show higher scores in spatial visualization (S-2). The experimental conditions seemed to be equally effective in promoting some slight improvement in spatial perception (CF-3 test). It seems that the somewhat limited training time with Tetris conferred some positive effects for some visuospatial abilities, but not all of them. In particular, it seems that spatial perception and mental rotation are more sensitive to this type of training than spatial visualization. We attribute this result mainly to the intrinsically higher complexity of the spatial visualization subskill (it requires multiple mental manipulations of spatial information), which probably means that a longer training time would be needed to detect any improvement. We also attribute these results to the fact that the tasks that the scales we found to be slightly improved by training with the videogame are probably the most similar to the game play of Tetris: rapid scanning of the visual space (CF-3, Dot matrix), movement in the X- and Y- axes (SS-1 Labyrinth) and rotation of bricks (S-1, Rotation of figures). Generalizing these results, it seems that – given the limited time spent in training with the videogames we provided – the training on the videogames could have had the role of a "trigger" that probably allowed the participant to recover previous abilities probably related to the habits of videogame use (all participants indicated that they played VGs). The literature in fact shows that more than intensive training, it is the frequent VGs that has a substantial effect in improving cognitive competencies linked to the spatial domain (Green and Bavelier, 2007; Cherney, 2008; Ferguson et al., 2008). We believe these effects should be taken cautiously, however, since the performances in the visuospatial tests were also characterized by a large amount of variability among participants.

These results as a whole could have some implications for educational software development. If we think about the growing educational potential of videogames in formal and informal education, results of our study could be of some use to aiding in the design of computerized training programs for disadvantaged children (cf. Demily et al., 2016), in particular in identifying the most appropriate graphic visualization style for addressing specific visuospatial abilities.

Limitations of the Research and Future Directions

The main limitation of this research, which is exploratory in its nature, is the limited control over the training sessions due to the home setting. This allowed the research to be carried out in a more ecologically valid setting and led to interesting results; however, we could not control compliance with the instructions, nor the equipment used to play the games. Unfortunately, we had to conform to setting constraints (i.e., some schools did not have enough computers for each participant and not enough time frames for the training during school hours), so we opted for a home setting to overcome these restrictions.

A second limitation of the research lies in its design. A mixed cross-sectional and longitudinal methodology would have allowed us to test not only the improvement effect of the training with the videogame on visuospatial competencies, but also the persistence of this effect.

A further limitation regards the pen-and-paper nature of the visuospatial tests used. As research by Okagaki and Frensch (1994) shows, the accuracy of the measurement in the visuospatial domain seems to be higher when the tests administered are formally consistent with the nature of the training.

A fourth limitation could regard the device where the VGs were played: PCs are just one of the options available and future research should differentiate the devices to assess any differences related to interaction (i.e., touch vs. keyboard) and screen dimension (i.e., PC monitor vs. tablet vs. smartphone). Future lines of research will need to generalize results of this PC-based research on different devices and settings.

Finally, a fifth limitation lies in the training time we were allowed to involve participants in, as it was several hours below the usual training time usually found in the literature. We believe that the small effect of the training with videogames we found on visuospatial competences can be mainly ascribed to this limitation. Nonetheless, the fact that, in some of the visuospatial tasks, the training was apparently effective in promoting a slight improvement can be read also as a testimony of the potentials of using videogames as a training tool. Overall, this exploratory research has shown a slight effectiveness of the training with videogames on some visuospatial competencies, at least in the short term, together with some differential effects of 2D vs. 3G graphics on subcomponents of these competencies. However, these preliminary results need to be replicated in more controlled experimental environments and with bigger samples, and to generalized to more ample age groups before they can be established as robust.

ETHICS STATEMENT

An ethics approval was not required at the time the study was conducted as per the Università Cattolica del Sacro Cuore's guidelines and national regulations. Written informed consent was obtained from the parents of all participants, and our study is compliant with Helsinki Declaration principles as regards research with humans, even in the absence of a formal Ethic Committee evaluation.

AUTHOR CONTRIBUTIONS

LM conceptualized the study, collected the data, performed statistical analyses, and wrote the first draft. SG contributed in performing statistical analyses and edited the manuscript. PDB conceptualized the study and edited the manuscript.

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Virtual Reality as a Vehicle to Empower Motor-Cognitive Neurorehabilitation

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In this paper, we advocate the combination of four key ingredients that we believe are necessary to design long-lasting effective treatments for neurorehabilitation: (i) motor-cognitive training, (ii) evidence-based neuroscience principles, in particular those related to body perception, (iii) motivational games, and (iv) empowerment techniques. Then, we propose virtual reality (VR) as the appropriate medium to encompass all the requirements mentioned above. VR is arguably one of the most suitable technologies for neurorehabilitation able to integrate evidence-based neurorehabilitation techniques and neuroscience principles into motivating training approaches that promote self-management by empowering patients to own their recovery process. We discuss the advantages and challenges of such an approach on several exemplary applications and outline directions for future developments. We strongly believe that the combination of positive psychology and positive technology mediated by VR-based interventions can heavily impact the rehabilitation outcomes of motor-cognitive functions along all the stages of the rehabilitation path.

Keywords: virtual reality, neurorehabilitation, motor-cognitive training, motivation, empowerment, neuroscience, stroke

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INTRODUCTION

Stroke remains a leading cause of long-term disability worldwide, making the improvement of post stroke outcomes a major healthcare objective. According to the American Heart Association (AHA), in 2014 the prevalence of stroke in the United States was 2.8%, with a projected increase of 20–30% by 2030 (Benjamin et al., 2017).

Among the multidimensional impairments of stroke (physical, cognitive, affective, and social), paralysis has historically centered major research investment. However, there is a close relationship between motor and cognitive deficits post stroke. For instance, spatial neglect severity, as observed in the activities of daily living, is a significant and independent predictor of upper limb outcome in right hemispheric stroke patients (Vanbellingen et al., 2017). In a prospective study contrasting functional independence and cognitive assessments at two time-points, Jokinen et al. (2015) showed that, even with a good recovery 3 months post-stroke (modified Rankin Scale = 0–1), 69% of first-ever-stroke patients suffered from cognitive impairment affecting one (25%), two (15%) or multiple (32%) domains. In addition, the presence of cognitive impairments was associated with functional dependence 15 months post-stroke. In another longitudinal study, depression and cognitive impairment at 3 months were significantly associated with disability 5 years post stroke (Yang et al., 2016).

Recovery is a long-term process that usually lasts longer than rehabilitation services (Demain et al., 2006). Longitudinal studies have reported that only 34% of stroke survivors are functionally independent 5 years after the accident (Wilkinson et al., 1997). Hence, the important of providing effective home-based solutions that focus on both clinical but also adherence goals. Indeed, evidence shows that the success of any therapeutic intervention is directly related to patient motivation (Maclean et al., 2000). Importantly, the level of adherence to home-based physical training programs is directly correlated to the level of physical activity before the treatment, as well as to the adherence to the training sessions in the clinic (Jack et al., 2010). In particular for stroke, evidence shows that adherence to home-based exercise programs is low, with lack of motivation consistently appearing among the main causes. Other reported barriers include musculoskeletal issues, fatigue (Jurkiewicz et al., 2011), mood disorder (Kim, 2016) and "dependence of therapist" (Ogwumike et al., 2014).

Neurorehabilitation programs inspired from positive psychology, which focuses on the bio-psycho-social aspects of cognitions, emotions, and positive experiences (Riva et al., 2012), may reveal particularly compelling. They can help promote self-confident, self-management and, thus, independence. When integrated into effective training programs, they can boost the rehabilitation outcome and significantly increase the quality of life of stroke survivors (Fryer et al., 2016).

In this position paper, we advocate the combination of four key ingredients that we believe are necessary to design long-lasting effective treatments for neurorehabilitation: (i) motor-cognitive training, (ii) evidence-based neuroscience principles, in particular those related to body perception, (iii) motivational games, and (iv) empowerment techniques. Then, we propose virtual reality (VR) as the appropriate medium to encompass all the requirements mentioned above. Finally, we discuss the advantages of such an approach on several exemplary applications and outline directions for future developments. For the sake of clarity, this paper is not a review of the available evidence on the efficacy of VR in neurorehabilitation – few review and meta-analyses papers are available (Lohse et al., 2014; Corbetta et al., 2015; Dockx et al., 2016; Gibbons et al., 2016; Massetti et al., 2016; Laver et al., 2017). The cited papers are functional to discuss the aforementioned aspects.

THE SYNERGETIC EFFECT OF ADAPTIVE MOTOR-COGNITIVE TRAINING

Up to 75% of stroke survivors suffer from upper limb movement disabilities (Henderson et al., 2007). In addition, up to 80% suffer from cognitive deficits affecting attention, perception or behavior control (Gottesman and Hillis, 2010), which persist 6 months after the vascular event in up to 70% of cases (Mellon et al., 2015). On the other hand, motor rehabilitation cannot proficiently be performed by patients with specific cognitive deficits (Dennis et al., 2011). Finally, such cognitive deficits are strong negative predictors not only of functional recovery (Robertson et al., 1997) but also of quality of life (Barker-Collo et al., 2010). Therefore, training programs should target both cognition and motor recovery, if possible addressing problems encountered in activities of daily living. For instance, one could train reaching (and other related) movements with the affected arm for cooking a sandwich in combination with the problem solving associated with the task (e.g., sequencing, planning).

It is important to tailor any intervention to both cognitive and motor levels of impairment. A preliminary assessment should clearly delineate the profile of motor and cognitive deficits. There is increasing evidence that physical exercise also contributes to improving cognitive functions post stroke (Cumming et al., 2012; Oberlin et al., 2017). Training both motor and cognitive functions simultaneously (instead of in separate sessions) would also increase therapy efficiency, maximizing the amount of therapy (dose) delivered for both modalities while reducing risk of fatigue. The benefits of combining physical and cognitive exercise go beyond recovery itself, as it may enhance overall well-being and reduce multiple risk factors responsible for recurrent strokes and coronary events (Tiozzo et al., 2015). Combination of motor and cognitive training has been shown to also reduce length of hospital stay (Kalra et al., 1997).

INTEGRATION OF EVIDENCE-BASED NEUROSCIENTIFIC PRINCIPLES

The 70% recovery rule has disrupted the neurorehabilitation field and has put the focus on the optimization level of current neurorehabilitation procedures and practice (Prabhakaran et al., 2008; Krakauer and Marshall, 2015). The question arises, however, whether we can do better (beyond that 70%), especially if we can predict recovery chances of stroke survivors. To this aim, neurorehabilitation programs ought to combine evidence-based clinical neurorehabilitation strategies and neurosciences principles. Within that context, few neuroscientific principles have been proposed for motor rehabilitation. Here, we highlight those targeting multisensory stimulation, the mirror neuron system and motivation.

Decades of research in fundamental neurosciences have shown that our senses perform better in the activities of daily living when they are provided with multisensory stimuli (Johansson, 2012). Congruent multisensory stimulation will reinforce reflexes and automatisms whereas incongruent inputs will slow down the responses while requiring higher attentional resources. However, most popular technological solutions for cognitive neurorehabilitation are based on videogame-like (or serious game) approaches, where patients move in front of a console and only receive visual feedback about their movements (often via abstract content not related to the own body). This represents a limited approach, whereby the feedback to the user is limited to a single sensorimotor action-perception loop: the patient moves and receives only visual feedback from the screen.

Since stroke survivors often present sensory loss, it is necessary to propose congruent, multisensory environments that stimulate not only visuomotor coordination but also the somatosensory system, e.g., via tactile and proprioceptive training (Aman et al., 2015). Likewise, multisensory stimulation can include congruent audiovisual stimulation. For instance, in a two-arm study with patients with hemianopia (a defective vision or blindness in half of the visual field), the group following audiovisual training with spatially matching sounds improved visual detection and exploration, oculomotor scanning and activities of daily life, whereas the visual training group did not (Passamonti et al., 2009).

In stroke rehabilitation, priming (a type of implicit learning) of the motor cortex is associated with changes in neuroplasticity that are associated with improvements in motor performance (Stoykov and Madhavan, 2015). Mirror neurons found in key motor areas respond not only during action execution but also to action observation, i.e., the motor system may be activated without overt movement, which enables training interventions also in case of severe hemiparesis (Garrison et al., 2010; Buccino, 2014). Together with related techniques like motor imagery and mirror therapy, these approaches have proven effective as potential adjuncts to motor training -with the caution that many articles include small samples and there may be a publication bias as adequate control conditions are sometimes missing (Deconinck et al., 2015)-, even though individual factors that may predict response to treatment (e.g., lesion size, co-morbidities, psychosocial) are still to be identified (Stoykov and Madhavan, 2015).

Neurorehabilitation interventions can also benefit from neuroplasticity enhanced by rewards. In particular, the ventral striatum has been suggested to act as a common motivational node able to switch connectivity between motor and cognitive circuits depending on the task demand: the same extrinsic reward (coin images) can trigger the recruitment of cognitive (by increasing caudate nucleus activity when the task is mentally demanding) and motor regions (by increasing the putamen activity when the task is physically demanding) (Schmidt et al., 2012). Rewarding tasks that combine both motor and cognitive demands could therefore lead to activation of both motor and cognitive pathways. Altogether, basing neurorehabilitation programs on current neuroscientific understanding and transferring them into clinical practice via personalized treatments (e.g., enabled by technology-mediated interventions), could therefore help boost recovery.

ENJOYMENT AND MOTIVATION THROUGH GAMIFICATION

Determining the training features to the patient's pace of recovery not only maximizes training potential, but also prevents habituation and frustration. This facilitates keeping patient motivation at an optimal level during the long rehabilitation process. Neurorehabilitation programs should, thus, inspire from Seligman's "PERMA" theory (i.e., positive emotions, engagement, relationships, meaning and achievement; Seligman, 2011) and include activities that enable the patient to float in their Flow Zone, defined as where the person is at a high level of enjoyment with a balance between the difficulty of the task and the abilities of the person (Csikszentmihalyi, 1990). In this state of flow, the person feels comfortably challenged and highly engaged by the task feeling high levels of enjoyment. Maintaining a state of flow is important for promoting patient adherence to treatment, especially for home-based rehabilitation.

Repetitive routines of same actions of current rehabilitation programs (either motor or cognitive) do not contribute to the endurance of patient motivation in the long term. The impact of physical activity can be strengthened when training activities go hand in hand with enjoyment (Hagberg et al., 2009). Enjoyment through computer (serious) games is likely the most common approach for healthcare applications, ranging from behavior change (Baranowski et al., 2008) to rehabilitation (Nap and Diaz-Orueta, 2013).

For instance, Anguera et al. (2013) showed that, by using adaptive computer games to provide fully controlled dual-task training based on principles of cognitive control, it was possible to improve multitasking abilities in neurologically healthy elderly individuals, with gains persisting for 6 months. Personalized gamified tasks can also help strengthen brain modulation through variable attentional demands. Indeed, strategic divided attentional training programs with variable task foci have been suggested to recruit larger brain networks than single repeated practice. This could help prevent cognitive decline in healthy older adults and for those involved in rehabilitation of individuals with brain damage (Belleville et al., 2014).

Appropriate and timely feedback (e.g., encouraging messages) together with online adaptation of difficulty levels (matching patients' needs and capabilities at every moment) can boost patient motivation. This can be achieved by setting realistic objectives, not too easy and not too hard, to maintain patients' motivation as long as possible. Another technique is to introduce both unexpected events (that generate reactions of surprise that capture attention), mechanisms of control (if patients have the impression they control the situation, then they will remain proactive), and rewards (both online and offline). Rewards need to vary as well to reinforce vigilance and an interest in understanding *why* and *when* they are given. Frank et al. (2004) have shown that rewards should be tailored to the patient pathology and to the prescribed treatment. For example, Parkinson patients off medication would be more sensitive to negative rewards than those undergoing dopamine treatment. Thus, modulating positive and negative feedback accordingly should lead to optimal reinforcement learning processes. In sum, a clever interplay between therapeutic goals and gamification tools should be taken into consideration to maximize outcomes (Mader et al., 2016).

PATIENT EMPOWERMENT

As their recovery progresses, it is important that patient autonomy is encouraged in order to reduce patient (and caregiver) dependence, especially when the return to home is approaching. Once back home, patients usually have to exercise on their own or with a fading supervision provided by both the caregiver and the therapist, with the latter sometimes remotely connected. Thus, training strategies should encourage patients to progressively manage their own motor and cognitive recovery as a motivational drive. This would have cascading effects on therapy intensity, duration and adherence, resulting in long-lasting positive outcomes. These, in turn, may transfer to real life and contribute to attaining a level of autonomy required for living independently.

"Patient empowerment is a core principle of patient-centered care and reflects one's ability to positively affect his or her own health behavior and health status" (Govender et al., 2015). It is thus crucial to teach a patient to admit that they can influence their own health. This should be done by first giving them the knowledge of *what* impairments they are suffering from, *when* they will encounter difficulties in their daily living activities and *how* they can deal with them by using different strategies (educational content). This process aiming at self-management involves both meta-cognitive (i.e., having both knowledge and consciousness of the problem) and learning strategies to face the daily living difficulties resulting from cognitive and motor deficits. Recent meta-analyses and systematic reviews on self-management programs for stroke survivors living in the community have shown reliable evidence that such programs increase participation, functional ability, and have positive effects on their quality of life (Warner et al., 2015; Fryer et al., 2016). Hence, these benefits are best transferred to daily life only when the program is personalized (mode of delivery, frequency, duration). In an empowerment intervention on stroke patients' self-efficacy, Sit et al. (2016) found that empowered patients reported better functional recovery, especially in activities of daily living, and better self-management of their cognitive symptoms than a control group receiving standard therapy.

VIRTUAL REALITY AS A VEHICLE TO BOOST MOTOR-COGNITIVE NEUROREHABILITATION

VR is likely today's most powerful experiential technology available, i.e., a technology able to create immersive live experiences. One of the most recurrent terms associated with VR is "videogame," particularly in the entertainment industry. Besides positively affecting motivation and enjoyment of training, videogames also impact cognition. In particular, playing action videogames (i.e., games that emphasize physical challenges, e.g., hand–eye coordination and reaction time) has been shown to robustly enhance attention and spatial cognition (Bediou et al., 2018). Exergames (i.e., physically active videogames) have been shown to improve cognition in both clinical and non-clinical populations, including executive functions, attention and visuospatial skills (Stanmore et al., 2017). VR can boost these effects by delivering those games in highly immersive and interactive environments and, importantly, tapping mechanisms of intrinsic (i.e., autonomous) and extrinsic (e.g., arising from rewards) motivation (Howard, 2017). For instance, one could imagine an immersive VR cooperative or competition task for promoting intrinsic motivation while reinforcing extrinsic motivation through gamification elements like progression scores and customization of the environment or virtual character. Those patients proud of their performance and progress and may be willing to share it with their close family and friends to reinforce their interindividual relationship.

From a neuroscientific perspective, VR offers multisensory stimulation able to evoke the mirror neuron system and mechanisms of action observation, among other therapeutic techniques, which have been suggested to be effective for motor recovery (Stoykov and Madhavan, 2015). VR represents a unique medium for neurorehabilitation where participants can embody a virtual body that can gather synthetic multisensory (visual, motor, touch) stimulation (Perez-Marcos et al., 2012). This stimulation versatility can be used to systematically modulate (stimulate or attenuate) activity in specific brain regions (You et al., 2005; Adamovich et al., 2009). Virtual embodiment (i.e., the illusion of having and feeling as if real a virtual body in VR) is a critical factor in VR experiences that can be exploited to improve not only visuomotor coordination (as shown in motor rehabilitation post stroke), but also for cognitive-related deficits such as spatial attention impairments, executive dysfunction or memory loss. For instance, by adding body manipulations through embodiment illusions in an immersive environment, the eventual affected spatial perception of a stroke patient could be challenged, e.g., by means of a visuomotor adaptation task.

Regarding multisensory stimulation, interactive technologies like VR are best placed to incorporate closed-loop mechanics of challenge adaptivity with gaming environments and enriched multisensory feedback (Mishra et al., 2016). Such enriched virtual environments have the potential to optimize motor learning by manipulating practice conditions that explicitly engage motivational, cognitive, motor control, and sensory feedback-based learning mechanisms (Levin et al., 2015). For example, people with Parkinson disease showed similar improvement in reaching performance after training to respond to moving balls both in VR and physical environments by using appropriate cueing speed (Wang et al., 2011). Real-time movement feedback can also be used to reinforce control of movement parameters, e.g., joint trajectory, and to reduce compensation movements, e.g., excessive trunk displacement (Subramanian et al., 2013). Adding vibrotactile feedback on tubes simulating oars in a VR-based rowing game, with an avatar representing the user's arms rowing from a first-person perspective, can help convey the illusion of movement to the user (Vourvopoulos et al., 2016). Vibrotactile feedback can also be used to improve the motion symmetry on stroke rehabilitation (Hung et al., 2015). Coincident audiovisual spatial feedback provided in a head-mounted display environment could help patients with hemispatial neglect to regain a coherent sense of space. This feedback can extend to other behavioral, cognitive, and emotional changes captured by dedicated sensors. Making these inputs explicit for patients gives them the opportunity to become aware of their problem (meta-cognition) and progress, which will favor patient autonomy in the long term and, thus, their empowerment.

VR-mediated motor-cognitive interventions can help retain and transfer to real life the outcomes obtained during the training period. For example, a longitudinal study with community-living older adults compared the effectiveness of motor versus motor-cognitive training, the motor component mediated by a treadmill and the cognitive component by non-immersive VR, to reduce the number of falls. The virtual environment imposed a cognitive load that demanded attention, planning and dual tasking. The effect was higher in the motor-cognitive group, with incident rate of falls continuously decreasing to half at 6 months after completion of the training (Mirelman et al., 2016). Personalization of the training content into the scope of patients' daily living activities can contribute to the transfer of training outcomes and to promote autonomy in activities of daily living, e.g., by training cooking activities in a virtual kitchen (Foloppe et al., 2018) or shopping in a virtual supermarket (Rand et al., 2009).

A critical feature for an effective rehabilitation program is the possibility of adapting the training based on the patient's needs and performance. When applied to motor rehabilitation post stroke, VR easily allows progressively adapting the training program via automated systems based on the patient's performance, for adapting the task difficulty levels (Ballester et al., 2016), or based on reinforcement-based therapies, for counteracting learned non-use of the impaired limbs (Ballester et al., 2015). In addition, and to lead to further improvements in performance (Anguera et al., 2013; Shin et al., 2016), adapting the motor and cognitive load can also help face different rehabilitation challenges, such as fatigue and adherence. For instance, a VR-based training program could progressively challenge patients with hemispatial neglect by adapting the difficulty of a visual scanning task and lateralizing the reward amount to drive patient attention to the neglected hemispace.

Kinematics and other objective measures provided by VR systems (e.g., motion capture, eye tracking) can be used for adapting the difficulty level of the tasks. Moreover, VR technology can also integrate physiological signals allowing monitoring the level of arousal or affective state (e.g., via galvanic skin response, heart rate, EEG). This information can be used to adapt the training, in real time, to the patient's status (at all three levels: physical, cognitive, and affective) in order to perpetuate the patient's feeling of completeness and energized engagement in the therapeutic activity. Ultimately, the training program should offer patients the opportunity to select the virtual environment/task that motivates them or better fits their interests and values, as well as its personalization (e.g., favorite color, avatar appearance). For instance, for bed bound patients, immersion into outdoor environments of their choice could represent a way to virtually leave the hospital for a while. Further approaches should also consider the integration of technologies able to read people's emotions, e.g., based on facial expressions or other neurophysiological markers, to enhance motivation levels.

Finally, VR-mediated rehabilitation programs provide an ideal means to ensure the continuum of care, from early stages at hospital to home-based interventions and follow-up. VR is destined to become ubiquitous in our society thanks to the mass-market arrival of ease-of-use and affordable devices, which are perfectly eligible for home treatment. VR platforms are easily scalable: measurement (motion capture, EEG, instrumented objects, etc.) and stimulation (head-mounted display, haptic feedback, functional electrical stimulation, etc.) instruments as well as accessories required at each rehabilitation stage and by each individual intervention can be integrated as required. In particular, any data collected can be remotely accessible to clinicians, therapists and caregivers to monitor patient performance and behavior, to act consequently (e.g., updating the training program, providing assistance).

How to Exploit Performance Measures for Objective Motor and Cognitive Assessment

The same neurophysiological and behavioral information collected for adapting difficulty levels and other parameters in VR-based training can also be applied for assessment of the treated deficits. For instance, head gaze and motor performance during exposition to an ecological task for evaluation of the far space in a virtual environment can extend the evaluation of stroke patients with unilateral spatial neglect. Preliminary results suggest that ecological immersive VR-based assessments could help detect unilateral spatial neglect in chronic patients who do not show signs of neglect in standard paper-and-pencil assessments (Ronchi et al., 2018).

Extending the use of VR to assessments presents at least three main advantages: (i) technologies inherently used in VR-mediated solutions can provide additional and objective measures to expand today's clinical assessments, e.g., using motion capture technology to evaluate range of motion based on acquired kinematic information of the limb movements (Shishov et al., 2017); (ii) integration of these assessments into the training programs can help develop "smart" protocols that optimize recovery and learning, e.g., determining specific attentional deficits in a real-world simulated scenario (something not possible with paper-and-pencil assessments) in order to prescribe the right training; and (iii) as VR-mediated medical devices will populate hospitals and clinics and, consequently, databases of clinical data will grow, new assessment standards may be created. Their cross-validation with clinical and other neurophysiological markers (e.g., neuroimaging) may help identify advanced predictors of recovery that may be used to personalize treatments, e.g., by means of machine learning algorithms.

Challenges of VR-Based Systems for Neurorehabilitation

All the above-mentioned potential advantages can be put best into practice with optimal VR systems. Nowadays, however, VR technology is not equally developed in all its domains. For example, while visual displays are highly immersive (with high resolution and low latency) and affordable (in a minimalistic form, just a cardboard and our smartphone are necessary), other sensory inputs and actuators are not mature yet. Regarding tactile haptic rehabilitation, there is still a need for both scientific and technological developments to ensure its full potential is realized

(Demain et al., 2006). Similarly, integration of olfactory and taste senses is still in its infancy (Spence et al., 2017).

The second big challenge is building clinical credibility. Despite the existence of several reviews and meta-analyses on VR for stroke (Lohse et al., 2014; Gibbons et al., 2016; Laver et al., 2017), Parkinson disease (Dockx et al., 2016), multiple sclerosis (Massetti et al., 2016) and multiple neurological conditions (Cano Porras et al., 2018), results about the effectiveness of VR-mediated training are yet inconclusive. One main reason for this is that many studies include small sample sizes as compared to the great variability of the tested clinical populations, which makes extremely difficult to control for other variables such lesion location and size, severity of impairments, phase of recovery and, importantly for cognitive functions, no separation between age or level of education (Fetta et al., 2017). Another key factor is the choice (or lack) of the control group to compare the effect with: for instance, for home rehabilitation, if the effectiveness of a VR-mediated training (with the therapist remotely shaping and monitoring the training program) is compared to that of 1-to-1 therapy sessions of the same intensity and duration with a highly trained clinician, the non-inferiority of the VR-mediated training should be actually considered as a positive outcome, independently of other socio-economic advantages such as reduced costs. Conversely, in motor rehabilitation for stroke patients, VR has been introduced with the aim of allowing increased rehabilitation dosage compared to traditional therapies. In this vein, there is encouraging evidence that VR may improve upper limb function in hemiplegic patients when added to standard physical therapy (Laver et al., 2017). However, only few studies have focused on the use of VR-mediated interventions for cognitive neurorehabilitation. Indeed, people with significant cognitive impairment are excluded from most studies of VR-mediated motor rehabilitation, making unable to pool results for cognitive function and, thereby, preventing comprehensive conclusions about how applicable VR-mediated interventions are to a wide range of stroke survivors (Laver et al., 2017). A recent feasibility study comparing both standard therapy and VR-mediated solutions has shown additional difficulties of subacute stroke patients to recover physically and cognitively when they present mild cognitive impairment, and particularly signs of depression (Cameirão et al., 2017). In a 1-month randomized controlled trial with 18 chronic stroke survivors, the VR group showed significant improvements in global cognitive functioning, attention, memory, visuospatial abilities, executive functions, emotion and overall recovery: a between groups analysis showed significantly greater improvements in global cognitive functioning, attention and executive functions when comparing VR-mediated to conventional therapy (Faria et al., 2016). However, that study did not include follow-up or measure of transfer to real life. Therefore, although recent studies start taking some of these aspects into consideration (e.g., Faria et al., 2018), additional larger and high-quality studies with stratification including different conditions are needed. Those studies should target the role of the diverse mechanisms underlying the therapy (e.g., the visual feedback, the multisensory integration, the embodiment), rather than comparing just VR versus other therapies. This would help us understand what is(are) the effective element(s) for each patient profile (based, for instance, on lesion size and location, deficit severity), how and under which conditions (how, how much, when, how often) they should be delivered.

CONCLUSION

In summary, VR is arguably one of the most suitable technologies for neurorehabilitation, able to integrate evidence-based neurorehabilitation techniques and neuroscience principles into motivating training approaches that promote self-management by empowering patients to own their recovery process. We strongly believe that the combination of positive psychology and positive technology (Riva et al., 2012) mediated by VR-based interventions can heavily impact the rehabilitation outcomes of motor-cognitive along all the stages of the rehabilitation path.

AUTHOR CONTRIBUTIONS

DP-M and MB-A drafted the manuscript with important contributions from AS. All authors participated in the review and revision of the manuscript and have approved the final manuscript to be published.

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MINI REVIEW
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Episodic Memory Assessment and Remediation in Normal and Pathological Aging Using Virtual Reality: A Mini Review

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Life expectancy is constantly increasing in developed countries. Unfortunately, a longer life does not always correspond to a healthier life, as even normal aging is associated with cognitive decline and increased risk factors for neurodegenerative diseases. Episodic memory (EM) is one of the most vulnerable cognitive functions in aging, and its decline is the hallmark of typical Alzheimer's disease. This memory system is defined as the ability to acquire and recollect personally experienced episodes associated with a specific affective, spatial, and temporal context. However, most of the neuropsychological and experimental tasks currently employed to assess EM consist in learning simple material (e.g., list of words) in highly stereotyped contexts. In the same vein, classical paper-and-pencil or numeric remediation tools have shown their limitations in the transfer of acquired skills to daily life. Virtual reality (VR), thanks to its immersive properties, and the possibility of delivering realistic and complex scenarios, seems a promising tool to address the limitations of the assessment and remediation of EM. Here, we review existing studies employing VR in normal and pathological aging to assess and reeducate EM. Overall, we show that VR has been mainly used via non-immersive systems. Further studies should, therefore, test the impact of different degrees of immersion. Moreover, there is a lack of VR remediation tools specifically targeting EM. We propose that future studies should fill this gap, addressing in particular the adaptivity of VR remediation protocols.

Keywords: episodic memory, virtual reality, assessment, cognitive remediation, aging, Alzheimer's disease

AGE-RELATED COGNITIVE DECLINE: THE CRUCIAL ROLE OF EPISODIC MEMORY

Given the global aging of the population and its associated cognitive decline, designing sensitive diagnostic tools for early symptom detection, and effective intervention to attenuate age-related cognitive decline is a global societal priority. One of the first cognitive functions impacted by aging is episodic memory (EM). EM is defined as the ability to acquire and recollect personally experienced episodes (what) associated with a specific spatial (where), and temporal (when) context (Tulving, 1972; Tulving and Murray, 1985). This type of memory is based on associative processes known as "binding" that connect the contextual features of the specific events. EM impairment is also considered as the earliest clinical sign of typical Alzheimer's disease (AD) (Epelbaum et al., 2018), preceding that of other cognitive functions (Grober et al., 2008; Derby et al., 2013). Rather than offering a complete measure of EM components, most clinical memory tests generally measure only one aspect in isolation (e.g., what). To overcome these limitations researchers have relied on advances in virtual reality (VR).

Virtual reality allows creating immersive and interactive multimodal environments. VR systems can vary in their degree of immersion and interaction which, in turn, modulates the subjective feeling of presence, defined as the feeling of "being there" (e.g., Cipresso et al., 2018). For the purpose of this review, we will classify VR systems on two orthogonal axes: immersion and interaction. On the first axis, there are at one extreme non-immersive systems (NIS) that present the VR environment on desktop computers, and at the opposite pole, fully immersive systems (FIS) that employ head-mounted displays (HDM) with head-movement tracking systems allowing sensory-motor contingency. On the second axis, at the lowest level, there are systems where participants are passive (PS), and at the highest level participants can complexly interact (IS) with the environment thanks to different kinds of devices (e.g., steering wheel, cyber-gloves, posture tracking sensors). For the sake of clarity, we will employ throughout the manuscript this terminology, while recognizing that VR systems can present intermediate levels on both axes.

At the theoretical level, the use of VR in memory studies addresses the pivotal role of self-experience and bodily representation, raised by the embodied cognition framework (Barsalou, 2008; Shapiro, 2011), in supporting EM (Bergouignan et al., 2014; Repetto et al., 2016; Tuena et al., 2017; Blanke et al., 2018). Repetto et al. (2016) pointed out three main VR features that may impact EM: (1) VR enables situations to be experienced from an egocentric point of view; (2) VR allows active exploration of the environment; and (3) VR provides environmental enrichment by using flexible scenarios with different degrees of complexity. Moreover, by employing VR researchers can reproduce complex real-like scenarios while maintaining high experimental control over stimuli presentation. This enables the complexity of EM to be investigated, in particular, its central feature of relying on contextual associations. Thus, one of the most important advantages of using VR consists in the evaluation of the binding process (Abichou et al., 2017; Plancher and Piolino, 2017). In this mini review, we give an overview of recent representative studies employing VR to assess and remediate EM in healthy and pathological aging. We will conclude by highlighting the limitations of existing work and proposing a roadmap for future studies.

EPISODIC MEMORY ASSESSMENT IN NORMAL AND PATHOLOGICAL AGING VIA VIRTUAL REALITY

Assessment in Healthy Aging

In a first pilot study, Plancher et al. (2008) employed NIS VR (the environment was projected on a 85 cm × 110 cm screen) to investigate the effects of age (young vs. older adults), encoding (intentional vs. incidental), and exploration (active vs. passive) on the main aspects of EM. In the passive condition (PS) subjects were immersed as passengers of a virtual car, while in the active one (IS) they drove the car with a steering-wheel and a gas pedal. Participants navigated in a virtual town, encountered different events (e.g., a car accident), and at the end of the navigation they carried out a recall session assessing memory for items and contextual information. The main results showed that aging was associated with diminished contextual memory, but not factual memory, and that the only significant difference was in intentional encoding. However, no effect of the type of exploration (active or passive) was observed. In a following study, employing the same VR system, the authors investigated the associative mechanism of EM by computing different binding scores according to the richness of the contextual information recalled (Plancher et al., 2010). The encoding phase (incidental or intentional) occurred during active navigation of the environment. They reported that older participants were selectively impaired in higher-order binding (e.g., associating several items of contextual information), in particular in recalling the spatio-temporal context in the intentional encoding condition. Moreover, they showed that memory performances assessed using VR were more reliably associated with general cognitive functioning and subjective memory complaints, compared with standard neuropsychological tools.

Other studies have compared the effect of passive vs. active navigation in a virtual environment in modulating age-related differences in memory performances. Sauzéon et al. (2016) used a NIS VR (the environment was projected on a 200 cm × 188 cm screen) based on the California Verbal Learning Test (Delis et al., 1987) to investigate memory for everyday objects (Sauzéon et al., 2012). They reported that active navigation, performed using the keyboard and the mouse, increased recognition hits compared with passive navigation in both young and elderly participants. Furthermore, active navigation decreased false recognitions in young adults, but an opposite effect was observed in older participants. The association between false recognition and age was totally mediated by executive function performances. This is consistent with the idea of an additional burden induced by real-life conditions (e.g., active navigation) on source monitoring in aging.

Jebara et al. (2014), employing a NIS environment (projected on a large screen covering 66° of the visual field), went a step further, studying the influence of different degrees of interaction on EM encoding: passive navigation (subjects were passengers of a virtual car), itinerary control (subjects chose the itinerary, but did not physically drive the car), low navigation control (subjects controlled the displacement of the car on rails by a gas pedal on a fixed itinerary), or high navigation control (subjects drove the car with the steering-wheel and a gas pedal on a fixed itinerary). The task was to memorize as many events as possible along with contextual features. Results showed a general age-related decline for immediate and delayed feature binding. Compared to passive and high navigation control conditions, and regardless of age groups, feature binding was enhanced in the low navigation and in the itinerary control conditions. Interestingly, memory performances following the high navigation condition depended strongly on executive functioning.

The aforementioned studies employed VR to simulate the encoding of real-life events and tested memory performance outside VR. Other studies, on the contrary, employed realistic virtual scenarios to test memory, while performing encoding in more classical conditions (e.g., memorizing a shopping list). Parsons and Barnett (2017) recently tested the Virtual Environment Grocery Store (VEGS) task as a measure of EM function in the elderly. VEGS comprises a NIS simulation of a grocery store in which participants have to carry out different activities (IS) constructed to measure both prospective memory (e.g., return to the pharmacist when they hear their number), and retrospective EM (e.g., finding and selecting items from a shopping list that has been previously learned). VEGS memory scores significantly correlated with scores of standard neuropsychological episodic verbal memory tests, but not with those of executive functions, supporting the construct validity of this tool.

The Virtual Shop is a new FIS-IS interactive environment in which participants have to select a list of items, previously memorized outside VR, during navigation in a convenience store (Corriveau Lecavalier et al., 2018). In their first study, the authors compared the performances of young and old participants, reporting that older adults performed less well. In the second study, they tested older adults with subjective cognitive complaints on the same task and standard measures of memory, executive functions, and a subjective measure of memory difficulties in daily life, comprising questions referring to shopping activities (e.g., How often do you forget to buy something you intended to buy?). They reported that performance in the Virtual Shop was correlated with the measure of memory in daily life and a standard measure of memory. In addition, their findings indicate that the use of a fully immersive task is feasible in older adults: it elicits presence, it is engaging, and provokes limited symptoms of cybersickness (Ouellet et al., 2018).

Another recent study designed a VR NIS-PS task to reproduce the CVLT rendered by a stereoscopic HD projection system (3D), in young and older adults using a kitchen scene (Pflueger et al., 2018). The results showed that age-related learning and performance decrements were mainly evident in the standard CVLT but not in the VR-memory examination. The authors concluded that performances in VR tasks might provide a more accurate "age fair" estimation of everyday life than standard neuropsychological tools.

Assessment in Pathological Aging

So far, the functioning of EM in AD and amnestic mild cognitive impairment (aMCI), such as memory for items, has been mainly evaluated with verbal material, indicating deficits of free and cued recalls, and recognition. There are only a few studies employing VR to assess EM in neurodegenerative diseases (García-Betances et al., 2015).

Widmann et al. (2012) used a photorealistic NIS virtual reality model of a city (projected on a 200 cm $\times$ 300 cm screen) with passive navigation (i.e., NIS-PS) to assess verbal and spatial EM, comparing it to standardized neuropsychological tests in healthy elderly control participants and patients with mild AD. Participants were instructed that they were going on a shopping trip through the jewelry district of a large city. Then they were asked to read and remember the names of specific shops. The authors reported that the increased complexity of learning in a virtual environment brings to the fore the impairment of free memory recall in patients in a more clear-cut way than that achieved with classical list learning tests. Thus classical neuropsychological tasks may underestimate memory capacity in daily life situations. The authors concluded that learning verbal material in a realistic virtual environment is comparable to classic list learning in healthy elderly individuals but is more severely impaired in very mild AD patients.

In another study, Plancher et al. (2012) tested healthy older adults, patients with aMCI, and patients with AD with a NIS-IS or PS virtual task similar to those employed in the aforementioned studies (Plancher et al., 2008, 2010). They found that AD patients' performances were poorer than those of aMCI patients, and even more so than those of healthy elderly. Spatial allocentric memory was found to be particularly useful for distinguishing aMCI patients from healthy older adults. Active exploration, compared to passive exploration, yielded enhanced recall of central and allocentric spatial information, as well as binding in all groups. This led aMCI patients to achieve better performances on immediate temporal memory tasks. Finally, the patients' memory complaints were more strongly correlated with their performances in the virtual test than with those achieved in classical memory tests.

In summary, some of the previous studies in healthy and pathological aging investigated the effect of the degree of interaction of the VR system on EM. The results are not consensual, with some studies reporting no differences between an active and passive condition (Plancher et al., 2008), while others reported a beneficial or detrimental effect for correct and false recognition, respectively (Sauzéon et al., 2016). Still other studies reported an enhancement or decrease in performances depending on the type of immersion (Jebara et al., 2014), with the highest benefit being obtained with degrees of interaction that do not excessively tax cognitive resources. Indeed, the association between the degree of interaction and memory performance has been shown to depend on the executive performances. These findings suggest that the interaction should be tailored, particularly when using VR as a cognitive remediation tool, to the cognitive abilities of the participants. On the contrary, with the exception of one study (Corriveau Lecavalier et al., 2018), the aforementioned research exclusively employed NIS. Thus, even if theoretically sound, the impact of different degrees of immersion on EM has not been directly tested. Although the study of Corriveau Lecavalier et al. (2018) suggests the feasibility of using FIS to assess EM in the elderly, they did not compare it to a NIS to assess the modulatory role of immersion on EM. These studies, however, highlight the benefit of using VR in assessing EM in both healthy and pathological aging, since the performances obtained with VR tasks correlated better with daily life difficulties and subjective memory complaints. Moreover, VR evidenced EM impairment in mild AD more straightforwardly.

REMEDIATION IN NORMAL AND PATHOLOGICAL AGING VIA VIRTUAL REALITY

Recent advances in VR technology have improved applications for cognitive rehabilitation (Larson et al., 2014). Several studies have shown the efficiency of VR in cognitive remediation (Rizzo et al., 2004), and its transfer to real life thanks to a multisensory and immersive environment. Within this context, Clemenson and Stark (2015) demonstrated that training (via NIS-IS) naive video gamers on a complex 3D strategic game, but not on a simple 2D fighting game, improved EM and spatial memory in tasks known to be related to hippocampal activity in young subjects (e.g., item discrimination, virtual water-maze). On similar lines, West et al. (2017) showed that video-game training (via NIS-IS) using a specific 3D video-game (Super Mario 64 with a Nintendo Wii console system) can have a positive effect on the hippocampal memory system in older adults.

Although these studies (Clemenson and Stark, 2015; West et al., 2017) used well-known video-games (e.g., Super Mario), instead of realistic environments, their findings support the view that EM can be enhanced in older adults by means of enriched 3D scenarios. In a more ecological context, Gamito et al. (2018) designed a set of NIS VR exercises that mimic activities of daily life by which elderly subjects can train different cognitive domains. They reported significant performance increases for some of the neuropsychological measures: visual memory, attention, and cognitive flexibility.

Other VR systems have been proposed to enhance cognition in both the elderly and in pathological aging. A systematic review by Jekel et al. (2015) suggested that various VR applications for instrumental activities of daily living assessment could also be employed for cognitive training in MCI patients (Werner et al., 2009). For instance, Zygouris et al. (2015) developed the Virtual Supermarket (VSM) NIS-IS cognitive training, designed to mimic daily shopping in a supermarket, aiming at improving multiple aspects of the cognitive functioning that are necessary for autonomous living in aging (e.g., the patient is asked to buy items displayed on a shopping list). Preliminary results suggested that monitoring longitudinal performance on the VSM training could provide useful diagnostic information to detect MCI (Zygouris et al., 2017). In the same vein, in the GRADYS FIS-IS software, which combines simulation of everyday life activities and different levels of difficulty, the participants are able to control their immersion and interaction with VR using a headset (Oculus Rift) and a control pad (Zając-Lamparska et al., 2017). The above-mentioned studies focused mostly on navigation skills, cognitive functionality, and other instrumental activities of daily living, not specifically on EM. VR has also been used for training patients with Alzheimer's disease in everyday activities. Foloppe et al. (2018) developed a NIS-IS VR platform for training AD patients in everyday cooking activities based on errorless learning, vanishing-cue, and virtual reality techniques. A first case study showed that the AD patients were able to relearn some cooking activities using VR and transfer this learning to real life.

CONCLUSION AND PERSPECTIVES

We have presented a glimpse of VR applications for the assessment and training of EM in normal and pathological aging. It is difficult to unambiguously conclude on which features of VR are the most important in assessing and stimulating EM, since although some studies manipulated the degree of interaction of the VR system, only one study employed FIS. The immersion dimension of VR, surprisingly, has not been studied extensively. Future studies should compare VR systems by systematically varying the degree of immersion and interactivity to determine the best setting for studying EM. Moreover, as emerges from the literature reviewed above, the best technological features (e.g., interaction) of a given system may partially depend on the population that is being tested. This is particularly important in designing VR remediation tools. A central aspect of VR experience that has been neglected in studies on EM is presence. This is surprising given the importance of presence in the VR literature *per se*, its relation with EM performance in VR (Nash et al., 2000), and recent empirical findings on the link between presence and EM in ecological settings (Makowski et al., 2017). One of the possible reasons for this gap is that presence is often assessed via subjective reports, with no consensual objective measures. Future studies should address this issue.

Moreover, to date, research on VR-based neuropsychological assessments has been largely exploratory and often lacking in psychometric rigor (Parsons and Barnett, 2017). Further research should provide normative data on the different tasks in order to introduce them in clinical neuropsychological practice.

Concerning rehabilitation applications, preliminary results point out the feasibility of VR training in healthy elderly as well as in pathological populations. Nevertheless, apart from two studies using 3D video-games, none of the VR studies based on simulation of a naturalistic environment and daily life activities specifically targeted EM. Moreover, even if research in other cognitive domains (e.g., cognitive control) has shown that the adaptivity of the training plays a pivotal role in its efficacy (Anguera and Gazzaley, 2015), no research has addressed this feature of VR training specifically targeting EM. A vital feature that could make an important impact on future VR clinical applications could be the development of virtual assessment and training tools that are flexible and adaptable to the individual's cognitive profile.

AUTHOR CONTRIBUTIONS

VLC, MS, and KA collected the materials and resources needed for this review. VLC and MS conceived and wrote the paper. PP provided suggestions on the structure of the paper and revised each draft. VLC, MS, and PP approved the final version of the manuscript.

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Combining Virtual Reality and Biofeedback to Foster Empathic Abilities in Humans

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Recent technological advances coupled with progress in brain and psychological sciences allow the controlled induction and regulation of human psychophysiological states. These progresses often aim toward the goal of developing human-machine interfaces to improve human factors such as mental health, human relations, well-being, and empathy. In this short article, we present some of such devices with a particular emphasis on technology aiming to foster empathic abilities in humans; that is, our ability to care, understand, and help our fellow human beings. In order to discuss any possible use for such devices in a clinical setting, we start by outlining definitions for the terms used in the article, and present three devices designed with the goal of modulating empathy in humans.

UNDERSTANDING EMPATHIC PHENOMENA

Empathy is a vague term often used to describe a broad range of phenomena. These empathic phenomena are related to several interconnected motor, cognitive, emotional, motivational, and behavioral functions (McCall and Singer, 2013). Two of the most discussed aspects of empathy are affective and cognitive empathy. Cognitive empathy simply refers to the ability to predict various mental states of another person (Reniers et al., 2011; Myszkowski et al., 2017). Affective empathy refers to an isomorphic emotional response to somebody else's feelings, combined with a clear self-other distinction—i.e., a metacognitive ability to recognize another as being separate from oneself (de Vignemont and Singer, 2006; Decety and Meyer, 2008; Singer and Lamm, 2009; Decety, 2010).

Affective empathy may lead to both positive and negative effects. Highly distressing empathic stimuli for example can lead observers to develop empathic distress, which in turn may lead to burnout (Hojat et al., 2009; Klimecki et al., 2013), or to self-centered responses with negative consequences on social behavior (Decety, 2010). To a certain extent, the negative effects of affective empathy can be trained, limited, and avoided. When such top-down processes of emotion regulation are successful in limiting the stress response, subjects can learn to transform empathic distress into healthy and prosocial reactions.

One critical prosocial mechanism is the emotion of compassion (Decety, 2010). Compassion involves recognizing someone else as part of a collective shared humanity and extending benevolence and care for the welfare of that individual. While empathy triggers a parallel isomorphic emotion to another person's distress, compassion has been found to trigger neural areas related to affiliation (Klimecki et al., 2014). In the following sections we examine how various technologies attempt to predict and control both negative and positive effects of these empathic phenomena at the three levels of mind, brain, and behavior.

BIOFEEDBACK AND BRAIN CONTROL INTERFACES TO MODULATE EMPATHY

Biofeedback mechanisms and brain-control interfaces are two of the main kinds of technology aiming to regulate the negative effects of affective empathy. Bio-feedback mechanisms are interactive systems, which record biosensor data to provide real-time feedback to the user through data visualizations, games, cinematic narratives, or virtual environments. Biofeedback systems have been incorporated into so called "serious games" to train self-awareness and emotion regulation abilities. This is often done so by means of reward: better performance at emotion regulation leads to in-game advantages.

For example, feedback of cardiovascular related signals has been found effective in reducing anxiety before public speaking presentations (Azevedo et al., 2017). By decreasing heart rate through a tactile feedback device, Azevedo and colleagues led participants to experience relaxation in a stressful context, in comparison to subjects exposed to accurate biofeedback. Concerning affective empathy and social emotions, one biofeedback game created by Blandon et al. (2016) aims at enhancing empathy in teenage populations. In this game, virtual telekinetic abilities and time-manipulation are mapped to changes in attention and self-regulation. In order to effectively cooperate and solve tasks collaboratively, the user must control attention and stress in response to visual parameters and objects.

Another line of work aiming to regulate affective empathy are brain computer interfaces (BCI). BCI function by measuring brain activity, extracting neural signatures, translating such neural signatures into computer commands, and providing this information back to the users through an interface (Vourvopoulos et al., 2017). BCI use neural measures to index attentional, emotional, and cognitive states. For example, evidence suggests that frontal alpha asymmetry can provide reliable estimation of emotional valence (Davidson et al., 1990), and that prefrontal brain activity is strongly related to the process of mentalizing (Heatherton et al., 2006). These studies are conducted under the assumption that users provided with information about their own psychophysiological activity through BCI feedback become increasingly aware of their own empathic arousal and cognitive engagement (Cavazza et al., 2014). Some researchers have also argued that combining biofeedback with compassion practices can maximize psychological and physical effects (e.g., Klich, 2015). Compassion meditation training is a technique for improving emotional self-regulation (Pace et al., 2009), and previous research has demonstrated effects of compassion training techniques on decreased stress-related behavioral and neurobiological responses (Carson et al., 2005; Gilbert and Procter, 2006; Lutz et al., 2008).

This early research is promising, yet much work needs to be conducted to verify the effects of technologies such as biofeedback and BCI on the regulation of human empathy. The following section presents a more specific technique to train empathic abilities, where users are invited to experience the sensory input of another person rather than their own. Embodied Virtual Reality (EVR), allows users to access sensorial data concerning the body of another person, its immediate context and peripersonal space.

EMBODIED VIRTUAL REALITY FOR EMPATHY TRAINING

The illusion of body ownership, or embodiment illusion, is a technique allowing users to virtually experience the body of another person (Botvinick and Cohen, 1998; Maselli and Slater, 2013). This alteration of self-representation through virtual reality (EVR) may lead to changes in behavior, referred to as *the proteus effect* (Yee and Bailenson, 2007). It seems that this effect relies much on the user's social schemas, stereotypes and models. For example, male subjects embodying an avatar of Sigmund Freud dialoguing about their personal problems with a virtual self can improve mood (Osimo et al., 2015). Similarly, embodying an avatar of Albert Einstein may increase performances in cognitive tasks (Banakou et al., 2018). By combining multimodal sensory and motor stimulations with first-person perspective visual input, this type of experience can lead users to feel actively engaged in a controlled virtual environment, and to behave in a realistic manner, adopting new attitudes, modulating cognitive biases and behavioral responses (Bertrand et al., 2018).

EVR have shown promising effects on increasing altruistic intentions and self-compassion (Rosenberg et al., 2013; Falconer et al., 2016). It has also proved useful in reducing short term implicit racial bias (Peck et al., 2013; Banakou et al., 2016). Recent experiments have shown that EVR can be used to alter behavior of aggressive populations (Seinfeld et al., 2018). After experiencing the perspective of a female victim of domestic abuses, offenders developed higher ability to recognize fearful female faces, reducing their bias of identifying fearful female faces of happy. Combined to biofeedback mechanisms these may offer powerful tool to study and modulate empathy in a clinical setting.

One of such embodiment systems is The Machine To Be Another (TMBA). This EVR has been widely presented in various artistic venues and uses different setups to allow two persons to exchange bodies in real time (Bertrand et al., 2014, 2018; Sutherland, 2014; Oliveira et al., 2016), and to allow users to experience the perspective and personal narrative of another human subject (Souppouris, 2014; Martín, 2016; Aragão, 2017). By allowing the use of real human individuals as characters to be embodied, TMBA has been applied to address issues in several contexts of prejudices, allowing a wide variety of users to experience the daily lives of migrants in Europe, muslims suffering prejudice, exiled individuals seeking asylum, and victims of military forces. TMBA has been used as a tool to bridge the gap between cultures, ideologies and backgrounds, aiming to expand individual's empathy toward actual human beings often considered outgroups, and to foster compassion (see Bertrand et al., 2018).

The current democratization of VR due to a greater access in technology allows the development of highly scalable therapeutic and educational methods for helping subjects develop positive emotional states and pro-social behavior. In the final section we present a proof of concept of how such EVR could serve to trigger more specific social emotions and their psychophysiological effects on mind and behavior in clinical and typical populations.

SENSOR-ACTUATOR SYSTEM TO CONTROL SOCIAL EMOTIONS

Technologists attempting to control emotions in human populations to foster altruism can either study the needs and conflicts of such populations, or target specific social emotions and their effect on human altruism. One of such social emotions is aesthetic chills or psychogenic shivers (goosebumps, gooseflesh, chills, thrills). In this section, we review the devices attempting to control this emotion and its psychological effects in humans.

Psychogenic shivering (PS) has received considerable attention due to the fact that it is conscious, measurable and universal (Pelowski et al., 2018; Schoeller et al., 2018b). Shivers are a small muscle tremor ordinarily involved in the regulation of body temperature (Haman and Blondin, 2017). Yet humans sometimes shiver independently of any changes in temperature (Schoeller, 2015a). Here, we refer to this event as psychogenic shivering (PS). Psychogenic shivers are most often triggered by music and film, but can also occur in the course of scientific or religious practices (Schoeller, 2015b). What is of particular interest to this article is the fact that humans often shiver in reaction to specific social situations (Schurtz et al., 2011; Schoeller et al., 2018b) and that PS inducing music has been found to enhance altruism (Fukui and Toyoshima, 2014). It is interesting to note that other primates (most notably chimpanzees) also show signs of psychogenic shivering in the course of bluff display (Aureli and de Waal, 1977). One striking property of situations provoking PS in humans is their social dimension (e.g., Keltner and Haidt, 2003). Humans shiver in groups, specifically when the group shares a common goal and when each member of the group focuses its attention on the evolution of context in light of the goal (in a football stadium for example, or in a public manifestation). PS can be elicited by music (Blood and Zatorre, 2001), films (Schoeller and Perlovsky, 2016), science (Cronin and Greenwood, 1982; Schoeller, 2015b), religious ceremonies (Inbody, 2015; Schoeller, 2015b), social situations. Interestingly, in all these domains, negative PS related to fear and lack of information can be observed as well (Halpern et al., 1986; Zald and Pardo, 2002).

In past decades various technological projects have been involved in the control of PS. Teams have been interested in measuring (Kim et al., 2014), controlling (Jain, Horowitz and Schoeller), or incorporating PS in VR (Neidlinger K. et al., 2017; Neidlinger K. L. et al., 2017; Quesnel and Riecke, 2017, 2018; Quesnel et al., 2018). An important questions, currently beyond measurement, is whether the amount of heat related to specific emotions can be predicted effectively (Schoeller et al., 2018a), that is whether the psychogenic shivers serves any evolutionary function (Tihanyi et al., 2018). Progress toward answering this question could help better understand the neural networks underlying human social emotions and their biological importance in humans (Dunbar, 2009).

There have been several attempts to control the generation of PS through actuators (e.g., Neidlinger K. et al., 2017; Neidlinger K. L. et al., 2017). An ongoing collaboration amongst the authors involves the creation of a wearable chill-actuator device designed to create artificial chills and shivers. Currently, the device form factor includes a custom circuit board, a vibrating motor disc, and a peltier thermoelectric cooler housed in a body-fitted photopolymer resin case. This form factor allows for concurrent delivery of sudden cooling temperature and concentrated vibration on the upper back of participants, where organic PS typically begin, to initiate artificial shivers. The device is tied to a custom Android application and can be triggered wirelessly and remotely, allowing for single or multiple networked devices to deliver chills at predefined moments during songs or videos which subjects are viewing.

Past research has elucidated the correlations between PS and many metrics relevant to the generation of empathy, including levels of openness to experience, awe, and perceived meaningfulness of a situation (e.g., McCrae, 2007; Schurtz et al., 2011; Fayn et al., 2017; Quesnel et al., 2018; Schoeller et al., 2018b). Devices such as the PS actuator thus allow future testing of whether these correlational relationships previously seen are also causal, allowing for the generation of greater openness to experience through generation of artificially induced chills (Schoeller and Perlovsky, 2015). If validated, this would allow researchers to induce and maximize social emotions through bodily actuators at a distance.

CONCLUSION

Different technological approaches, from biofeedback signals to embodied virtual reality and psychophysiological actuators, have been used to support the enhancement of human empathic abilities. The complementary nature of these stimuli regarding the different effects they may trigger lead us to reflect on the possible combination of these technologies to produce even more effective responses. For example, heart-rate biofeedback has been shown effective in enhancing embodiment (Aspell et al., 2013; Suzuki et al., 2013), but as previously discussed could also be used to enhance emotion regulation, an important aspect of avoiding empathic distress. One can envision a system combining both stimuli to help users to step into the shoes of a distressed individual while training for compassion. In the same way, VR could be used to offer immersive neurofeedback environments and help develop fine grained awareness of one's own empathic arousal and cognitive engagement. VR and PS could be combined to create social situations and shared goals for networked users in immersive environments.

In order to increase a sense of shared goals in VR, a chill-actuator device could be incorporated in such situations, increasing the likelihood of PS and theoretically increasing correlated social emotions such as shared group identity or synchronicity. The design of chill-eliciting VR stimuli, and the incorporation of chill-actuator devices into existing empathy related VR experiences such as TMBA, offer unique avenues for the study and generation of empathy and the physiological underpinnings of social emotions. Although further research is required to properly explore the effects of integrating these technologies, the development of new systems of empathic abilities reveals to be a promising field for positive technologies.

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Walking in a Patient's Shoes: An Evaluation Study of Immersive Learning Using a Digital Training Intervention

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Objectives: Evidence suggests that immersive learning increases empathy and understanding of the patient experience of illness. This study evaluated a digital training intervention 'In Their Shoes' which immerses participants in the experience of living with inflammatory bowel disease (IBD), highlighting the biopsychosocial impact. The simulation program uses a mobile application to deliver time-based tasks and challenges over 36 h, supplemented with telephone role-play and 'kit' items to open and use. This study investigated changes in IBD understanding and connection to patients, empathy and perception of job value in a group of pharmaceutical employees. Additionally, it explored experiences and impact of taking part in the intervention.

Methods: A mixed methods pre–post design was utilized, with an opportunity sample of employees taking part in the training. 104 participants from sites in 12 countries completed measures at baseline and 97 post-intervention. Measures included the Toronto Empathy Questionnaire, Prosocial Job Characteristics Scale, and structured questions around IBD understanding and connection to patients. Two focus groups ($N = 14$) were conducted regarding participants experiences of the intervention to complement an open-response question in the questionnaire ($N = 75$). Qualitative data was analyzed using thematic analysis.

Results: Following the intervention, there were statistically significant increases in IBD understanding and connection to patients ($p < 0.00025$), evaluation of organizational innovation ($p < 0.00025$), empathy ($d = 0.45$) and prosocial job perceptions ($d = 0.28$). Qualitative analysis revealed more fully the transformative personal journey undertaken by participants which provided 'eye opening' insight into the psychosocial impact of living and working with IBD. This insight encouraged patient perspective-taking and a strong desire to promote patient advocacy and reduce stigma around chronic illness. Finally, greater organizational pride and connectivity was evident for some participants.

Conclusions: An immersive training program, focussing on the lived experience of illness, led to significant increases in disease understanding and empathy. These findings align with other literature evaluating immersive learning and the potential for increasing knowledge, empathy and motivation. The present study offers opportunities to extend this outside of the body of work focussing on healthcare practitioners and explores the benefits of using this type of learning experience within an organizational setting.

Keywords: inflammatory bowel disease (IBD), human–media interaction, immersive learning, digital intervention, empathy, patient connectivity, job role, mixed methods

INTRODUCTION

Immersive learning involves placing individuals into scenarios, either physically or virtually, to teach knowledge as well as practice techniques and skills. The learner may undertake the task as themselves or may become someone else, 'walking in the shoes' of another person experiencing a different point of view. Immersive learning and simulation experiences which deliver this perspective-taking are many and varied: attending a theatrical performance with structured discussion (Shapiro and Hunt, 2003), inhabiting a virtual game world (Ke, 2016), or putting on a pair of virtual reality goggles to transport you to a specific location or particular perspective (Hansen, 2008). Research evidences the impact of these novel learning interventions across different age groups and disciplines. In primary schools to reduce bullying (Sapouna et al., 2010); in Universities to promote social empathy (Nickols and Nielsen, 2011), policy learnings (Kelley and Johnston, 2016) and global citizenship 'REAL LIVES' (Bachen et al., 2012) and in workplace settings to enhance customer engagement skills (Saini et al., 2017). Immersive learning is also an established and popular tool in healthcare. Interventions aim to increase understanding of patienthood, the impact of living with a chronic or acute illness and to enhance empathy. The present study concerns a digital training intervention 'In Their Shoes' which uses immersive learning and simulation techniques to replicate the experience of living with a chronic condition for employees of a pharmaceutical company.

Experiential and Immersive Learning

Kolb's (1984) experiential learning cycle describes the process "whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). In a four-stage process, Kolb outlines how an individual moves through: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization and (4) active experimentation. The individual 'grasps' the information, taking it in and then 'transforms' it as they interpret and act. Immersive and simulation learning interventions, especially those that require the learner to take on a role, facilitate experiential learning by providing the opportunity to actively experiment, interpret and act on knowledge gained during a single learning experience. A common objective of immersive learning is to enhance empathy, which can be described as having two inter-related dimensions: cognitive and affective (Preston and de Waal, 2002). This could be taken to align with the experiential learning cycle: cognitive empathy measuring the skills-based aspect of learning, where a person is able to recognize and understand another's experience (Kourakos et al., 2018). Then affective empathy linking to the transformative aspect of the learning cycle, where the understanding resonates emotionally with the individual and they start to be able to interpret their knowledge, exploring concepts beyond the facts they are presented with (Kourakos et al., 2018). Batt-Rawden et al. (2013) note that healthcare training interventions traditionally target the cognitive empathy component for modification because it can be considered a skill, whereas some authors argue that affective empathy is regarded as a personal trait, which lies beyond the scope of teaching (Cuff et al., 2016).

Empathy Within Healthcare Professional Training

Connecting with 'patienthood,' the experience of living with an illness (Breathnach and Kelly, 2016), is a common objective for healthcare professional (HCP) training, in order to enhance understanding of the patient perspective. Increasing HCP empathy is of interest as this is demonstrated to positively impact the therapeutic alliance, leading to increased patient satisfaction (Kim et al., 2004), adherence (Di Blasi et al., 2001), and improved health outcomes (Hojat et al., 2011; Rakel et al., 2011; Canale et al., 2012; Roche and Harmon, 2017). As Derksen et al. (2013) found in their systematic review, empathy lowers patient anxiety and distress and delivers significantly better clinical outcomes for patients. However, enhancing empathy for the benefit of the HCPs themselves (rather than their patient) is not without controversy (Pedersen, 2009). Wilkinson et al. (2017) note in their systematic review the conflicting evidence for whether enhanced empathy protects against burnout or increases its likelihood. Nevertheless, empathy interventions and their impact for HCP training is a well-studied area. Recent reviews include simulation as a methodology for teaching empathy to health professional students (Bearman et al., 2015) as well as two reviews focusing on empathy interventions more generally (not limited to simulation) for medical students (Batt-Rawden et al., 2013) and nurses (Brunero et al., 2010). However, as the review authors note the variety and complexity of empathy related simulations, and variety of their measures, make definitive conclusions about effective design and evaluation challenging.

Examples in the literature where a healthy learner vicariously experiences illness use a variety of simulations to create the experience. Corr et al. (2017) simulate living with melanoma by requiring participants to wear a temporary tattoo. Eymard et al. (2010) use a variety of physical items to replicate the disability of older age such as a physical limitations suit, COPD lung simulator and glasses that simulate age-related sight conditions such as glaucoma and macular degeneration. Bunn and Terpstra (2009) used a 40-min recording to simulate an auditory hallucination associated with mental illness. Tong et al. (2017) used an avatar to experience the restrictions of chronic pain on daily life activities. Other studies have focused on pill burden or dietary adjustments associated with chronic illness, requiring participants to adhere to medication (Welborn and Duncan, 1980; Pinkston, 2009) or dietary regimens (Whitley, 2012; Harris et al., 2018). One study with student nurses placed them in a hospital bed for 4 h to experience the lack of agency as a bed-bound inpatient. With the exception of Tong et al. (2017), where the intervention was designed to help care-givers access the experience of living with chronic pain, programs reported in the literature are designed for HCP training.

Characteristics of Empathy Interventions

Despite the heterogenous nature of evaluation studies, some key characteristics of successful interventions of patient perspective-taking do emerge. In their review of 17 nursing empathy interventions, Brunero et al. (2010) found 11 which reported statistically significant improvements in empathy – noting that experiential styles of learning offered most promise. Similarly, Bearman et al. (2015) review of 27 HCP educational interventions found that those where the student was required to 'be' a patient, for some or all of the intervention, were more successful in increasing empathy. In contrast, a nursing education intervention to build empathy for patients with acquired brain injury found higher post-intervention empathy scores for those taking the role of the rehabilitation nurse not the patient (Levett-Jones et al., 2017).

Duration of simulated learning programs vary. A single short intervention – for example the well-established 'Aging Game' which takes place in a single 90 min session (McVey et al., 1989; Varkey et al., 2006). For this, students receive a series of props to simulate common physical disabilities of aging (sight loss, poor motor skills etc.) and then have to complete a role-play at five different 'stations' simulating different healthcare encounters. Other simulation training is structured as an entire module, integrated into medical school curricula (Rosenthal et al., 2011). There are fewer descriptions of interventions where the simulation is merged into a daily routine. Harris et al. (2018) evaluated the impact of pharmacy students planning for and following a 3-day diet plan for a patient with diabetes to enhance empathy and counseling confidence; Corr et al. (2017) had medical students wear a melanoma tattoo in a prominent place for 24 h. In both studies, the authors attribute this durational aspect as central to the intervention's success in promoting empathetic perspective-taking, noting that as the simulation moved out of the classroom and into daily social interactions, the reality of the impact of patienthood is further revealed. Another attribute of the Corr et al. (2017), study was the authenticity of the simulation where the tattoo was a direct copy of an actual patient's melanoma. Authenticity, credibility and attributable scenarios have been found to support participant engagement more widely, for example Tong et al. (2017) where the authors designed a pain simulation game 'AS IF' using a chronic pain patient as a narrator to a series of challenges.

Interestingly, only one of the empathy interventions included in the Brunero et al. (2010); Batt-Rawden et al. (2013) or Bearman et al. (2015) systematic reviews involved digital delivery [Bunn and Terpstra (2009) auditory hallucination]. However, there are examples of empathy intervention design borrowing devices from the gaming discipline. This includes employing a central narrative, peaks of intensity, branching and aspects of what the serious gaming literature classifies as 'adventure' (overcoming obstacles); 'strategy' (planning) and 'role-play' (Boyle et al., 2016; Ke, 2016). Other characteristics of serious gaming are not present, for example reward mechanisms for persistence or competition between 'players.' The use of avatars within computer-based simulation games for healthcare teaching is evident (Norris et al., 2013, 2014), although not reported specifically for empathy.

Empathy Beyond the Healthcare Environment

There are fewer user or beneficiary perspective-taking interventions documented outside the healthcare setting, although some evidence for benefits does emerge. Work-place psychology literature shows a relationship between perceived role value and job performance: feeling that your role 'does good' motivates you to do it better. In a sales environment, this concept is developed by Grant (2008) who describes how pro-social behaviors (a behavior intended to help another), increased following contact with beneficiaries and led to improved job performance and customer (beneficiary) orientation. Grant (2008) and Saini et al. (2017) link customer-orientation and pro-social behaviors to job satisfaction, organizational commitment, engagement and motivation. Parallels might be drawn with findings from the healthcare domain where empathetic physicians are less likely to experience burnout and compassion fatigue (Brazeau et al., 2010; Gleichgerrcht and Decety, 2013). Empathy has also been linked to design thinking and innovation (Brown, 2009; Kolko, 2015). Design Thinking describes a process for problem solving and product design which uses experimentation and rapid prototyping (Razzouk and Shute, 2012; Roberts et al., 2016), which has at its core a focus on user experience, and a belief that building 'user-empathy' is the critical first step for innovation and problem solving. Examples in the literature include Johnson et al. (2014) who conducted an experiment which demonstrated that participants who engaged in empathetic experiences produced concepts (for an alarm clock or litter collection device) with significantly higher rates of original product user interaction features than those who did not. Gamman et al. (2012) asked designers to 'Think Thief' in order to inspire and help them design against crime – for example in strategies to prevent bike or bag theft. Research into effective leadership highlights the importance of empathy skills, particularly for leaders working in global organizations (Walumbwa et al., 2008).

Disease Simulation for Pharmaceutical Company Employees

Immersive learning thus offers opportunity to deepen understanding of patienthood, with implications for employee and organizational benefits beyond healthcare practice. Regular training for pharmaceutical employees, including those who are not in a medical role, covers basic epidemiology and disease pathology for therapy areas of relevance to the company product portfolio. Created by Takeda Pharmaceuticals, with development partner The Method, In Their Shoes® is designed to enable employees to 'live' the life of a person with a chronic condition, specifically inflammatory bowel disease (IBD). The intention of the immersive training program was to enhance understanding of the disease, engage and motivate employees in their role, as well as challenge them to think differently about solutions for people living with IBD.

Inflammatory bowel disease encompasses ulcerative colitis (UC) and Crohn's disease (CD), which are characterized by chronic gastrointestinal inflammation. Typical symptoms include diarrhea, fatigue, abdominal pain and cramping, blood in stools, reduced appetite and weight loss. The impact of IBD on patient quality of life is well documented (De Rooy et al., 2001; Rochelle and Fidler, 2013; Matini and Ogden, 2015; Palant et al., 2015). This impact is influenced not only by physical symptoms but also by psychosocial factors. The course of these diseases is unpredictable, and the treatment of IBD focuses on the maintenance of remission and treatment of relapse (Goldring et al., 2002). IBD prevalence is on the rise, with estimates placing prevalence at around 0.5–1% (Molodecky et al., 2012; Ghosh and Premchand, 2015), with diagnosis typically in early adulthood (Johnston and Logan, 2008). Amiot and Peyrin-Biroulet (2015) note that despite intensive research, IBD remains incompletely understood.

Given the relative paucity of research in the workplace context, we were interested in the process and experience of a digital immersive program to simulate patienthood, as well as its impact on outcomes with potential value for the organizational setting. The present study therefore aimed to investigate the impact of an immersive training program on pharmaceutical employees' understanding of IBD and connection to patients, empathy, and perception of job value. We hypothesized significant increases in disease understanding, empathy and prosocial job perceptions pre–post program. Additionally, we employed qualitative methods to explore employees' experiences and perceptions of taking part in the intervention.

MATERIALS AND METHODS

Design

The evaluation used a mixed methods design with an opportunity sample of pharmaceutical employees taking part in the training intervention 'In Their Shoes' between September 2017 and February 2018. A mixed methods approach is particularly valuable in this context to illuminate both the processes and effects of a novel intervention (Abildgaard et al., 2016). An online questionnaire delivered via Qualtrics was administered at baseline and post-intervention. Additionally, two focus groups with selected study participants took place in the United Kingdom and France post-program to explore in-depth experiences of taking part in the intervention. All those indicating a willingness to take part in a focus group conducted in the English language were invited to take part (from United Kingdom and French offices). Ethics approval for the evaluation was obtained from the University of Westminster Ethics Committee.

Participants

One hundred and fifty five employees of a pharmaceutical company took part in the immersive program which is run periodically in Takeda offices in Europe, Asia, North and South America. Recruitment to the program followed standard company procedure whereby staff either volunteered to take part, or teams/key personnel were nominated by managers. All those taking part were invited to participate in the evaluation. One hundred and four participants from 12 countries completed baseline measures (67% response rate), 97 completed post-intervention measures. Seventy four completed both baseline and post-intervention questionnaires (71% response rate). Participant flow is presented in **Figure 1**.

At baseline, there were 66 females and 37 males, with a mean age of 40.6 years (*SD* = 8.85, range 20–62 years). Virtually all (97%) were educated to at least degree level, with 43% having postgraduate qualifications. The majority of participants (56%) had been with the company for less than 3 years, 26% for 3–10 years, and 16% for more than 10 years. Twenty (19%) were registered HCPs, but the majority (88%) were not currently practicing. Only five (4.8%) had taken part in an immersive training program previously. Over a third (36.5%) had personal experience of chronic disease (self, close family, or friend).

The Intervention

The design of In Their Shoes® draws on the biopsychosocial model of illness (Engel, 1977), highlighting the psychological and social impact of living with a chronic condition as well as physical symptoms. The 36 h constructed narrative contains around 70 individual challenges typically faced by someone living with Inflammatory Bowel Disease. As well as simple directions ("go immediately to the toilet") it also creates scenarios and jeopardy where the individual is required to 'choose' between their disease or their life: ("you have left your medication at home, do you hope you'll be ok, or risk missing an important

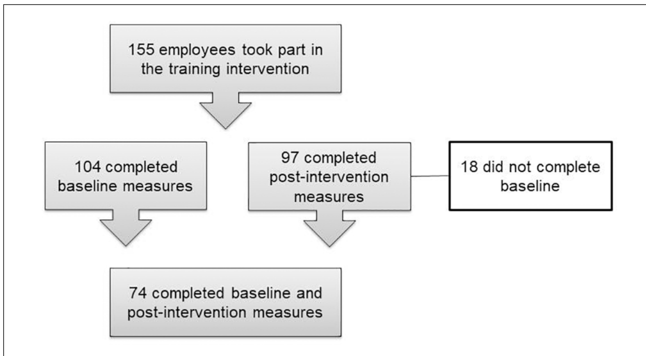

FIGURE 1 | Participant flow.

business meeting to return and collect?"). Scenarios touch on the stresses chronic illness exacts on work and personal relationships. To add urgency and monitor engagement, certain challenges are timed and require the participant to send a photograph to document that they have completed the task. Participants are not incentivized to complete the tasks and there is no competitive element between 'players.' However, some challenges include text from real IBD patients commenting on when they faced a similar scenario.

The immersive simulation is primarily delivered through a smartphone application. The participants download this and read a standardized patient profile detailing basic disease state information and time since diagnosis, there is also dietary guidance. The application has an avatar (head and shoulders only) with basic personalization (hair/eye color; skin tone; face shape; hair style; glasses/facial hair; shirt color and style). The avatar is present on the initial application screen and shows signs of stress and illness during the more intense narrative sections (e.g., sweating, turning red or pale). At four points during the experience there are live role-plays (via phone) with an actor following a specific script. In the first, a 'nurse' uses the Bristol Stool Chart (Heaton and Lewis, 1997) to classify the participant's stool (feces) and describes how to give a stool sample in preparation for an upcoming clinic appointment. In the second the 'boss' invites the participants to a high level meeting – which requires long-haul travel; the third involves a friend frustrated that the participant will miss an important social engagement. In the fourth a 'surgeon' calls to discuss the risks and benefits of stoma surgery. Participants are given a kit of wrapped items which they keep with them during the experience, this contains 12 items which underscore challenges (e.g., blood capsule to simulate blood in stool; stool sample pot – used during nurse role-play; protective bed sheet for those participating in the optional night experience). The narrative structure and challenges that occur during the immersive intervention draw from published literature on the patient experience of IBD (e.g., Palant et al., 2015) and input from patients and patient groups.

Measures

Demographic Information

Demographic information was collected at baseline only: age, gender, education, nationality, length of service, current company role and personal experience of chronic disease (self/family/friends).

IBD Understanding and Connection to Patients

Questions were adapted from Shapiro and Hunt (2003) which measured disease specific understanding following a theatrical educational intervention. The seven questions were rated on a 7-point likert scale from 'not at all' (1) to 'very much' (7). They assessed understanding of IBD and its impact, empathy toward people with IBD, confidence in talking about IBD, and degree of connection with patients. An additional question assessed perceptions of organizational innovation.

Impact of Evaluation

Two questions were included in the post-intervention questionnaire to assess perceived impact of the intervention (confidence in incorporating insights into work role; gaining a valuable, new perspective on how patients' live with IBD). A further question asked participants to rank the four elements of the program (text messages, role play, avatar, kit items) from most to least impactful (1–4).

Toronto Empathy Questionnaire

Toronto Empathy Questionnaire (Spreng et al., 2009) consisting of 16 questions, rated on a 5-point scale, from 'never' (0) to 'often' (4). Half the items are negatively phrased and reverse scored. Scores are summed to derive total empathy score (0–64). In the present study, Cronbach's alpha was 0.86 at baseline.

Prosocial Job Characteristics Scale (PSJC) (Grant, 2008)

A self-report measure of the extent to which jobs provide opportunities to impact on others, rated on a 7-point scale from not at all (1) to very much (7). Whilst the original PSJC contains two sub-scales (impact and contact), only the first was included here as it was deemed most relevant to the current study, a nine-item subscale 'Job opportunities for impact on beneficiaries' (Cronbach's alpha 0.96). This incorporates three further subscales: frequency of positive impact on others, magnitude, and scope.

Procedure

Participants were notified of the evaluation study during the normal registration process for 'In Their Shoes®'. The study was open to all and participation was voluntary. A Participant Information Sheet was provided as part of the pre-registration information. The standard briefing meeting (face-to-face or via web conferencing) was extended to allow for a short presentation about the study with open question and answer session (10 min duration in total), led by a member of the study team (CH). For quantitative data collection, a web link was sent to all participants directly after the briefing meeting. This link took participants to a webpage with study information and consent form. If the consent form was completed, participants were then directed to the baseline questionnaire. This had to be completed prior to the start of the intervention. The post-intervention questionnaire link was sent by the study team to all participants directly after the close of the intervention. A debrief meeting at the end of the training period provided an opportunity for duty of care. All responses were collected in English.

For the focus groups, participants from the United Kingdom and France were asked if they were interested in taking part during the debrief session and provided with a Participant Information Sheet. They completed a consent form and were given the opportunity to ask further questions prior to the start of the focus group.

Qualitative Data Collection

Qualitative data was obtained from two sources: (a) an open question included in the post-intervention questionnaire (please tell us how it felt to take part in the In Their Shoes program) (N = 75); (b) two focus group discussions in France and the United Kingdom (N = 8 and 6, respectively). Participation in the focus group discussions was voluntary. These took place post- intervention in Takeda offices, lasting approximately 70–90 min. Focus groups were facilitated by the research team (led by TC) and were conducted in English. Topics covered included how it felt to take part in the program, what participants had learnt from the intervention, how they felt toward patients with IBD, any impact on their job role and what elements of the program they felt were most effective. The facilitators encouraged group discussion about experiences and allowed for natural development of topic areas relevant to the group (Parker and Tritter, 2006). Recordings were transcribed by a professional agency and checked by researchers.

Data Analysis

Statistical data analysis were conducted using SPSS version 23. All statistical analyses comparing baseline and post-intervention scores are based on the 74 complete datasets. Non-parametric tests (Mann–Whitney-U, Wilcoxon signed rank, Chi square, as appropriate) were used to compare differences between those who did/did not complete on baseline measures, and to assess pre–post differences on ordinal level variables (disease understanding and connection to patients). To assess pre–post differences in empathy and prosocial job role, paired t-tests were conducted. Independent t-tests were conducted to assess group differences in primary outcome variables (e.g., gender). Effect sizes for scale changes were calculated using Cohen's d, with effect sizes defined as small (d = 0.2) and medium (d = 0.5) (Cohen, 1988).

Qualitative data (responses to the open ended questions from the post-intervention questionnaire and focus group transcripts) were analyzed inductively using thematic analysis as outlined by Braun and Clarke (2006). An experiential or realist approach was adopted to identify patterns in participants' accounts of their experiences of taking part in the intervention (Braun and Clarke, 2006). The second author (TC), an experienced qualitative researcher, read through the open response data set several times and undertook detailed coding, noting key words and sections of text. In the second stage, this was further refined to develop an initial list of codes and broader themes that represented recurrent patterns in the data and discussed collaboratively with the second author (CH). Analysis of focus groups was based on codes from stage two of the open response analysis and further expanded to add new codes and further interpretative detail. Then a list of key themes and illustrative quotes relating to participants' experience of the intervention was compiled by TC. At this stage, CH independently coded the focus groups and both authors compared coding frameworks to debate and arrive at a final thematic structure for the whole data set. Quotes from both data sets are used to illustrate the findings and reflect responses across countries, notation is used to indicate when quotes are derived from focus groups (FG).

RESULTS

There were no statistically significant differences between post intervention completers and non-completers on demographic or study variables at baseline.

IBD Understanding and Connectivity

As hypothesized, there were significant increases in reported IBD understanding and connectivity to patients post-intervention (see **Table 1**). All seven questions showed statistically significant change: understanding of living with IBD (z = 7.475), understanding of physical symptoms of IBD (z = 6.197), understanding of emotional and psychological issues (z = 5.867), empathy toward people with IBD (z = 6.008), confidence talking to stakeholders about the impact of IBD on patients' lives (z = 6.045), and connection to patients (z = 5.607). There was also an increase in perceptions of organizational innovation in its approach to patient-centered care (z = 3.687, N-Ties = 46, $p < 0.00025$).

Evaluating the value of the program, the intervention was highly ranked in terms of providing a valued perspective on living with IBD and participants felt confident in incorporating these insights into their role (see **Table 1**).

Empathy and Prosocial Job Perceptions

As hypothesized, there was a statistically significant increase in empathy post-intervention, compared with baseline (see **Table 2**), with a medium effect size (d = 0.45). There were small but statistically significant increases in prosocial job perceptions, both for the overall scale (d = 0.28) and three subscales: frequency of positive impact on others (d = 0.33); magnitude of positive impact (d = 0.2), and scope of positive impact (d = 0.19).

There were no statistically significant differences in empathy or prosocial job perceptions change scores by gender, previous experience of chronic illness, or whether participants were HCPs.

TABLE 1 | Disease understanding and connectivity descriptives, at baseline and post-intervention.

Item	Baseline median (interquartile range)		Post-intervention median (interquartile range)	
Understanding of:				
IBD	4.0	(3.0–5.0)	6.0*	(5.0–6.0)
Physical symptoms	4.0	(4.0–5.0)	6.0*	(5.0–6.0)
Psycho-emotional issues	4.0	(3.0–5.0)	6.0*	(5.0–6.0)
Empathy for people with IBD	5.0	(4.0–7.0)	7.0*	(5.0–7.0)
Confidence in talking about IBD	4.0	(3.0–6.0)	6.0*	(5.75–7.0)
Connected to patients	4.5	(4.0–5.0)	6.0*	(5.0–6.0)
Organizational innovation	5.0	(4.0–7.0)	6.0*	(5.0–7.0)
Post-intervention only variables				(6.5-7.0)
ITS offers new perspective on IBD			7.0	(6.5–7.0)
Able to incorporate insights of ITS			6.0	(5.0–7.0)

Statistically significantly different from baseline ($p < 0.00025$), 1-tailed.

TABLE 2 | Descriptives for empathy and prosocial job perceptions measures, baseline and post-intervention.

	Baseline mean (*SD*)	Post-intervention mean (*SD*)	95% confidence interval	*t*	df	*p*-value*
Empathy	43.51 (8.44)	46.88 (6.62)	1.24–5.47	3.167	73	0.002
Job role	4.84 (1.12)	5.13 (1.00)	0.10–0.49	2.984	71	0.002
Frequency	4.61 (1.17)	4.98 (1.06)	0.15–0.58	3.396	71	0.0005
Magnitude	4.99 (1.23)	5.25 (1.08)	0.02–0.50	2.157	71	0.017
Scope	5.00 (1.18)	5.21 (1.04)	0.02–0.44	1.821	71	0.037

**1-tailed.*

TABLE 3 | Ranking of program elements (%).

	Most impactful 1	2	3	Least impactful 4	Median score
Text messages	37.2	32.6	26.7	3.5	2
Role plays	43.0	29.1	11.6	16.3	2
IBD kit items	15.1	30.2	47.7	7.0	2.5
Avatar	4.7	8.1	14.0	73.3	4

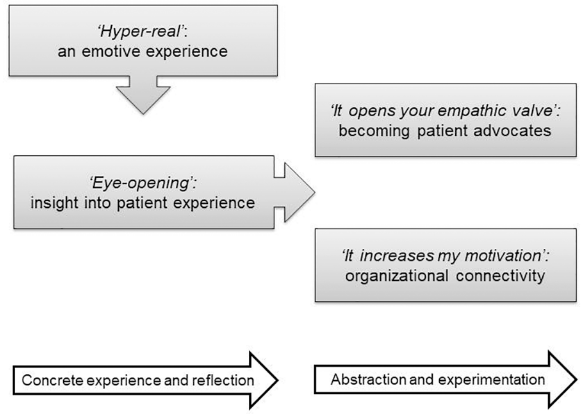

FIGURE 2 | Overview of qualitative themes.

Evaluation of Program Elements

Median scores indicated that the text messages and role plays were ranked most highly, with the majority ranking these elements in the first two categories (70 and 72%, respectively). IBD kit items were ranked third, with the avatar rated as the least impactful (see **Table 3**).

Qualitative Findings: Experiences of Taking Part in the Immersive Program

Four core themes were identified from the qualitative data (see **Figure 2** for overview of themes). The first, *A 'hyper-real' and emotive experience*, describes the physical and emotional intensity of taking part, which enabled personal *insight into the patient experience* as described in the second theme. The emotional engagement and understanding gained from the program was described in the third theme as building empathy toward patients resulting in a desire to increase awareness *('It opens your empathic valve': Becoming patient advocates*). The final theme outlines the increase in *organizational connectivity* described by some participants through greater appreciation of their role in patient care. Together the themes appear to reflect an experiential journey, consistent with Kolb's learning cycle, in which participants build their understanding of the disease, reflect on the real-life impact and then deepen their reflections as they interpret and act on their new insight. This provides a new, critical, perspective on the wider implications of living with a chronic condition.

A "Hyper-Real" and Emotive Experience

"Initially there was this "bit of fun" element to it, but by the time that I had the phone call from the doctor I felt fully immersed in the experience, and actually felt quite emotional about being told that I'd need the operation - and I don't have IBD." (United Kingdom)

All participants described the intensity of taking part in "a brutally realistic experience" that was stressful and intrusive and yet overwhelmingly a positive experience: "It was a great experience, I felt sick, lonely and sad" (Austria). The rollercoaster of emotions experienced during the program facilitated a strong connection to the reality of people's experiences of living with IBD. Commonly described were sadness and distress, anger and frustration, fear and anxiety, guilt (when a task was missed), shame and embarrassment, venting ("I want a doughnut!"), all of which impacted on mood ("you feel pretty low by the end of it all," United Kingdom). It was this depth of emotional engagement that often led participants to recognize the effectiveness of the program. Participants described feeling physically and emotionally exhausted and found managing the conflict between the demands of work and illness particularly stressful, with many discussing lost productivity ("I found it impossible to combine IBD flare period with my job," Czechia). The experience stimulated reflection on the processes involved at managing different phases of the disease, with one participant describing how he felt "completely lost in the middle of the jungle."

Such personal and visceral experiences were seen to result in deeper impact ("you don't simply return to your life," United Kingdom) in comparison to other educational programs: "you have to ask yourself questions…you can't feel that In Their Shoes is a game" (France, FG). There were individual differences with regard to which elements of the program were most impactful, nevertheless for all participants it was the package of elements ("the richness of the application") that made it particularly powerful. The frequency and duration of toilet visits were frequently mentioned challenges along with the emotional impact of the role plays ("I cried when I got the call from my Doctor saying surgery was the next step"). Kit items were often discussed in relation to impact on self and others, for example, one participant described feeling "like I'd aged 30 years", whilst another joked that his wife got "a bit of a shock" when using the paper pants/bed cover. Although the avatar produced mixed responses, for some it enabled stronger emotional connection, "almost like you're looking in a type of mirror" (United Kingdom). Only one participant mentioned dislike of the "gamification style" of the program.

Several described how the experience had caused them to appreciate their own health ("I feel blessed for being healthy," Croatia) and led to reprioritization "it changes my perspective of things that I do on a regular basis" (UK FG). Thus, despite the discomfort of taking part in the simulation, the personal insight was deemed transformative: "I'll never be the same" (France).

'Eye Opening' Insight Into Patient Experience

> *"The In Their Shoes program was very eye opening for me to understand how someone with IBD needs to manage not only the treatment of their disease but the other aspects of their life. This disease, and many others, proved to be very disruptive and I have an understanding on how IBD not only causes discomfort and pain but also the tremendous psychological and emotional impact it can have on patients and their loved ones." (United States)*

The physical and emotional challenges faced by participants during the intervention led to a deep-seated appreciation of the psychosocial impact of living with IBD. Participants commonly alluded to the difference between knowledge about the disease and understanding of the patient *experience* enabled by taking part in the program ("a key to get into the life/house of an IBD patient," Germany). In the focus groups, this led to reflections about the broader implications of living with a chronic condition ('just imagine if...') and discussions about stigma, disability rights, and the conflict surrounding decisions to conceal versus acknowledge the disease. For some, "it's easier to lie than tell the truth" (France, FG) to avoid the shame and potential misunderstanding from others, whereas disclosure was seen as more empowering and facilitative of increasing public awareness by bringing "it out in the open" (United Kingdom). Additionally, impact beyond the individual was widely discussed in focus groups, with many relating how the program had increased awareness in family members, particularly their children: "they found it hard to believe that there were actually people out there that suffer with this every day" (UK FG).

Insight could be categorized into three main areas: loss of control, impact on professional lives, and psychological challenges. The day-to day challenges and frustrations of dietary restrictions ("easier not to eat") and access to toilets were framed in terms of loss of control: "you realize how many choices it takes away from you" (UK FG). Participants recognized the consequential impact on both social and family life, particularly around the difficulties of planning. Frequent mention was made of the impact of IBD on professional lives, in relation to difficulties in carrying out work roles, curbing ambitions and managing the challenges of commuting – "I probably couldn't do my job if I had CD" (United Kingdom).

Whilst participants recognized the physical difficulties of IBD – frequent toilet visits, physical pain and sleep disturbance - the greatest focus was given to the psycho-emotional impact of the disease. The demands of the condition was recognized as mentally intrusive, emotionally draining and potentially overwhelming. Focus groups discussed the impact of IBD and other conditions on identity ("it's like a handicap," France), with a sense of isolation highlighted as a key vulnerability that should be addressed with access to appropriate support:

> *"to have someone to speak to, but someone who would be able to understand you as well, and not only someone who can listen to you." (France FG)*

Indeed, it was seen as particularly upsetting when role-play actors lacked understanding, creating a "feeling like no-one cares" (United Kingdom). Lack of public awareness and societal discrimination were perceived as creating further difficulties for people with IBD and other chronic conditions: "those people are totally outside of the society as a lot of things are not adapted to them" (Switzerland).

'It Opens Your Empathic Valve': Becoming Patient Advocates

> "*I come away with a huge amount of respect for those people that manage their IBD so successfully and feel I am closer to being able to empathize with the patient population." (United Kingdom)*

This insight into the patient experience – "a window into how patients are feeling" (UK FG) - enabled participants to take on the perspective of those with IBD, at least temporarily, and also connect with the emotional experience of the sufferer.

> *"We train our compassion very effectively with this exercise and become much more compassionate toward patients with the disease." (UK FG)*

Reflection around the experience of how it feels to live with a health condition extended beyond IBD to incorporate a broader understanding of the challenges of managing long term conditions ["it creates that, or almost encourages that depth of thinking across the board, not just about IBD" (UK FG)]. This more personal connection to the patient experience is illustrated in a discussion around defining patient benefit, reflecting a shift from a paternalistic biomedical perspective to a reprioritization of patient-centered criteria for measuring drug outcomes:

> *"I think what this exercise made me reflect upon was the fact that we need to, to understand, of course not only the scientific very clear rationale, [of] what we do (in drug development), but we also need to think in the practical daily life, how does it reflect to the patient so that the patient can really have benefit?" (UK FG)*

As well as challenging professional assumptions, increased empathy and understanding led to a strong desire for broader action to promote patient advocacy. For example, to increase public awareness ("how do you bring it out in the open, and how do you make people aware of it?" UK FG), reduce stigma and improve access to support.

> *"Maybe that's our best advocate for anyone that we see suffering from a disease that is unfairly treated, because we really felt for, in our skin." (UK FG)*

Participants expressed a desire to support colleagues with long term conditions and reflected on ways in which the workplace might better support people with health conditions, whilst also recognizing the complexities surrounding practices, such as home-working, which have the potential to further isolate and differentiate employees. Participants drew on their own experiences of feeling isolated or being able to share their experiences during In Their Shoes to highlight the therapeutic value placed on social support.

"The big discovery for this experience is the, the key part of the community, because this time I was not alone with my desk but in a group. And to, to talk about my disease with my colleague I . . .I think it's very important, and that's changed my mind about patient associations." (France FG)

Organizational Connectivity

"It increases my motivation for my daily job. I do now feel more involved about our mission" (Switzerland).

Although a less dominant theme, a substantive number of participants reported feeling greater pride in working for their company and increased emotional connection to the organization and its mission to serve patients ("the emotional grab wasn't always there," United Kingdom). This was particularly evident in those that had more distal, non-patient facing roles.

"*I don't really have an insight on what's really going on outside of my department. . . And I actually felt blessed to be able to work for a pharmaceutical company. I know I'm not a huge part of it, but I'm still part of the people who makes it happen. And I, going home on, on the Wednesday evening, I nearly kind of, nearly cried, because thinking oh God, I've got the best job in the world" (UK FG).*

"I am proud that Takeda develops and market IBD medicine for IBD patients" (Japan).

Participants described several mechanisms, firstly, the recognition that their job could make a difference to patients' lives, irrespective of their role. Secondly, greater connection to patients and confidence in integrating their experience into job roles, such as speaking to others about IBD and considering patient-centered outcomes in research and development. Thirdly, through favorable organizational comparisons and respect for the implementation of novel initiatives ("there's not many companies out there that would do this sort of thing," UK FG). Finally, participants valued being able to share their experiences with colleagues, thereby increasing collegiality and providing the opportunity for open discussion and reflection on broader issues around patient experience and care:

"The program allowed people to talk more openly about the impact of IBD and even allowed me to have a discussion with a member of staff who suffers from IBD." (United Kingdom)

DISCUSSION

This study found that an immersive training program, conducted amongst pharmaceutical company employees, led to increased understanding of and empathy for the lived experience of patients with IBD. We found statistically significant increases pre/post participation on self-rated disease understanding, self-rated connection with and advocacy for people living with IBD, and belief that job role can positively impact others (prosocial job perceptions). Central themes of how it felt to take part demonstrate significant emotional engagement, with activation of both cognitive and affective empathy, and evidence of a progression from lower order to higher order cognitive skills, moving beyond knowledge (taking on facts) to understanding (drawing conclusions). These findings align with other literature evaluating immersive learning and the potential for increasing empathy through simulation experiences. The present study offers opportunities to extend this outside of the body of work focussing on healthcare practitioners and considers the benefits of using this type of learning experience within a workplace setting. The study's mixed methods approach offers an in-depth perspective on how empathy can propel learners through the experiential learning cycle and how this may activate behavioral change in the workplace.

Experiential Learning

Participants' progression through the experiential learning cycle (Kolb, 1984) is evidenced in both the quantitative and qualitative data. The first phase 'concrete experience' is characterized by taking on facts. Improvements in self-rated understanding of the different aspects of IBD demonstrates this knowledge acquisition and a more nuanced picture is offered in the qualitative data with participants highlighting the stress of managing the physical aspects of IBD, particularly the frequent toilet visits. In common with IBD patients, food was also a prevalent topic. One participant venting frustration at the dietary limitations imposed by the condition ("I want a doughnut") echoed findings by Palant et al. (2015) "And then you start to loose [sic] it because you think about Nutella." The second phase 'reflective observation' is richly described in the qualitative data with participants reporting the intensive, exhausting and emotional burden of IBD in detail. This heightened sense of the psychological impact may be a consequence of the program design and the difficulty of simulating the physical symptoms of IBD. It could also be supported by Kolb's assertion that the second phase is particularly characterized by the need to address any inconsistencies between past experience and new understanding. So it could be that participants, as employees of a pharmaceutical company, had a working knowledge of disease symptoms, but had not previously considered their psychological and social impact. Illustrations of the third 'abstract conceptualization' and fourth 'active experimentation' phases can be found in qualitative data as participants explore their insights and reflect on how it would feel if they were unable to 'switch off' the experience. Participants interpreted their experience readily and hypothesized how they might incorporate learnings into their role. This finding is supported in the quantitative questions reporting greater connection to people living with IBD and the desire to be personal advocates and enhance representation for those living with the condition, and the increase in prosocial job beliefs.

Participant Engagement

Findings demonstrate a high level of emotional engagement amongst participants. The central narrative was described as challenging and unpredictable. The frequent text messages distracted participants from their work and removed a level of agency, with qualitative responses including frequent mention of a sense of loss of control. The intensity of the experience was widely reported across program elements, provoking strong emotions (shock, horror, and upset). Participants viewed the authenticity of the simulation both positively and negatively: a tension between knowing that the simulation was robust and accurate set against the reality of the emotional and physical burden. This finding is echoed in other simulation evaluations. Some of the text messages within the central narrative contained patient quotes validating a specific scenario. Participants commented positively on this device. The approach of validating a seemingly fictional scenario as the personal experience of a genuine patient is reported elsewhere to be impactful (Corr et al., 2017; Tong et al., 2017; Ter Beest et al., 2018). The durational nature of the experience, and that participants 'lived with IBD' and continued with their work and personal lives deepened the understanding of the impact of illness, yet also helped participants look beyond the disease ("we're always talking about the patient, the patient, the patient . . . but it's not, this is someone leading their everyday life," UK FG). The value of this intersection of 'patienthood' (what it means to be a patient) and real life within a durational experience is supported by Corr et al. (2017) who describe the persistency of the simulation as crucial to its success. In common with other empathy-enhancing interventions, (Batt-Rawden et al., 2013) the program was well received; participants reporting the paradox of enjoying something that was not pleasurable.

Evidence in both the quantitative and qualitative data suggest that the interlinking program elements amplified the central narrative and helped to immerse participants, delivering an enriched and heightened sense of disease impact. Multiple delivery mechanisms may open up a single training intervention to different personal learning styles, although this was not evaluated in the present study. Although this training program cannot be characterized as a serious game, qualitative responses indicated that the gamification devices (for example timed challenges) supported engagement. Participant feedback on the individual intervention characteristics showed that the text messages and role plays were most highly valued. Although the evaluation did not directly ask for feedback on a smart phone mobile application as a training delivery device, it is clear from the qualitative data that this facilitated the intervention's intensity and intrusiveness as participants' phones became a constant reminder of their disease state. This may point to mobile applications being a useful delivery mechanism for simulation training. Interactions with others, both those within the simulation (role-play actors) and outside (colleagues, family, and friends) were reported as important for reflections on the psychological and social impact. This is supported in both digital and real-life learning scenarios literature. Bearman et al. (2015) found evidence for role-play as a design feature of successful empathy interventions. The kit items overall were ranked third although those relating to the physical symptoms of IBD were described as particularly impactful. Physical items are reported elsewhere to be confronting for simulation participants, for example nursing students required to wear an incontinence pad for 6 h (Karlowicz and Palmer, 2006). The avatar was less consistently valued, although forms of empathetic mirroring are evidenced in other literature (Norris et al., 2014). Whilst the personalized avatars did show signs of stress and illness during intense narrative sections it may be that the customization features were too basic in this application to influence users' behavior and motivation, as has been demonstrated elsewhere (Yee and Bailenson, 2007).

Activating Empathy

The use of mixed methods in this study enabled evaluation and exploration of the activation of empathy amongst participants. Results support both cognitive and affective empathy impacts: an intellectual or imagined understanding (cognitive) and emotional reaction (affective). Spreng et al. (2009) describe an overlap and likely shared processes of these two components hence the Toronto Empathy Questionnaire reports a single score representing both components. Empathy scores significantly increased following participation in the training program. The medium effect size seen in this study is larger than comparable studies reported in Batt-Rawden et al. (2013) review, where only small effect size is reported for seven of the 11 studies where data was sufficient to calculate. Cognitive empathy indicators included conceptualizing the biopsychosocial impact of the illness and being able to explore previously unconsidered components of the disease (for example invasive or embarrassing procedures). Affective empathy was particularly evidenced in the qualitative data, with participants using strong and emotive language to describe their connection to the experience of the IBD patient. This was an interesting finding given the discussion in the literature around whether or not affective empathy can be 'taught' (Cuff et al., 2016). The qualitative findings highlight the possibility for empathy to act as a catalyst for behavior change, or as an antecedent to innovative problem solving. Participants discussed their motivation to advocate for patients and their desire to challenge everyday prejudices encountered by people living with IBD – and other chronic conditions. Whilst the current study did not assess behavior change, using an experimental paradigm Batson et al. (2002) were able to evidence an empathy-attitude-action model where participants induced to feel empathy for a stigmatized individual allocated increased funds to an agency providing support.

Workplace Setting

Disease specific simulation is well documented in HCP training where there is a strong evidence base for enhanced connection between patient and practitioner, supporting improved communication, shared decision making and adherence (Kim et al., 2004; Hojat et al., 2011). However, this has not been studied within the pharmaceutical industry workplace, where a focus on patients is a well-recognized organizational goal. The study participants were from different business roles, both those who had more regular contact with patients (e.g., Marketing and Medical), and those in more administrative settings (e.g., IT, Finance). The study results showed no significant differences based on gender or HCP training. This contrasts with some previous studies which have identified gender (Toussaint and Webb, 2005) and HCP status (Charles et al., 2018) as mediators of empathy. The study also explored in more detail the training's impact on individual's perception of role and engagement. This was characterized as the opportunity to have a positive impact on others: how often you could do good (frequency), how much good you could do (magnitude) and the range of positive impacts (scope). Participants perceived the positive impact of their role was greater after they had taken part, recording increases in amount, frequency and opportunity. This connection to role beneficiaries has not been previously studied in a simulation context; only actual exposure to genuine recipients has been shown to improve engagement and performance using this measure (Grant, 2008). Additionally, qualitative findings reflected a more emotional connection to corporate culture ('pride,' 'admiration') and a shift from a biomedical to patient-centered approach.

Strengths, Limitations and Future Directions

This was a multicentre international evaluation study, although conducted in a single pharmaceutical company. It provides a novel contribution to the immersive learning literature in its focus on a non-medical audience and workplace context. Moreover, it is the first to measure the impact of immersive learning on job role focus and connectivity. The triangulation of quantitative and qualitative approaches enables an in-depth exploration of the intervention process and mechanisms of change and also tentatively suggests that the observed changes in disease understanding and empathy may have longer-term impact on behavior. Results also demonstrate the success of digital immersive learning to enable perspective-taking inside and outside the workplace – enhancing understanding of the biopsychosocial impact of chronic disease. This points to the potential for mobile applications to deliver immersive learning, offering opportunities to extend training to larger audiences in different disciplines.

However, like the majority of studies in this area, the pre–post evaluation design was a limitation. The lack of a control group or comparator intervention limits our ability to draw definitive conclusions about the causal mechanisms of the intervention on outcome variables. Given that the intervention was delivered and evaluated in the workplace, the observed changes may be due to demand characteristics rather than the intervention itself. The depth of engagement and rich examples of insight and empathy evidenced in the qualitative data suggests, however, that this is not the case. The current study focused only on immediate impact of the training program, so was unable to determine actual behavior change or longer term impact of the intervention. Notwithstanding these limitations, the findings suggest valuable potential directions for future research, to investigate whether changes in empathy and understanding of the lived experience of illness are maintained over time and perhaps more importantly, whether they lead to behavioral change, either on an individual or organizational level.

CONCLUSION

The study demonstrated that an immersive training program, focussing on the lived experience of illness, led to significant increases in disease understanding, connectivity and empathy toward patients amongst employees of a pharmaceutical company. In addition to increases in patient connection, this study was the first to demonstrate increases in prosocial job perceptions and organizational engagement in a simulation context. These findings align with other literature evaluating immersive learning and the potential for increasing empathy, motivation and connectivity through simulation experiences in both organizational and medical settings.

DATA AVAILABILITY

Datasets are available on request: The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the ethics committee of University of Westminster. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the University of Westminster Psychology Ethics Committee (ETH1617-1855).

AUTHOR CONTRIBUTIONS

CH and TC designed the evaluation and wrote the manuscript. CH managed participant enrolment and data collection. TC conducted the quantitative and qualitative analysis with input from CH. CH and TC read and approved the final manuscript.

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OPINION
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Mixed Reality for Cross-Cultural Integration: Using Positive Technology to Share Experiences and Promote Communication

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In the contemporary society, migrations from other countries or even from other regions of the country are a common phenomenon that rises cultural and psycho-social issues, as well as political and economic challenges. People move from their place of origin for educational or professional purposes or because they are forced to leave due to political, economic and social conditions, and also natural disasters which produce population flows. Whatever the push and pull factors are, when people move permanently or temporarily they tend to maintain close ties with their place of origin (with people, places, culture, practices etc.), while trying to develop attachment with the place of residence (Ehrkamp, 2005).

The literature (Appadurai, 1996; Faist, 2000; Smith, 2001) highlighted the dichotomy between transnational and local levels, arguing that transnational ties may prevent assimilation and adaptation to the new place, while other authors (Bhabha, 1994; Kaya, 2002; Ehrkamp, 2005) promoted the concept of "hybridity" between home and host society, or between ethnicity and assimilation, showing that immigrants' transnational practices create new places of belonging that allow them to engage with the receiving society.

According to Berry (2001), four strategies are mainly used by immigrants interacting with the culture of the hosting country:

- **Assimilation**, where the person prefers not to maintain his cultural heritage and seek continuous interactions with the culture of the hosting country;
- **Separation**, where the person tries to preserve the attachment to the culture of origin and avoid the contact with the culture of the hosting country;
- **Integration**, where the person tries to engage within both cultures;
- **Marginalization**, or detachment from both cultures

As Ehrkamp says, "Conceptualizing migrants' identities as constantly negotiated in relation to multiple societies and places enables us to think beyond dichotomies and mutually exclusive notions of local and transnational ties, and to recognize immigrants as agents who are able to forge their belonging and multiple attachments" (Ehrkamp, 2005, p. 348). Indeed, people have a cultural identity or a "set of beliefs and attitudes themselves in relation to culture group membership" (Berry, 2001 p. 620); usually one becomes aware of his/her own cultural identity when coming in contact with people from other cultures (Phinney, 1990; Berry, 1999). In other words, immigrants construct their identities in the context of a negotiation between old and new homes' contexts.

However, such a process is not free from obstacles and issues, with notable consequences on immigrants' well-being. According to literature, some psychosocial issues can be identified regarding identity re-negotiation while moving to a different place, and cultural integration.

First of all, immigrants could experience feeling of isolation, estrangement and alienation, related to the difficulty to create strong social ties in the new place (Hurtado-de-Mendoza et al., 2014), with consequences ranging from negative emotions to depression and other serious treats to health (Lackey, 2008); such risks can be reduced by being part of the community, belonging, and contributing to the community development (Esser, 2001).

Other important aspects are the strains and stresses associated to practical issues such as adapting to new culture, language, ways of doing things, and/or dealing with different practices and new institutions (Takyi, 2002; Perreira et al., 2006), a process sometimes labeled "acculturation stress" (Birman et al., 2007).

Moreover, homesickness is a frequent phenomenon associated with leaving one's home, either temporarily or permanently, voluntarily or in some forced manner. Several studies (for a recent review see: Stroebe et al., 2015) suggest that homesick individuals can experience substantial distress and are at increased risk for psychological and physical health problems and lowered well-being. Indeed, homesickness correlates range from emotional (e.g., yearning, loneliness), cognitive (e.g., exaggerate concerns and intrusive toughts about home and attachment figures), social (e.g., withdrawing from relationships in the new environment), to somatic reactions (e.g., loss of weight and appetite). In the context of immigrants' experience, and especially that of refugees, traumatizing experiences may establish, with negative consequences ranging from emotional suffering to psychological disorders, but also positive ones such as the development of new resources (i.e., adversity activated development) (Papadopoulos, 2007).

Finally, it should be noticed that integration is not desirable for emotional well-being only: immigrants need to integrate in the hosting country for practical reasons too, for example getting education (Zhou and Kim, 2006), or participating in shared decision making regarding healthcare (Cutica et al., 2014; Renzi et al., 2016).

The purpose of the present opinion is to highlight some innovative resources to deal with these challenges, starting from the positive technology paradigm and, more specifically, from the concept of mixed reality. Broadly speaking, Positive technology is a theoretical and applied approach that considers human health and well-being as the main objective for technological advancement (Riva et al., 2012). It is not a mere philosophical stance; on the contrary, positive technology offers guidelines for designing technology, in order to pursue specific well-being outcomes. In a broad sense, technology may be used to structure, augment or replace user experience with digital content; also, positive devices may be used to promote positive emotions (hedonic technology), to support the user in the achievement of engaging and self-actualizing experiences (eudaimonic technology), and to enhance connectedness among individuals, groups and societies (social-interpersonal technologies).

Since the first theorization of the positive technology paradigm, digital and immersive devices have been considered some of the most advanced and promising tools for promoting health and well-being (Riva et al., 2016). Specifically, virtual reality and augmented reality are able to (1) expose users to stimuli and complex situations that are normally impossible to reproduce in a physical laboratory or clinical setting; (2) are characterized by inherently engaging properties (e.g., users often perceive them as interesting, funny, intriguing, and may prefer them over more traditional devices); (3) are scalable and adaptable to different contexts and issues, in that virtual environments and digital stimuli can be designed *ad-hoc*.

The term "mixed reality" has been used to identify situations in which digital/synthetic elements co-exist with real ones (Milgram and Kishino, 1994), "somewhere in the middle" between only-physical and totally-immersive virtual environments. Although the positive technology paradigm refuses any extreme idea of the so-called "virtual reality continuum" (because virtual experiences could be "real" from a subjective viewpoint no less than digital ones, and they could have "real" positive and negative effects on users' health and behavior), this term is still used as a broad label including any user experience in which physical or digital elements are not predominant in an absolute sense, but rather an admixture of the two can be envisaged. This points to augmented reality (AR), or the superimposition of digital objects on physical environments and/or composition of the two, which users perceive thanks to equipped devices ranging from the smartphone to dedicated digital glasses.

What has AR to do with the cross-cultural integration issue? Augmented Reality is widely used in fields ranging from medical, military and entertainment (Azuma, 1997; Berryman, 2012), while in socio-psychological interventions its usage is still generally limited to exposure therapy (Chicchi Giglioli et al., 2015).

It can be said that some of the main issues in immigrants' experience, which can generate externalized (e.g., prejudice, unfair social treatment) and internalized problems (e.g., depression, isolation, negative emotions) can be described in terms of lack of something in the new environments. First of all, there is the lack of people, places, practices, and objects from home; this can be contextualized in terms of homesickness and refusal of the new place. Secondly, there may be lack of skills and/or opportunities to communicate with new people as well as with new institutions, which are fundamental factors in the integration process.

In a general sense, AR could provide resources for intervention in that it is based on the *addition* of digital elements to the physical environment, instead of its substitution with an immersive experience which, in this case, may act as a palliative care for sadness but does not help to integrate oneself in a new, "real" physical environment and social context. This relates to the fact that social and mobile technology became "a cornerstone of immigration experience," with immigrant families making an extremely frequent use of computer-mediated communication with their distant relatives about daily decisions and life cycle core issues (Bacigalupe and Cámara, 2012). Indeed, people use any possible means for communication when they feel a urgent need for contact and social support (Wellman et al., 2001), and the use of social media is common among immigrants to maintain contact both with people and community identity (Mallapragada, 2013), to the point that media usage seem not

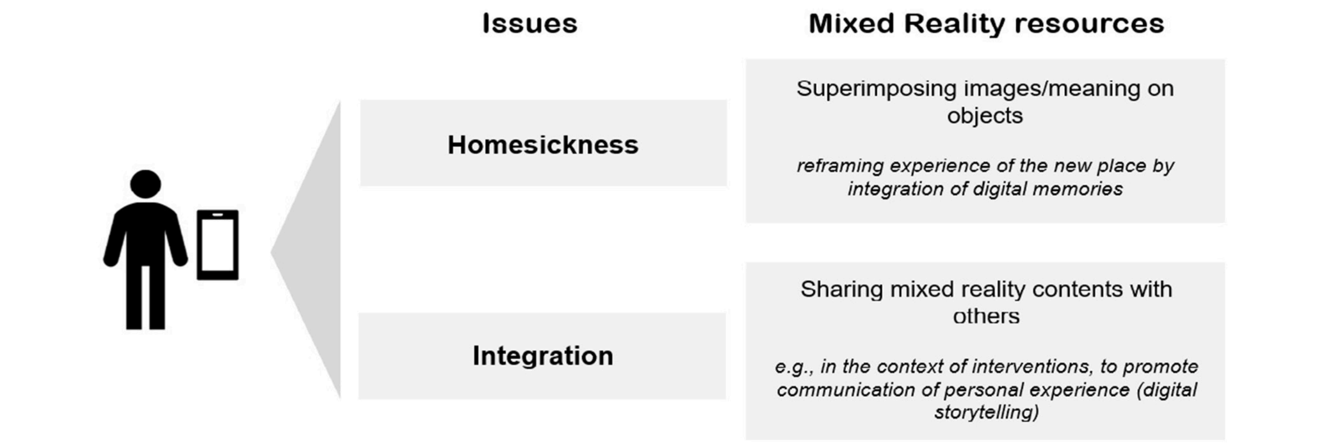

FIGURE 1 | Resume of mixed reality resources for addressing integration issues.

to dissolve geographical identity or connectivity, but rather it reinforces them (Van Den Bos and Nell, 2006).

On the basis of such a widespread usage of technologies among immigrants, new technologies can be used to provide new resources both for dealing with distress and promoting integration.

AR-based Positive technologies can help to maintain the relation with the home country, and also to foster the inclusion in and attachment to the receiving society, by providing users with sources of identification that stretch beyond the national and local contexts of their old and new homes. Addressing social connectedness, mixed reality can provide the medium to share the meanings people attach to places, people and cultures, and creating belonging in the receiving society. Indeed, people can better approach the receiving society by understanding the cultural meanings connected with places, history, and activities.

An example can be derived from the NostalgiaBits project (Morganti et al., 2013), that aimed to enhance the intergenerational relationships (i.e., elderly and youngsters) through the sharing of experiences and memories about places and circumstances. Based on an integrated web-based platform, this project effectively improved young users' representation of the elderly as well as the elderly's well-being by making available new affective and social outcomes (Morganti et al., 2016). Indeed, technologies based on sharing memories/experiences can be used to improve both social and emotional well-being (Giorgi et al., 2013; Talamo et al., 2017).

Such concept can be further explored using AR, by providing the digital medium to enable exchanges between people of different ages, or with different cultural backgrounds.

Specifically, users could share reminiscences, experiences, or even future projects by superimposing personalized images (e.g., pictures, drawings…) on environmental features they are observing together, on site or at a distance. Such a sharing technology, based on the augmented visualization of past or future objects in the environment, may be used for example to combat homesickness (Scopelliti and Tiberio, 2010), or to favor integration among different cultural backgrounds, in that experience sharing is proven to promote empathy and perspective taking and to reduce prejudice (Pettigrew and Tropp, 2008).

Figure 1 resumes the ideas highlighted here as resources to address immigrants' emotional and social issues.

The process of social inclusion can be fostered by enabling meaningful practices that include the social, cultural, and emotional aspects in immigrants' intercultural communication with people in the receiving culture.

To sum up, the proposed concept:

- acts on how the new environment is perceived, by "revealing" the cultural meanings, the practices, memories and personal representations developed by the community;
- builds virtual bridges, to decrease immigrants' sense of distance from their countries of origin and feelings of isolation;
- is based on digital storytelling as a practice to make meaning and share experiences of places, events and people (Alexandra, 2008).

In storytelling, by the process of re/considering and actively re-constituting stories, a sense of agency is constructed against disempowering circumstances (Jackson, 2002). Immigrants use narratives and share memories of the homeland to re-affirm their identities (Ramsden and Ridge, 2013; Lenette et al., 2015). Reminiscence and storytelling involving the communities and neighborhoods promote exchanges, mutual understanding, and respect between different age- and cultural-groups (Mercken, 2002).

The proposal expressed in the present opinion article is still in its infancy. However, it provides an innovative idea for positive technology (social-interpersonal), which may guide the development of future devices and applications to enhance health and well-being in the growing population looking for a new life in places distant from home.

This idea deserves future research, not only for technical development, but also regarding its inclusion into psycho-social interventions for integration; these would be focused on structuring and regulating its usage. Indeed, mixed reality-based shared storytelling may feature some shortcomings; for example, it may be used among immigrants only, this way reinforcing intragroup processes that promote nostalgic complacency, and prevent immigrants to build new resources for integration in the hosting culture and social context. Social-interpersonal positive technologies should be managed from design to intervention, in order to make use of their affordances for social inclusion of new relationships with outgroup members.

AUTHOR CONTRIBUTIONS

AR conceptualized the work. AR and ST drafted the paper. CM contributed with discussion about issues related to migration and immigrants' experience. AT revised the paper and supervised the whole process. All the authors provide approval for publication of the content.

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Can New Technologies Make Us More Human? An Inquiry on VR Technologies in Social Cognition

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INTRODUCTION

There is a heavily ingrained image in contemporary culture, that new technologies can have a negative impact on human relations and bring us closer to dehumanization. For example the immersive worlds of games, virtual reality and social media, provide a surrogate of human relationships and interactions. Despite these dangers, we believe that new technologies can also make us more empathetic, altruistic and understanding toward each other. So we ask a question: can new, emerging technologies make us more human and become a factor in the process of humanization? In this article we present an idea that is a positive answer to this question, which could be called digital humanism. According to our thesis, new technologies extend and develop new tools of social cognition, especially when we consider the possibility to take perspectives of others that without the aid of said technologies would be impossible to comprehend. We can experience in first person, via VR technologies, how one suffers from various cognitive disorders and deficits like the ones associated with attention, autism, MCI (mild cognitive disorder), schizophrenia or color blindness. This refers to "digital" part of our thesis. The aforementioned experiences can influence, mainly through understanding and empathy, our moral actions and can overcome various biases like harmful stereotypes (Yee and Bailenson, 2006) or enhance altruistic attitudes in social cognition. At the same time it creates conditions for the formulation of new social relations (Bailenson, 2006; Bailenson et al., 2008). This refers to "humanism" in our thesis.

Even without using VR technology, perspective taking affects our behavior and attitude (Galinsky and Moskowitz, 2000). Generally speaking, taking perspective of another person (while interpreting him/her as intentional and equipped with a mind) is an essential human trait. It is a form of social cognition, which in turn is understood as:

> General term used to describe different forms of cognition about, or actions in regard to, agents or groups of agents, their intentions, emotions, actions and so on, particularly in terms of their relation to other agents and the self (De Jaegher et al., 2010, p. 441).

The skills of perspective-taking also enable cultural learning, which allowed us, human species, development of new processes of sociogenesis and cumulative cultural evolution (Tomasello, 1999).

In this approach, cultural practices and the culture itself are understood as abilities to create, accumulate and take perspectives of another person. For instance, through the works of Plato, we can take his historically accumulated perspective on various subjects. In contemporary culture, we also have other media that enable us to do the same. New technologies (like VR) help us develop new tools of social cognition that are essential to our species. Our aim is to present VR technologies as new tools of social cognition and to consider what path the modeling of social relations may take in the context of "extended mind" and procedurally modeled ontology-driven virtual reality.

EMPIRICAL EXEMPLIFICATION OF DIGITAL HUMANISM

To exemplify digital humanism, we refer to the studies of Ahn et al. (2013), Ahn et al. (2014) among other publications. Their study (Ahn et al., 2013) demonstrated how perspective taking while being immersed in VR environment affects dispositions attitudes and behavior. The mechanism that governs our affinity toward helping others is described as self-other merging which was used to explain the theoretical basis for the study (Ahn et al., 2013). A series of experiments was performed, that subjected participants to an environment that simulated perception of the world while suffering from colorblindness, others were instructed to only imagine such perspective. Experiment 1 was a comparison between the two groups in 24 h timeframe after. The results showed that participants with lower overall disposition toward helping others were affected more by the immersed experience. Experiment 2 showed that enhancing spatial immersion in VR also enhances longevity of the effects of the treatment and its impact. This was measured by a survey that took into account various parameters adapted from different psychological tests (the parameters were manipulation check, oneness, helping and attitude). Additionally participants wrote down their thoughts about the experience or the perspective they attempted to take. Experiment 3 was a demonstration of the effects of immersed VR experience in real world, and how sustainable they were. In that last part of the study, participants spent time helping colorblind people. The results showed a stronger impact of the VR experience compared to using solely traditional perspective taking.

To better understand the intricacies of perspective taking and perspective taking enhanced by VR experience, we need to take into account similarities and differences of those phenomena. Traditional perspective taking engages our imagination to assume others' point of view, to see through someone's eyes, so to speak. Virtual reality in this case gives us access to a "multilayer perceptual information simulated by digital device" (Ahn et al., 2013, p. 8) which allows us to see and hear as if we were experiencing someone else's point of view in the real world. Because of this multimodal aspect, we can call it an "embodied experience" (Ahn et al., 2013). Perspective taking has a substantial effect on social attitudes and cognition as well as learning (Tomasello et al., 1993). For instance, it has been found that it enhances empathy toward people from stigmatized social groups (Batson et al., 1997). Having said that, what is the difference between traditional perspective taking and embodied experience? Perspective taking requires significant cognitive resources (Roxβnagel, 2000) and also various factors that may motivate us to do it (Gehlbach et al., 2012). In case of embodied experience, seeing through someone's eyes is easier to achieve because of multimodal influence of VR.

Moreover, VR studies focus on the effect of embodying the physical traits of another person. During such investigations we can indicate the so-called "Proteus effect." It is caused by changes in physical appearance of VR avatar that affect behavior of the person experiencing it. The results demonstrated that short amount of time in VR embodying a visual self-representation (i.e., an avatar) modified behavior of a person in the real world (Yee and Bailenson, 2006). For example, participants given attractive avatars in VR were more confident in interacting with strangers offline compared to those given unattractive avatars (Yee and Bailenson, 2009; Yee et al., 2009). It is speculated that the "Proteus Effect" is a different cognitive process than self-other merging mentioned above (Yee and Bailenson, 2009). Another way to influence our attitudes through embodied experiences is to diminish out-group and in-group racial bias by visualizing an avatar of different skin color than the participant (Maister et al., 2015; Hasler et al., 2017). There are also other studies that show the extent of the influence of VR environment that can affect real-world behavior (Peck et al., 2013; Ahn et al., 2014), as well as enhance prosocial behavior (Rosenberg et al., 2013; Shriram et al., 2017) and is considered to be used in health and education (De Oliveira et al., 2016). There is a need to investigate these processes further as well as the individual capacities, and socio-cultural practices they rely on.

THEORETICAL ASPECTS OF DIGITAL HUMANISM

Aside from the empirical studies, digital humanism is considered from a theoretical standpoint. From a purely theoretical standpoint, new VR technologies can be understood in the context of the "extended mind" conception of Clark and Chalmers (1998), according to which cognitive processes are not bound physically only by functioning of the brain, but are indeed extended into the agent's environment. In this view the distinction between the internal (within the person's cognitive system) and external (beyond the person's cognitive system) part of cognitive processes is arbitrary. In the context of digital humanism for the most part we take into consideration liberal interpretation by S. Gallagher (2013) who coined the term "social extended mind." According to this account, "mental institutions" "not only accomplish certain cognitive processes but also are such that without them such cognitive processes would no longer exist" (Gallagher and Crisafi, 2009, p. 6). In our interpretation, VR technologies are a form of extended mind. In fact, they are "mental institutions" and they enable various cognitive processes, like aforementioned embodied experiences, which are in fact new tools of social cognition.

Taking this into account, knowledge about said mental institutions may be used as a model to further develop our understanding of social phenomena. So, how can we improve VR scenes for embodied experience? How can we be more precise in simulating intricacies of social dynamics within VR?

One of the possible ways of modeling and visualizing of these mental institutions with the use of new technologies may take into account social ontology, which can be understood as "a statement or understanding of the nature, character, or basic features, structures, or constituents of this. It is an explication or understanding of the basal "what there is" to social existence" (Woolgar and Schatzki, 2010). In our account, we consider social ontology in the sense of knowledge representation theories and its engineering apparatus (Davis et al., 1993). By creating social domain ontology, we can start to delve deeper into the analysis of its parameters and metrics. The data and parameters of social domain ontology can also be applied to VR technology. There are already methods of automated generation of virtual reality scenes representing domain defined in an ontology (SEMIC approach) (Flotynski, 2014). Additionally, SEMIC approach also can be understood as a type of procedural modeling method. By using a given set of instances of a domain ontology, the system automatically generates objects as contents of a VR scene. It uses provided data (properties, relations, hierarchy) to integrate it into set of objects to be used in an interactive environment. This provides an automated way to generate VR environments based on mental representations rather than aesthetic and design-driven standpoint. It may be a way create more accurate embodied experiences that would become a testing ground for social phenomena that incorporate mental institutions.

Combining virtual reality and knowledge representation allows for a unique way of designing and evaluating social mechanism models. The aforementioned automated generation of a fragment of a domain, (in this case, a social ontology) by using SEMIC, can become a scene for social interaction between two or more people connected to such virtual environment. There are two stages where mental representations of two or more subjects are combined—first, when two or more experts design domain ontology, their collective effort allows them to conceptualize said domain; second, for example, when two firefighters are immersed in a such SEMIC-generated VR scene of a burning building we can see how fast they can achieve mutual understanding by combining their representations to solve a problem. This can possibly give us new ways to view social interactions and also makes the transition of mental institutions from social domain to VR more seamless and specifically tailored to the user.

CONCLUSIONS

In this Opinion we proposed a theoretical framework for conceptualization and systemic approach for further development of digital humanism. To be precise, we have described embodied experiences and VR technologies as a form of extended mind, more specifically socially extended mind and in turn as mental institutions that may be used as a model to further develop our understanding of social phenomena. We have given an example of how we can use domain ontologies to improve VR scenes for embodied experiences and how we can improve the simulation of details of social dynamics within collective embodied experiences.

We consider various forms of research in the future. More specifically, the analysis and creation of VR tools that enhance our social competencies and cognition. It is possible that VR technologies will become a common tool to diagnose, evaluate and refine these competencies. It would make VR not only a type of entertainment, but a formidable, widely-used scientific tool. For example, the use of VR might become equally important as questionnaires and surveys, especially in assessing employability skills. With this in mind, we may attempt to follow the development of VR technologies and how it will affect social cognition, or more generally, human mind.

AUTHOR CONTRIBUTIONS

To emphasize the individual work put into this paper, Introduction, Theoretical Aspects of Digital Humanism, and Conclusions were written by DŻ and AF, while Empirical Exemplification of Digital Humanism was done by AF, DŻ, and EM.

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Designing Awe in Virtual Reality: An Experimental Study

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Awe is a little-studied emotion with a great transformative potential. Therefore, the interest toward the study of awe's underlying mechanisms has been increased. Specifically, researchers have been interested in how to reproduce intense feelings of awe within laboratory conditions. It has been proposed that the use of virtual reality (VR) could be an effective way to induce awe in controlled experimental settings, thanks to its ability of providing participants with a sense of "presence," that is, the subjective feeling of being displaced in another physical or imaginary place. However, the potential of VR as awe-inducing medium has not been fully tested yet. In the present study, we provided an evidence-based design and a validation of four immersive virtual environments (VEs) involving 36 participants in a within-subject design. Of these, three VEs were designed to induce awe, whereas the fourth VE was targeted as an emotionally neutral stimulus. Participants self-reported the extent to which they felt awe, general affect and sense of presence related to each environment. As expected, results showed that awe-VEs could induce significantly higher levels of awe and presence as compared to the neutral VE. Furthermore, these VEs induced significantly more positive than negative affect. These findings supported the potential of immersive VR for inducing awe and provide useful indications for the design of awe-inspiring virtual environments.

Keywords: awe, virtual reality, presence, emotions, emotion induction

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INTRODUCTION

Awe is a complex emotion characterized by intense feelings of astonishment, wonder and connectedness that arises when one is confronted with something vast that transcends previous knowledge schemas (Keltner and Haidt, 2003). This emotion can be triggered by natural phenomena, such as the view of the ocean or a starry night, but it may also be elicited by more conceptual contents, such as great works of art and "grand theories" (i.e., the theory of relativity).

In the last decade, the scientific interest of awe has significantly increased, especially because research on positive emotions has shown that experiencing awe is associated with transformative changes at both psychological and physical levels (e.g., Shiota et al., 2007; Schneider, 2009; Stellar et al., 2015). For example, awe can change our perspective toward even unknown others thus increasing our generous attitude toward them (Piff et al., 2015; Prade and Saroglou, 2016) and reducing aggressive behaviors (Yang et al., 2016). Generally, awe broadens our attentional focus (Sung and Yih, 2015), and extends time perception (Rudd et al., 2012). Furthermore, this emotion protects our immunity system against chronic and cardiovascular diseases and enhance our satisfaction toward life (Krause and Hayward, 2015; Stellar et al., 2015).

Considering the transformative potential of awe, an important methodological question concerns how to elicit intense feelings of awe within controlled laboratory conditions

(Chirico et al., 2016). However, the intrinsic complexity of this emotion is hard to be reproduced in the lab (Silvia et al., 2015). According to the prototypical model of Keltner and Haidt (2003), awe can be conceived as a complex emotion encompassing the two main appraisal themes of *vastness* (i.e., the perception of being in front of either perceptually or conceptually grand and vast stimuli) and *need for accommodation* (i.e., the urge to adjust mental frames according to new incoming information). Consistently with this operationalization, previous experimental studies on awe have attempted to induce this emotion by exposing participants to grand and vast panorama or natural phenomena (Saroglou et al., 2008; Griskevicius et al., 2010; Van Cappellen and Saroglou, 2012; Van Cappellen et al., 2013) ranging from deep space images, earth and stars (Silvia et al., 2015) to supercell (Gordon et al., 2016). Awe arises from "*information-rich stimuli,*" which entail a need to update our current knowledge of ourselves and the world (Shiota et al., 2007; p. 946).

Recently, virtual reality (VR) has been proposed as a new technique to induce awe in the lab (Chirico et al., 2016). VR is a technology that combines multi-sensory stimuli to generate the perception of being "present" within computer-generated environments and users with the possibility to interact with 3-D contents, resembling real-life interactions, even in a controlled laboratory setting. However, the potential of VR for inducing awe in the lab has not been fully explored yet. A first study carried out by Chirico et al. (2017) showed that the use of immersive videos (i.e., 360-degree video recordings that capture the entire scene around the camera) could generate more intense feelings of awe than conventional 2D videos. Here, we aimed at assessing the effectiveness of computer-generated, three-dimensional virtual environments (VEs) in inducing awe. Differently from immersive videos, VEs are fully interactive graphical scenarios that the user can explore as a 'real' physical space. These VEs can be populated with any type of objects and animated characters (i.e. humans, animals, or other creatures) the users can interact with. From a methodological viewpoint, the main advantage is that VEs allow researchers to design any possible scenario and situation, both realistic or imaginary. Furthermore, a VE can be programmed to include specific tasks and challenges, thus widening the range of experimental manipulations. Another possible asset offered by VEs in awe research is that they allow the experimenter accurately tracking participant's behaviors within the virtual world, i.e., by logging his/her 'virtual' actions. Last, but not least, in contrast with 2D videos, a VE can also simulate physically "impossible" phenomena, that is, events breaking the physical or logical laws (i.e., flying over a city, reversing the direction of time etc. (Rosenberg et al., 2013; Friedman et al., 2014; Serino et al., 2015). Finally, immersive VEs are known to generate strong feelings of "presence" in the user, that is, the subjective feeling of being in another physical or imaginary place (Waterworth et al., 2010, 2015; Riva et al., 2011; Riva and Waterworth, 2014; Waterworth and Riva, 2014). Actually, previous research (Diemer et al., 2015) has shown that presence and emotions are closely linked psychological phenomena. Specifically, the feeling of presence can be enhanced by a sense of *immersion* within the VEs (Coelho et al., 2006; Diemer et al., 2015). Immersion consists in the possibility to experience a VE from a first-person perspective and in the sensorial isolation from the real world, as well as in the technological degree of sophistication (Diemer et al., 2015). Crucially, also the possibility to interact with 3-D objects, as a property of immersion, is a key element able to enhance the sense of presence (Blackmon and Mellers, 1996). This VR feature is called *interactivity*. Interactivity has been defined as "the degree of which users of a medium can influence the form or content of the mediated environments" (Steuer, 1992; p. 80). Previous studies have shown that these components of presence (i.e., immersion and interactivity) can amplify emotions reported by users navigating VEs. For example, Baños et al. (2004a) evidence a key relationship between immersive emotional environments and the sense of presence. Specifically, it has been evidenced that immersion can enhance emotional intensity, especially for high arousing emotions (IJsselsteijn et al., 2001; Baños et al., 2008; Diemer et al., 2015). In line with this, Riva et al. (2007) developed a neutral, relaxing and anxious virtual park to test the ability of VR to induce emotions and the link between affects and the sense of presence. They evidenced that the more activating the emotional state was, the higher the sense of presence. However, they focused only on general affective states and not on specific discrete emotions.

On the other hand, Felnhofer et al. (2015) combined visual and auditory cues to design *ad hoc* VR scenarios able to convey specific discrete emotional states (joy, sadness, boredom, anger, and anxiety). They found that the sense of presence was similar across all emotional scenarios, suggesting that presence is not connected to the type of emotion, but maybe, on the presence/absence of an emotional content.

Finally, also realness is a crucial variable conveying a high sense of presence, thus influencing subsequent emotional states (Schubert et al., 2001; Freeman et al., 2005). This would involve several aspects of a VEs, starting from the kind of interaction provided, to the visual and auditory stimuli together (Riva et al., 2007).

Although several studies showed that VR has a potential for both general affect and discrete emotional states, the relationship between complex emotions, such as awe, and VR still needs to be fully explored (Chirico et al., 2017).

In order to test the effectiveness of VE for inducing awe, we designed four different scenarios: three VEs included elements that were assumed to induce different instances of awe (i.e., view of tall trees, high snow mountains, seeing the earth from deep space; please see the Section "Materials and Methods" for a detailed description of VEs). The fourth scenario did not include awe-inspiring elements, and was included as control condition. Our main hypothesis was that awe-VEs would induce greater feelings of awe than the 'neutral' VE. Furthermore we expected that presence and awe are positively related, as suggested by previous studies. In other words, the aim of this study was threefold. First, the aim of this research was to validate a set of VR awe-inducing stimuli. Consequently, we were also interested in elucidating which environment was the most awe-inducing one (i.e., the one which induced the higher intensity awe). To this aim, we realized three interactive evidence-based awe-inducing VR environments resembling three instances of awe, following guidelines provided by literature on this complex emotion (Keltner and Haidt, 2003; Shiota et al., 2007; Krause and Hayward, 2015; Piff et al., 2015; Gordon et al., 2016; Yaden et al., 2016). Then, we contrasted the effects of awe, sense of presence and general affect induced by these three environments with those induced by a neutral content created *ad hoc* in VR. Finally, we aimed to advance knowledge in the positive technology field about the efficacy of two different awe-induction techniques: 360°-videos and VR. To this aim, we focused on 360° videos and VR environments to compare their standardized effects on the same variables (i.e., presence and awe). This study has also implications for the methodology of the study of awe. The validated stimuli can be used in other studies to manipulate this emotion.

MATERIALS AND METHODS

Participants

Thirty six participants voluntarily took part in the study (18 females – mean age = 23.33; *SD* = 0.333; 18 males–mean age = 23.67; *SD* = 0.404). Participants were graduate students recruited through campus announcements at an Italian University. We excluded participants reporting vestibular and/or balance disorders. The experimental protocol was approved by the Ethical Committee of the Università Cattolica del Sacro Cuore prior to data collection. Each participant provided written informed consent for study participation. Written consent and all methods were carried out in accordance with the Helsinki Declaration.

Stimuli

We modeled four interactive and immersive VEs with Unity software (version 5.5.1.). Three contents were designed to be awe-inducing, thus they depicted natural scenes of (i) Forest (Piff et al., 2015) (see **Figure 1**); (ii) Mountains (Chirico et al., 2016) (see **Figure 2**) and (iii) Earth view from deep space (Gallagher et al., 2015; Yaden et al., 2016, 2017) (see **Figure 3**). The neutral environments represented a natural scene including green grass with few flowers and trees (see **Figure 4**). To be consistent, we chose only natural scenarios to induce awe, since they are indicated as prototypical awe-eliciting stimuli (Keltner and Haidt, 2003). Further, to enhance the feeling of immersion within the VE, we provided participant with headphones supplied with Oculus rift DK2, so that they could hear the environmental sounds consistently within the virtual landscapes.

Specifically, we followed literature on awe and its sub-components as design principles to be implemented into VR scenarios. First, we drew extensively from the literature on the subdimension of vastness, which emerged as the most crucial component in the experimental study of awe (Chirico et al., 2016).

Since vastness can be either conceptual (in terms of complexity) or perceptual (in physical terms) (Keltner and Haidt, 2003; Yaden et al., 2016), the three target stimuli were designed in line with these two components of vastness. Therefore, this study used an evidenced-based design approach, drawing from literature on awe to "design" vastness. Mountain scenario relied on a concept of vastness as "width" (large panorama), whereas, we designed vastness in terms of "height" (Tall trees and the downfall) in the Forest condition. Finally, the Earth view, which can be conceived as an instance of conceptual vastness (Yaden et al., 2016), was designed to reproduce a prototypical instance of awe, basing on vastness conceptual component.

Finally, each environment was designed also to induce a need for accommodation as well. Since need for accommodation can be operationalized as a type of surprise (Chirico et al., 2016), we relied on this indication to build the environments, by creating a standardized navigation path leading to an unexpected cue (panorama, waterfall and Tall trees, Earth). See **Figure 5** for the design process of these stimuli.

Forest

The composition of this scenario was chosen based on the work of Piff et al. (2015). These Authors led participants to stand in a grove of highest Tasmanian eucalyptus trees. Similarly, our environment displayed a forest of luxuriant forest culminating in a high waterfall, hidden behind trees. Awe is related to high stimuli, both natural (Piff et al., 2015) or artificial (Joye and Dewitte, 2016) and Forest are one of the most prototypical awe elicitors. We chose to enhance the awe-potential of our trees by introducing another highest awe-inspiring stimulus, that is a waterfall (Rudd et al., 2012). Specifically, the waterfall fulfills two important functions. First, the waterfall was used in combination with trees, to enhance the global feeling of vastness. More, since awe is an emotion entailing not only a vastness component (i.e., here the Forest and high waterfall) but also a need for accommodation dimension (i.e., something able to surprise the viewer), we chose to introduce the waterfall behind trees to support this last complex component, which can be assimilated to a special case of surprise (Chirico et al., 2016). Finally, within the forest grove there is a path helping participants to reach the waterfall. We chose to create a standardized path (i.e., the same length and the same navigation speed in all environments) that participants must follow, to prevent them from frustration (Santos et al., 2009). Indeed, we created quite vast virtual space in which participants can navigate but they

FIGURE 1 | The Forest.

FIGURE 2 | The High Snow Mountains environment.

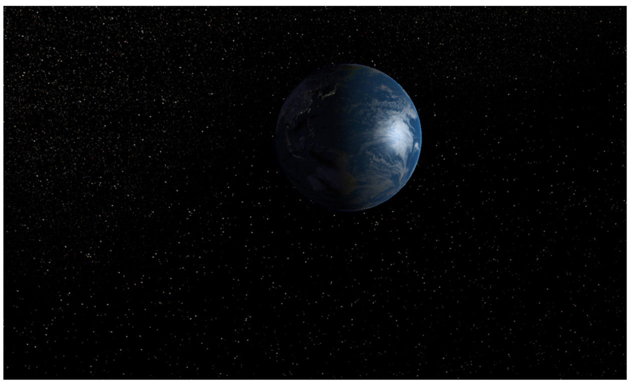

FIGURE 3 | The Earth view from deep space environment.

did not know the environment previously, so, it was possible that they never reached the final target, in this case the waterfall, but just wandering. This would lead to a partial awe experience in which the need for accommodation component would be undermined.

We integrated visual stimulation with consistent environmental sounds including chirping of birds, typical of this kind of forest, along with the noise of wind flowing through the fronds of the trees. Finally, the sound intensity was calibrated according to participants' proximity to the sound source (i.e., the waterfall falling on the rocks).

Mountains

This environment featured high snow mountains with a path of stones culminating in a beautiful panorama. We designed this scenario in line with works of Keltner and Haidt (2003) and Rudd et al. (2012). Here, the vastness component was conveyed by means of the panorama showing the snow-capped picks, while the component of need for accommodation was supported by the unexpected view of the magnificent panorama behind picks. Also in this environment, participants were instructed to follow a path of stones, which led them to the view of panorama, after going through rock walls.

FIGURE 4 | The Neutral environment: green clearing.

We included the background sound of wind blowing through the peaks. This sound element would enrich users' experience thus enhancing their sense of presence within the VRE.

Earth from Deep Space

Watching at the earth from the space is considered the most prototypical case of awe. This experience was described by White (1987) for the first time as the "overview effect." Yaden et al. (2016) deepen this phenomenon by analyzing the reports produced by astronauts during space travels. We designed a scenario in which the user is immersed into the deep space in front of the earth. Participants could navigate toward the earth which rotates on itself, as it naturally occurs, showing different sides (illuminated and obscured). In this experience, both vastness and need for accommodation are supposed to be conveyed. Specifically, the vastness is conveyed through the possibility to see something much larger than ourselves and which includes all the people we could have ever known in our lives. The awareness of this condition is related to the newness and to the paradoxical nature of this experience. It is highly unlikely that people could see earth from outside its atmosphere in their lives unless they become astronauts. This contributes to the dimension of the need for accommodation, because it acts as something able to alter people' accustomed schema, defined as "organized conceptual framework through which individuals approach new information and make sense of old experiences" (Yaden et al., 2016, p. 6).

Here, to be as close as possible to the equivalent real situation, we did not include any kind of sounds, since no sound could be heard in the deep space.

Neutral Environment

To induce a non-specific emotive state, we followed guidelines by Baños et al. (2004b, 2008), Riva et al. (2007), Diemer et al. (2015) and we deprived this environment of several other cues used in the other scenarios. Specifically, this scenario displayed a park consisting of a green clearing with very few trees and some flowers. To contrast the effect of vastness conveyed by

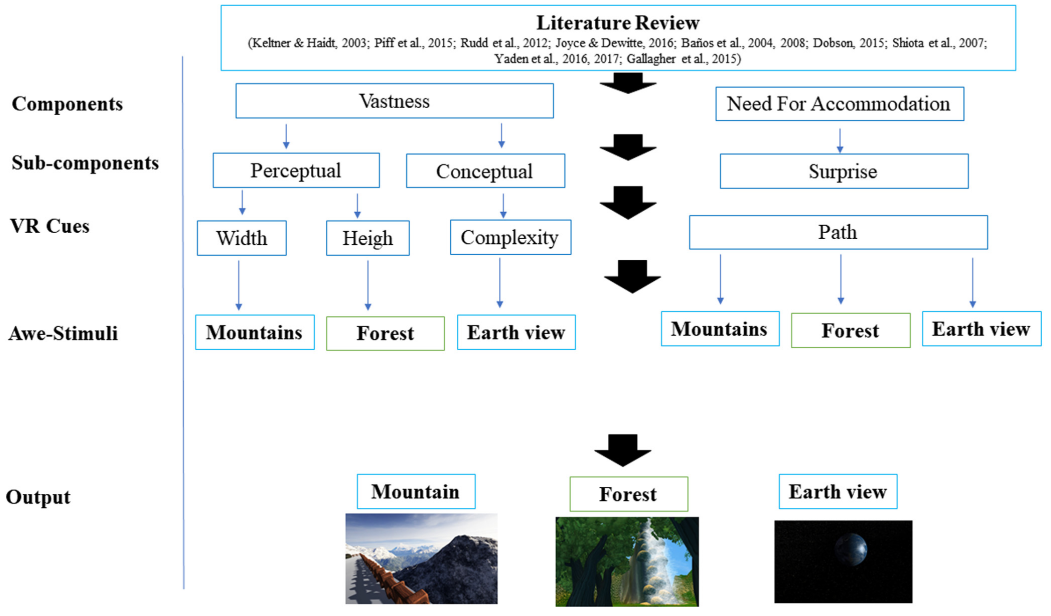

FIGURE 5 | Diagram of evidence-based stimuli design.

previous scenarios, we surrounded the whole scene with high stones which hindrance the view outside the woodland. We hypothesized that this physical closure, would be followed by a feeling of psychological closure, the opposite of vastness. Moreover, to ensure that this environment would not convey a need for accommodation, we excluded all elements that could result as unusual or unlikely. For example, the whole environment could be perceived at a glance, nothing was hidden or to be discovered as it happened in the other environments. Participants in this condition followed the same standardized path as in the other conditions (i.e., the same length in all environments).

No sound was included in order not to orient participants' emotional state.

Measures

At the baseline, participants were requested to complete:

(i) Again, a single item Likert self-report measure was used to assess *awe* on a 7-point Likert scale (from 1 = not at all; to 7 = extremely), along with other items measuring other seven distinct emotions (from 1 = not at all; to 7 = extremely): Joy, and consensual definitions of emotions taken from literature (Frijda, 1988; Morreall, 1989; Haidt, 2003; Algoe and Haidt, 2009; Griskevicius et al., 2010; Lewis et al., 2010; Herring et al., 2011; Tong, 2015).

(ii) *General affect* was assessed by mean of the Italian PANAS version (Terraciano et al., 2003), which measures two main clusters of the affective experience. This questionnaire consists in a list of 20 adjectives measuring the positive affect (10 adjectives) and the negative affect (10 adjectives). This scale showed an adequate reliability for PA ($\alpha = 0.76$) and for NA ($\alpha = 0.83$).

After the navigation phase, again, participants' awe and general affect was assessed. Moreover, also the sense of presence, perceived vastness and need for accommodation were measured:

(i) A single item Likert self-report measure was used to assess *awe* along with other items measuring seven distinct emotions (from 1 = not at all; to 7 = extremely): Anger; Disgust; Fear; Pride; Sadness, Amusement and Joy. This questionnaire was used to obtain a measure of "*global perceived awe.*"

(ii) We administered the ITC-Sense of Presence Inventory (ITC-SOPI) (Lessiter et al., 2001) to assess *perceived sense of presence*. It is a well-validated questionnaire composed of 42-items on a 5-point Likert scale (1 = strongly disagree; 5 = Strongly agree). This questionnaire consists in four subscales, each referring to a specific dimension of presence, with a good internal consistency (Cronbach Alpha ranging between 0.76 and 0.94): Sense of Physical Space (0.94); Engagement (0.89); Ecological Validity (0.76); Negative Effects (0.77).

(iii) *Perceived vastness* and *Need for accommodation* were assessed through *ad hoc* questionnaire developed by Chirico et al. (2017), according to the guidelines provided by Schurtz et al. (2012) and Piff et al. (2015). Specifically, *Perceived vastness* was assessed using these four items: (1) What I watched provided me with a deep sense of vastness; (2) I felt small in front of what I watched; (3) I felt meaningless in front of what I saw; (4) I felt my sense of self diminish in front of what I saw). *Perceived need* for accommodation was measured through four items: (1) It was hard to grasp what was going on in the video; (2) I felt confused and bewildered in front of what saw; (3) I was struck by the video).

Procedure

First, participants read and signed the informed consent document. Then, they were given a written and an oral description of the study. They were seated on a chair in front of a computer, and they completed the baseline measures. Then, they were asked to stand up in front of a computer and were tested once per session. Before the navigation phase, participant received a set of instructions about the experiment. The experiment was divided into two phases: baseline and navigation. In the baseline phase, participants were required to report their general affect (PANAS) and the extent to which they felt seven discrete emotions including awe. Then, they were provided with information about how to use the Oculus Rift DK2 and its fitted Microsoft Xbox controller (plugged to the laptop). Finally, they navigated in each VE once in a counterbalanced order. The Oculus Rift DK2 (Oculus VR LLC, Irvine, CA, United States) is a head-mounted display (HMD) with a resolution of 1920 × 1080 pixels and a frame rate of 90 Hz. And also, to avoid cybersickness, we used the following computer: graphic card NVIDIA GTX1070, and a CPU Intel i7. More, we optimized the VEs to avoid low framerates and screen flickering. Immediately before wearing the HMD, participants were instructed to close their eyes until the VE was displayed. The same VE was visible on a desktop computer (i.e., Virtual Desktop application developed for the Oculus Rift), so that also the experimenter could check for it to start correctly. Then, participants received standardized instructions about how to navigate in each environment. The instruction form was the same for all environments, as well as the length of the initial path they could navigate in.

Standardized instructions format was as follows:

> "*Please, follow* (specific natural cues embedded into the VEs to provide participants with the same task: stones, a path, the earth), *and then explore the virtual environment freely, as you prefer.*"

When participants indicated that they were ready to begin, the experimenter started countdown. The navigation phase lasted 3 min. After each VE, participants completed the self-reported measures described above. This procedure was repeated four times, one time for each condition, with each participant. After all, four environments had been experienced by the subjects, a debriefing phase concluded the session and interviews were recorded. The entire experiment lasted about 55 min.

RESULTS

Data Analyses

Two normality tests (i.e., Kolmogorov–Smirnov and Shapiro–Wilk) were carried out to determine if variables were normally distributed. Only positive affect dimensions, sense of perceived vastness, sense of physical presence, perceived engagement in each condition were normally distributed. Also, ecological validity in the High snow mountains and in the Neutral condition followed a normal distribution. Given the small size of our sample, we chose to carry out parametrical statistical analyses for normally distributed variables (i.e., repeated measures ANOVA) and the equivalent not parametrical tests for not normally distributed variables (i.e., Friedman test and Wilcoxon Signed Rank tests).

Discriminant Ability of Each Virtual Environment

Results showed that the three awe-inducing VEs induced higher levels of awe compared to the neutral stimulus and to the baseline. **Table 1** shows descriptive statistics concerning emotions scores for each condition.

Awe

Awe variable was not normally distributed across conditions; thus, we chose to carry out a Friedman test of differences among repeated measures (all conditions including the baseline) was conducted and rendered a Chi-square value of 73.07 which was significant ($p < 0.001$). Then, a Wilcoxon Signed Rank test to compare awe levels across all environments including the baseline. When multiple statistics are applied to discover pairwise associations, it is necessary to adjust the significance levels since the probability to commit Type I errors increases. With this regard, Bonferroni correction lowers the critical *p*-value for the Wilcoxon test and it relies on the number of performed tests. Therefore, for adjustment, we computed the corrected level of significance ($\alpha = 0.05$) to address the multiple statistics. Since we had 5 conditions the number of possible combinations is 10 (=5*4/2) [N(N-1)/2] and we adjusted the significance level to 0.005 (=0.05/10) (Cabin and Mitchell, 2000). Resulted showed that Forest [Mdn = 6.00; $Z = -2.406$, $p < 0.001$; $r = 0.294$], Mountains [Mdn = 5.00; $Z = -4.635$, $p < 0.001$; $r = 0.546$], Earth [Mdn = 5.00; $Z = -3.557$, $p < 0.001$; $r = 0.419$] induced significantly higher levels of awe compared to the Neutral stimulus (Mdn = 3.00). Forest [$Z = -4.852$, $p < 0.001$; $r = 0.571$], Mountains [$Z = -4.984$, $p < 0.001$; $r = 0.576$], Earth view [$Z = -4.969$, $p < 0.001$; $r = 0.585$] significantly differed from the baseline (Mdn = 2.00) regarding awe levels. No significant difference emerged between baseline awe and awe induced by the Neutral environment.

Please, see **Table 2** for Wilcoxon test between each condition and the baseline for each emotion.

Finally, we carried out also Wilcoxon Signed Rank test to compare awe levels only across the three target conditions (i.e., Forest, Mountain, Earth), in order to elucidate which environment was the most awe-inducing one. For adjustment, we computed the corrected level of significance ($\alpha = 0.05$) to address the multiple statistics. Since we had only 3 conditions, the number of possible combinations is 3 (=3*2/2) [N(N-1)/2] and we adjusted the significance level to 0.017.

Results showed that Mountain [Mdn = 6.00; $Z = -2.406$, $p < 0.01$; $r = 0.232$] induced significantly higher levels of awe compared to Forest (Mdn = 5.00) and to Earth (Mdn = 5.00). No significant difference between Forest and Earth was evidenced.

TABLE 1 | Emotions scores for each condition: mean and standard deviation for each emotion in each condition.

Measure	Baseline		Forest		Mountains		Earth view		Neutral	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Anger	1.889	1.214	2.167	1.648	1.472	0.696	1.667	1.352	1.972	1.521
Disgust	1.472	0.941	1.389	1.202	1.333	0.756	1.250	0.770	1.778	1.333
Fear	1.861	1.046	1.472	1.055	2.417	1.713	1.611	1.202	1.361	0.682
Pride	2.778	1.570	2.333	1.219	2.611	1.379	2.361	1.397	2.111	1.214
Amusement	2.500	1.424	2.333	1.493	2.750	1.680	2.417	1.574	2.056	1.012
Sadness	1.861	1.334	1.306	0.822	1.444	0.909	1.278	0.741	1.444	1.027
Joy	2.806	1.582	3.389	1.777	3.694	2.215	3.194	1.940	2.556	1.361
Awe	2.222	1.417	4.556	1.647	5.250	1.697	4.611	1.856	3.194	1.546

TABLE 2 | Significance levels for each condition compared to baseline using Wilcoxon test.

Measure	Forest vs. baseline		Mountains vs. baseline		Earth view vs. baseline		Neutral vs. baseline	
	Z	*p*-value	*Z*	*p*-value	*Z*	*p*-value	*Z*	*p*-value
Anger	−0.726	0.468	−1.908	0.056	−0.861	0.389	−0.158	0.874
Disgust	−0.574	0.566	−0.615	0.538	−1.254	0.21	−1.152	0.249
Fear	−1.65	0.099	−1.733	0.083	−0.753	0.451	−2.165	0.03
Pride	−1.418	0.156	−0.853	0.394	−1.722	0.085	−2.392	0.017
Amusement	−0.667	0.505	−0.569	0.569	−0.301	0.764	−1.569	0.117
Sadness	−2.312	0.021	−2.025	0.043	−2.371	0.018	−1.917	0.055
Joy	−1.941	0.052	−2.295	0.022	−0.94	0.347	−0.848	0.396
Awe	−4.852	<0.000*	−4.984	<0.000*	−4.969	<0.000*	−2.335	0.02

*Significance at p < 0.001 = *.*

Sense of Perceived Vastness and Perceived Need for Accommodation

We carried out a one-way repeated measures ANOVA (conditions: Forest, Mountains, Earth view, Neutral), with vastness as a measure. It emerged a statistically significant effect of condition on the sense of perceived vastness [$F(3) = 29.526$; $p < 0.001$; $\eta^2 = 0.458$]. *Post hoc* comparisons were made to determine the significance of pairwise contrasts, using the Bonferroni correction ($\alpha = 0.05$). High snow mountains elicited a significantly higher sense of perceived vastness (mean =18.527; *SD* = 4.953) compared both to Forest (mean = 15.889; *SD* = 5.306) and the Neutral stimulus (mean = 11.500; *SD* = 4.982). Mountains and Earth view (mean = 18.278; *SD* = 6.738) did not significantly differ regarding the ability to convey a sense of vastness. Earth view conveyed a higher sense of vastness than the Neutral stimulus only. No statistically significant difference emerged regarding perceived need for accommodation across conditions.

To test whether Mountains and Earth view were statistically similar in conveying vastness, we carried out the paired sample *t*-test Bayes Factor (BF), namely a ratio between the likelihood of the data given null-hypothesis and the one given the alternative one (Masson, 2011; Liang et al., 2012; Nuzzo, 2014; Rouder, 2014), using JASP (see **Figure 6**).

Results showed that Mountains and Earth view, the most vastness-conductive stimuli, were statistically significant regarding their ability to convey vastness. Results evidenced a substantial effect for the condition ($BF_{01} = 5.349$; err = 2.093e-8). In other words, Mountains elicited levels of vastness significantly similar to the Earth view condition.

Presence

First, we carried out a one-way repeated measures ANOVAs (conditions: Forest, Mountains, Earth view, Neutral), with the

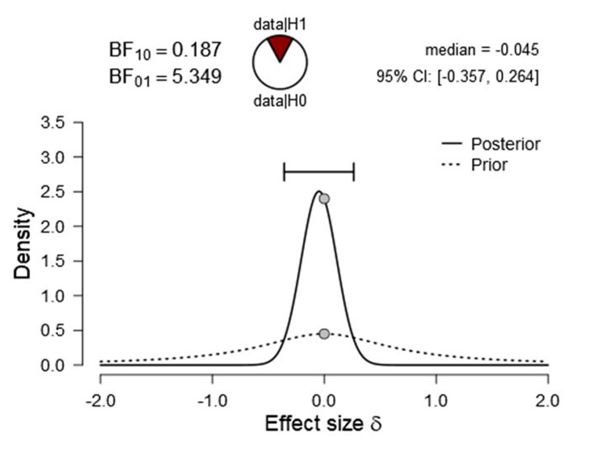

FIGURE 6 | Bayesian graph of Mountains vs. Earth view conditions considering vastness measure.

two normally distributed dimensions of presence as measures (i.e., physical presence and engagement).

Physical Presence

There was a statistical significant effect of condition on the perceived physical presence [$F(3) = 29.180$; $p < 0.001$; $\eta^2 = 0.456$]. *Post hoc* comparisons were made to determine the significance of pairwise contrasts, using the Bonferroni correction ($\alpha = 0.05$). Results showed that Forest, Mountains, significantly enhanced the perceived sense of being physically present within the VE more than the Neutral environment. Contrarily, Earth view induced a significantly lower level of physical presence than the neutral condition. In other words, the Earth view condition induced the lowest level of perceived physical presence compared to other conditions. See **Table 3** for descriptive statistics.

Engagement

There was a statistical significant effect of condition on perceived engagement [$F(3) = 9.964$; $p < 0.001$; $\eta^2 = 0.222$]. *Post hoc* comparisons were made to determine the significance of pairwise contrasts, using the Bonferroni correction ($\alpha = 0.05$). Again, results showed that Forest and Mountains conveyed significantly higher levels of engagement compared with the Neutral environment. However, Earth view induced significantly lower levels of engagement compared to the other two target conditions. See **Table 3** for descriptive statistics.

Ecological Validity and Negative Effect

First, we carried out Friedman test of differences among repeated measures (including the four conditions) was conducted and rendered a Chi-square value of 27.42 which was significant ($p < 0.001$). Secondly, we computed Wilcoxon Signed Rank test adjusting alpha as mentioned in the "awe" results section both with ecological validity and negative effect as measures. Here, we had 4 conditions, so the number of possible combinations was 4 (=4*2/2) [N(N-1)/2], consequently, we adjusted the significance level to 0.008 (=0.05/6). Resulted showed that Mountains (Mdn = 4.00) induced the highest levels of ecological validity compared to Forest [Mdn = 3.60; $Z = -3.118$, $p < 0.001$; $r = 0.424$], Earth view [Mdn = 3.50; $Z = -4.335$, $p < 0.001$; $r = 0.895$] and the Neutral environment [Mdn = 3.60; $Z = -3.531$, $p < 0.001$; $r = 0.416$]. Regarding negative affect, scores ranged between 1 and 2 on a 5 point-likert scale. Friedman test showed a Chi-square 9.26 ($p < 0.05$). We carried out a Wilcoxon Signed Rank test which showed that Mountains (Mdn = 1.500) elicited significantly higher levels of negative affects compared to Earth view condition [Mdn = 1.167; $Z = -2.702$, $p < 0.001$; $r = 0.602$]. Neutral stimulus (Mdn = 1.500) induced higher levels of negative affect compared to Forest [Mdn = 1.500; $Z = -2.834$, $p < 0.001$; $r = 0.334$] and Earth view conditions [$Z = -2.769$, $p < 0.001$; $r = 0.326$]. Consider **Table 4** for descriptive statistics.

Positive vs. Negative Affect

Since, awe is a composite emotion with a not well-defined valence, we chose to integrate the discrete approach to emotions, with a dimensional one, which allows capturing nuances of positive and negative affective states associated with each environment. First, we carried out a separate *t*-tests to investigate the differences of in the positive affect before (baseline) and after the exploration of environments. No significant difference was found for Forest, Earth view and Neutral environment with respect to the baseline. However, exposure to High snow mountains significantly increased positive affect (mean = 3.461; $SD = 0.714$) compared to the baseline condition (mean = 3.161; $SD = 0.512$) [$t(35) = -2.900$; $p < 0.01$].

More, we carried out a Friedman test of differences among repeated measures, considering negative affect as a measure (including all the four conditions and the baseline) which rendered a Chi-square value of 33.51 ($p < 0.001$). A separate Wilcoxon Signed Rank tests to investigate the differences in the negative affect before (baseline) and after the exploration of environments. Forest [Mdn = 1.1; $Z = -4.003$, $p < 0.001$; $r = 0.471$], Mountains [Mdn = 1.1; $Z = -3.092$, $p < 0.001$; $r = 0.364$], Earth view [Mdn = 1; $Z = -4.135$, $p < 0.001$; $r = 0.487$] and Neutral condition [Mdn = 1; $Z = -2.837$, $p < 0.001$; $r = 0.334$] significantly

TABLE 3 | Physical presence and engagement scores for each condition: Mean and standard deviation for each condition.

Measure	Forest		Mountains		Earth view		Neutral	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Physical Presence	3.402	0.862	3.382	0.825	2.545	0.8706	3.048	0.929
Engagement	3.660	0.824	3.754	0.874	3.20	0.985	3.305	0.914

TABLE 4 | Ecological validity and negative effect scores for each condition: Mean and standard deviation for each condition.

Measure	Forest		Mountains		Earth view		Neutral	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Ecological validity	3.506	0.998	3.937	0.9213	3.178	1.1854	3.389	1.0715
Negative effects	1.718	0.959	1.991	1.034	1.472	0.5697	1.982	1.1054

decreased negative affect compared to the baseline. Overall, all environments conveyed positive affect and significantly reduced the intensity of negative one. High mountains resulted as the most positive affect conductive, able to significantly increase participants' positive moods.

Secondly, we carried out a one-way repeated measures ANOVA considering all four conditions (Forest, Mountains, Earth view, Neutral) with positive affect as a measure. There was a statistical significant effect of condition on the perceived general positive affect [$F(3) = 29.180$; $p < 0.05$; $\eta^2 = 0.08$]. *Post hoc* comparisons using the Bonferroni correction showed that only the Neutral condition (mean = 3.116; *SD* = 0.870) elicited significantly lower level of positive affect only compared with the Mountain condition (mean = 3.461; *SD* = 0.714). No significant effect for negative effect across condition was found after correcting with Bonferroni. However, even not significant, High snow mountains displayed the highest level of negative affect (mean = 1.289: *SD* = 0.432) followed, respectively, by the Neutral stimulus (mean = 1.286; *SD* = 0.3766), the Forest (mean 1.228; *SD* = 0.366) and the Earth view (mean = 1.172; *SD* = 0.3141).

360° Awe-Inspiring Contents vs. VR Awe-Inspiring Contents

To compare the effectiveness of VR and 360° as two novel emotion-induction techniques, regarding awe induction, we contrasted effect sizes from Chirico et al. (2017) with effect size calculated in this experiment. Specifically, we focused on two measures: awe and sense of presence.

First, since we chose to compare awe scores in this study with those calculated in a previous study (Chirico et al., 2017) with a similar experimental design, we had to be consistent with the distribution of data. In this current study, perceived awe measure was not normally distributed, thus we calculated effect size starting from *z*-score from Wilcoxon Signed Rank test. We computed effect size from the previous study by comparing 360° awe-inspiring video and 360° neutral video regarding the ability to convey a feeling of awe, following the same statistical procedure (we carried out a Wilcoxon Signed Rank test). Results showed an effect size (computed as "r") of 0.58 [$Z = -5.367$, $p < 0.001$; $r = 0.471$]. On the other hand, we compared these effect sizes with those calculated in the current study. In this study, we computed effect size of awe by comparing each awe-inspiring condition with the neutral VRE. Effect size (r) calculated from the comparison between Forest and Neutral condition was 0.294. Mountains vs. Neutral effect size was $r = 0.546$. Earth view vs. neutral effect size is 0.419. 360° awe-inspiring videos resulted as more effective than VR awe-inspiring environments, although the difference was not wide.

Moreover, Chirico et al. (2017) considered only engagement and physical presence as measures for the sense of presence. Therefore, in the current study, we considered engagement and physical presence as dimensions of presence.

First, we used data from Chirico et al. (2017) to compute a repeated measure ANOVA comparing 360° awe-inspiring video with 360° neutral video with engagement as a measure. Results showed a statistical significant effect of condition on engagement [$F(1,41) = 48.846$; $p < 0.001$; $\eta^2 = 0.544$]. Then, we compared this effect size with those calculated in the current study. Particularly, we calculated effect size (η^2) comparing each awe-inspiring environment of the current study with the neutral condition. Effect size from Forest vs. Neutral comparison is 0.560. Effect size from Mountains and Neutral is 0.571. Effect size from Earth view vs. Neutral is 0.390. Both virtual Forest and Mountains resulted as more effective in inducing higher levels of engagement compared to 360° videos. Finally, again, we used data from Chirico et al. (2017) to compute a repeated measure ANOVA comparing 360° awe-inspiring video with 360° neutral video with physical presence as a measure. Results showed a statistical significant effect of condition on physical presence [$F(1,41) = 125.045$; $p < 0.001$; $\eta^2 = 0.753$]. Then, we calculated effect size (η^2) comparing each awe-inspiring environment of the current study with the neutral condition. Effect size from Forest vs. Neutral comparison is 0.236. Effect size from Mountains and Neutral is 0.246. Effect size from Earth view and Neutral is 0.381. Physical presence was higher in the 360° study, considering a 360° neutral environment as a comparison condition.

DISCUSSION

In this study, we tested the possibility of inducing awe through VR. To this end, four immersive and interactive VEs were developed to induce awe and a neutral emotional state, according to guidelines provided by literature (Piff et al., 2015; Yaden et al., 2016, 2017; Chirico et al., 2016, 2017). As hypothesized, the three target environments (i.e., Tall trees, High snow mountains, Earth view) induced a significantly greater awe than the Neutral stimulus (i.e., cleaning). Furthermore, each stimulus induced more awe compared to other potentially intervenient emotions (Chirico et al., 2017). In other words, it emerged the possibility to elicit awe even using interactive elicitors. This is far more relevant if we consider that awe is considered as a contemplative emotion (Darbor et al., 2016).

Further, our aim was also to elucidate which environment was the most awe-inducing one (i.e., the one which induced the higher intensity awe). This study demonstrated that Mountain environment was the most awe-conductive one. Specifically, High snow mountains scenario displayed slightly higher level of fear and joy, as well as of vastness and need for accommodation if compared to the other two target stimuli. With this regard, Keltner and Haidt (2003) stated that awe could be elicited by stimuli perceived as conceptually and perceptually vast. A recent article by Yaden et al. (2016) identified the overview effect as a case of conceptual vastness "Vastness can be (..) conceptual (..) as (..) the fragility and complexity of life on a small planet in the vastness of space" (p. 4). On the other hand, Mountain and Forest are usually conceived as perceptual instances of awe (Yaden et al., 2016). This is the first study that focus on the ability of conveying awe by two perceptual and conceptual instances of this emotion. Specifically, this research evidenced that High snow mountains stimulus, which was designed to convey vastness through a large panorama, was the most effective elicitor of awe. Surprisingly, also Earth scenario, which can be conceived as a conceptual instance of awe, was able to convey a sense of vastness statistically significant to that induced by High snow mountains. This result can be extended also to the need for accommodation component. That is, all three target scenarios did not significantly differ regarding their ability to convey need for accommodation. This suggests that High snow mountains and Earth view, which can be conceptualized as perceptual and conceptual instances of awe, were equivalent regarding their ability to convey both a sense of vastness and a need for accommodation. However, High snow mountains and Earth view did not convey more need for accommodation than Forest stimulus. Far from being an outcome of vastness and need for accommodation components manipulation, these results can suggest how it is possible to design interactive virtual scenarios able to target different facets of awe. Future studies can take inspiration from these findings to address a more controlled manipulation of such awe components.

For instance, this study evidenced that empirical translation of vastness in terms of "width" worked better in VR compared to that in terms of "height," and that different instances of vastness can be equivalent into a VR setting.

Moreover, this study is in line with findings from Reinerman-Jones et al. (2013), Gallagher et al. (2014, 2015), Quesnel and Riecke (2017) who demonstrated that VR was able to generate awe through one of the most prototypical experiences of this emotion, that is, the overview effect (i.e., the experience of viewing landscapes from far above, which includes the Earth view as the "quintessential version of this experience"; Yaden et al., 2016, p.2). Here, we showed that the overview effect, when displayed in VR, can be considered closer to natural-based VR experiences. One of the main features of the overview effect it is its intrinsically extraordinary nature. It is very alike that we can see earth from outside its atmosphere during our life. Therefore, it is the component of the need for accommodation that is stressed in this experience. Indeed, if vastness changed significantly across conditions, the need for accommodation did not. In other words, VR could be considered as a sort of natural generator of need for accommodation. It is noted that VR itself could be considered as a source of paradoxical, unusual experiences (e.g., Friedman et al., 2014; Gaggioli, 2016; Gaggioli et al., 2016; Pallavicini et al., 2016; Serino et al., 2016) this would open to a broad array of possibilities regarding the creation of VR scenarios for eliciting complex emotions in the lab. First, these findings indicated that it is possible to induce vastness and the need accommodation components of awe differentially. This can be promising for the design of VR environments able to induce even other complex awe-related states, such as the emotion of admiration (Onu et al., 2016) or elevation (Haidt, 2000), or to manipulate different components of awe effectively. According to the prototypical model of Keltner and Haidt (2003) on awe, this emotion is structured as a family. In the core part of this family there is the prototypical awe, and it is possible to find other complex emotions around it, which are closely connected to awe, such as surprise, admiration or elevation. These VR scenarios are a promising starting point for the design of other awe-family emotional states, allowing also an integrated assessment of theme (combining physiological, behavioral and self-reported measures).

At a more general level, all these environments conveyed also a high positive affect. Consistently with our purposes, the Neutral environment elicited the lower positive affect. Interestingly, High snow mountains induced a higher level of negative effect compared to all other conditions, but the only relevant difference was between the Earth view and the Neutral stimulus. At the design level, it emerged that the Earth view condition led to less negative effects related to navigation, maybe because there were less reference points that could make participants feel disoriented. This hypothesis is in line with qualitative reports of participants at the end of the experimenter. Indeed, two main themes emerged regarding the use of each environment. First, the circular trajectory of navigation of the Neutral stimulus was perceived as monotonous and disorienting. Secondly, the possibility to see a vast panorama near to a cliff, was perceived as dangerous but extremely fascinating, thus leading to a feeling of disorientation. Therefore, two different kinds of disorientation emerged. The first, which regarded the Neutral stimulus, was related to the navigation trajectory. The second one, which concerned the Mountains, consisted of the expected feeling of disorientation related to intense episodes of awe. However, the relevance of this effect is limited since ecological validity scores ranges from 1.5 to 1.7 on a 7-point Likert scale.

Furthermore, Forest and Mountain resulted as more engaging than the Neutral environment, as well as more presence conductive. Unexpectedly, Earth view environment induced a lower sense of engagement and physical presence, as dimensions of presence, than the Neutral environment. This could be due to the intrinsic paradoxical nature of this experience, which led to a decreasing in the sense of physical presence (i.e., participants struggled to believe and feel as if they were there). On the other hand, a reason for lower engagement levels could be that this experience was almost static (in the deep space perception of movement is different from the one perceive on Earth) and totally silent. This could have led to an unusual perception that contributed to a less engaging experience.

Together all this evidence showed that awe can be elicited at high intensity even in the lab. Specifically, mean scores of awe, in awe-inducing environments, ranged from 4.611 to 5.250 on a 7 point Likert scale and the distribution of awe variable showed a high negative skewness. This showed that the bulk of the values lie to the right of the mean, that is, closer to the maximum score of awe (Kim, 2013). Specifically, compared to the baseline, each target environment elicited a significantly higher amount of awe. More, each target condition elicited also other emotions besides awe, compared to the baseline. At the same time, also the neutral condition resulted as inducing different emotional states (i.e., pride, awe, fear) compared with the baseline. However, the neutrality of an emotional stimulus should be evaluated also in relation to other emotional material (Dan-Glauser and Scherer, 2011; Piff et al., 2015). With this regard, our results supported the idea that our Neutral condition acted as a control condition if compared with the other VEs. These results suggested that VR alone, cannot induce intense awe states, but also an *ad hoc* content is required (Chirico et al., 2017). This result was also supported in this study. Even though the neutral stimulus was able to induce a higher amount of awe compared to the baseline, it was not as high as that induced by other VEs whose content was designed to induce awe.

Finally, also each target condition elicited awe as well as other emotions. This effect is well-known in emotion induction research as it is common that a stimulus induces other emotions beyond the target one. However, it is relevant that other intervenient emotions are not higher (in mean) compared to the target emotion (i.e., awe) (Mayer et al., 1995), even they can be considered in line with awe sub-components (joy, fear).

In other words, results showed a satisfactory degree of specificity in emotion induction for our stimuli, therefore, VR emerged as an effective inductor of awe and its sub-components.

With this regard, even Chirico et al. (2017) tested the potential of immersive videos (highly realistic and immersive videos displaying natural scenes) in inducing awe, they had only scratched the surface. In other words, they have only addressed the first part of the continuum of interactive technologies. They considered the lowest level of interaction with VE (i.e., head-tracking). Here, we moved forward by improving their previous emotion-technique and we tested a more advanced form of awe-inducing technique, as well as more complex forms of interactions. In other words, we compared the effect of 360° videos and VR scenarios developed *ad hoc* for this study on awe and sense of presence. Indeed, there are many differences between these two forms of VR. First, the representational apparatus of 360°-videos is composed of a camera situated in a real time-space environment, while VR adopts a 3-D representational apparatus, which is sensitive to users' input at many levels. At the same time, these two media conveyed the feeling of "presence" differently. 360°-videos can ensure a lower sense of presence compared to VR in which a user is physically located in the space of the video camera. This was reflected into our comparison between 360°-videos and VR. We carried out a direct comparison between 360° videos and VR based on effect size. VR enhanced the sense of engagement – component of presence – more than 360° videos. However, 360° videos increased awe intensity more than VR. This could be due to the requirement to interact and navigate in an unfamiliar VR environment that we gave to participants. While in the 360°-video participants had a sort of omniscient view of the scene and subsequent higher sense of control, users in the VR settings could have perceived a lack of control on the scene. This could affect awe rates. Indeed, this emotion entails a sense of uncertainty which can be tolerated only at some extent (Valdesolo and Graham, 2014).

However, there was a small difference in awe induced by VR vs. 360°, thus, we suggested VR, compared to 360° videos, to induce an intense awe for several reasons. First, VR environments allow for a more ecological interaction with virtual content closer to the equivalent real one. Here, we proposed a higher form of interaction (i.e., navigation within a VE), but it is possible that future works could focus on more sophisticated ones. For instance, it could be possible to consider interactions with other avatars or objects, thus creating a sort of awe-inspiring virtual world (e.g., Bartle, 2004; Triberti and Chirico, 2016). Further, it would be useful to consider whether the component of interaction acts differently in a natural context, compared to a virtual one. Moreover, VR provides the possibility to design almost infinite scenarios including different objects and characters users can interact with. This allows for planning tasks and challenges within the VE. Further, VR allows for a complete tracking of participants' performance. As previously mentioned, another advantage provided by VR compared to 360° videos is that VE can reproduce "paradoxical" phenomena (i.e., violating laws of physics) in controlled settings. This could be one of the assets that can contribute to the natural ability of VR to induce a need for accommodation. Regarding the sense of physical presence, we considered effect size from the comparison between 360° awe vs. 360° neutral environment (Chirico et al., 2017) with those from this study (Forest vs. Neutral; Mountain vs. Neutral; Earth view vs. Neutral). Indeed, results indicated a higher effect size in the 360° study. However, in any case, effect size was based on the comparison with a neutral condition. It could be possible that this VR format could enhance the sense of physical presence even for neutral stimuli, as a matter of medium. Thus, the differences between emotional VEs and Neutral one were lower.

Finally, at the level of usability, these environments have been highly tolerated by participants.

In short, these validated environments can be used in different contexts and propose some design guidelines to be followed when creating an awe-inspiring VE.

For instance, it is possible to design multiple and continuative experiences in VR such as a VR training for repeated awe induction, maybe in combination with conventional emotion induction technique, such as emotional recall (e.g., Gilet, 2008; Gaggioli et al., 2014). This repeated but controlled exposure could lead to longer-term positive outcomes for individuals' wellbeing and health. With this regard, it is possible to imagine several applications for awe, related to its positive consequences for health and wellbeing. For instance, it would be possible to integrate a biofeedback device with one of these validated VEs helping participants recognizing and self-inducing and regulating intense awe emotional states in an ecological way or sharing feelings of awe with another person at the physiological level (e.g., Neidlinger et al., 2017). All people could navigate in these environments and benefit from their effects. It is possible to design different training to empower several cognitive, social or emotional skills. Indeed, awe can enhance our prosocial attitude toward even unknown others (Piff et al., 2015), it can improve our ability to manage stress (Stellar et al., 2015), or it can increase the satisfaction toward our life. Interestingly, awe can affect even the perception of our body, thus making feel people smaller than they actually are. All these aspects can be potential targets of an awe-inducing training.

We are on the edge of a new modality to design complex emotions fully exploiting their unique potential for human progress and wellbeing.

Limitations

This is the first study testing the potential of VR in inducing awe. As a preliminary and explorative study, some limitations exist.

First, we used the conventional single item to assess awe but more sophisticated instruments of assessment could be considered to measure this complex emotions, such as psychophysiological measures, as it has been already successfully done (Chirico et al., 2017). In this specific case, an eye-tracking system could be used to track participants' fixations points and saccades, to determine environmental cues participants focused on more. This would help design effective awe-inducing environments. More, this is an exploratory study in which the aim was to test the potential of immersive and interactive VR in inducing awe. However, it could be possible to test whether immersive and interactive VR is more effective than simply immersive VR systems in inducing this complex emotion. More, we assessed only seven other potentially intervenient emotions besides awe, but future works should consider also other positive and negative emotions that could co-occur with awe (for instance, see Hofmann et al., 2017). Finally, we did not consider the role of individuals' proneness to live discrete positive emotions, in the likelihood to experience awe in response to these environments. Personality and stable dispositional factors resulted as relevant for other positive emotions such as amusement (Pietquin and Dupont, 2011). Therefore, they should be considered in future studies to define a more comprehensive model of awe and self-transcendent experiences in VR.

AUTHOR CONTRIBUTIONS

Authors contributed according to their competences and interests. AC and AG conceived the main idea of the article. AC collected all data and carried out statistical analyses. LC and FF conceived and developed the technical setup. AC wrote the first draft of the manuscript, while AG, FF, and LC contributed to the final writing of the manuscript by giving suggestions regarding the issues related to the rhetoric and to the literature. AG supervised the entire work. All authors contributed to the manuscript, read, and approved the final version.

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Are You Awed Yet? How Virtual Reality Gives Us Awe and Goose Bumps

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"Awe" is a category of emotion within the spectrum of self-transcendent experiences. Awe has wellness benefits, with feelings of social interconnectivity and increased life satisfaction. However, awe experiences remain rare in our everyday lives, and rarer in lab environments. We posit that Virtual Reality (VR) may help to make self-transcendent and potentially transformative experiences of awe more accessible to individuals. Here, we investigated how interactive VR as a positive technology may elicit awe, and how features of aesthetic beauty/scale, familiarity, and personalization (self-selection of travel destinations) may induce awe. In this mixed-methods study, participants used an interactive VR system to explore Earth from ground and orbit. We collected: introspective interviews and self-report questionnaires with participants' experience of awe; information on personality traits and gender; and we recorded physiological goose bumps on the skin (using an arm-mounted goose bump camera instrument), which is a documented marker of an awe experience. Results showed that on a scale of 0–100 for self-reported awe, four different interactive VR environments yielded an average awe rating of 79.7, indicating that interactive VR can indeed induce awe. 43.8% of participants experienced goose bumps: awe ratings positively correlated with the occurrence of goose bumps with those who experienced goose bumps having showed significantly higher ratings of awe than those who did not. Most (64%) of the goose bumps occurred when participants self-selected their VR environment. Participant statements from the interviews were characteristic of an awe-inspiring experience, revealed themes of social connection, and usability problems with the VR interface. Personality traits yielded no clear correlation to awe ratings, and females appear to experience more goose bumps than males. In summary: (1) Interactive VR can elicit awe, especially within familiar, self-selected environments; (2) Physiological goose bumps can be recorded to provide reliable, non-intrusive indications of awe; (3) Care must be taken to design interaction interfaces that do not impede awe; and (4) While personality traits are not correlated to awe ratings, goose bumps were experienced more frequently among females. We aim to conduct future studies using custom VR environments, interfaces, and additional physiological measures to provide further insight into awe.

Keywords: positive technology, virtual reality, immersive technologies, emotions, emotion induction, awe, experience design

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INTRODUCTION

A transformative experience is an event in which an individual's worldview is reconstructed, resulting in a shift in perspective or change to an individual's identity (C'de Baca and Wilbourne, 2004; Piff et al., 2015; Gaggioli, 2016). These changes can be positive, and transformative experiences tend to support a long-term change that comes with this worldview reconstruction (Gaggioli, 2016). Many people who have experienced such changes reported feeling a eureka, "a-ha," or epiphany-like moment as a "peak experience" (Miller and C'de Baca, 2011).

To understand a transformative experience, researchers search for emotions to measure, leading to "awe" identified as an emotion of interest. Specifically, awe is a positive emotion with self-transcendence qualities (Prade and Saroglou, 2016; Yaden et al., 2017; Chirico and Yaden, 2018), in which an individual feels connected to the universe and others. Awe has two core features, "**perceived vastness**," and "**a need for accommodation**" (Keltner and Haidt, 2003). Individuals in "awe" often do not fully understand their experience in the moment and will make changes to their mental model to comprehend the scale of the situation afterward (Stepanova et al., under review). Keltner and Haidt (2003) and Schneider (2009) stress the potential of awe-inspiring experiences to be among the most powerful personal transformational experiences. Awe-elicited shifts feel pleasant, with focus transcending from the self to the needs of many (Stellar et al., 2017b). Experiences of awe can be very positive, characterized by social interconnectivity (Shiota et al., 2007; Schurtz et al., 2011; Prade and Saroglou, 2016), pro-sociality (Piff et al., 2015; Stellar et al., 2017b), and increased well-being and life satisfaction (Rudd et al., 2011; Cappellen et al., 2013; Stellar et al., 2015). Many go to lengths to seek out awe-inspiring experiences, especially those that lead to a sense of oneness with others (Van Cappellen and Saroglou, 2012); examples include musical concerts, spiritual retreats, and travel to monuments. With awe being such a profound experience, researchers are increasingly interested in learning how to elicit and study it in detail.

One of the most intense awe-inspiring experiences may be the sight of the Earth from Space, coined the "Overview Effect" (White, 2014). Research by Yaden et al. (2016) explored astronaut accounts of the Overview Effect, demonstrating awe and self-transcendence. We can see an example through astronaut Kathryn D. Sullivan:

> "It's hard to explain how amazing and magical this experience is... If you float up by the forward seats, you have six large windows providing you with a spectacular panorama of the Earth below, spanning at least 180 degrees of the horizon. I'm happy to report that no amount of prior study or training can fully prepare anybody for the awe and wonder this inspires." (Sullivan, 1991).

However, most will never get to see the Earth from space, but astronaut accounts provide us with a typology of awe to learn from (Stepanova et al., under review). Awe is also elicited by being in nature, through stargazing, witnessing solar eclipses and beautiful vistas, seeing art and architecture (Keltner and Haidt, 2003; Shiota et al., 2007; Grewe et al., 2011; Gordon et al., 2017); even technology, like social media with its vastness of data and ability to connect people, can be awe-inspiring (Bai et al., 2017). Yet, experiences that elicit awe can be quite rare. How do we gain awe and personal, positive transformation in our lives? For many individuals with limitations to income, mobility, and ability, these awe experiences listed above are inaccessible and are difficult to integrate into daily lives. Thus, we look at new ways in which technology can create a new category of awe experiences.

VIRTUAL REALITY AS A POTENTIAL SOLUTION FOR ELICITING AWE

The Properties of Virtual Reality

A potential solution to accessibility of awe-inspiring experiences is immersive Virtual Reality (VR), a technological medium (Chirico et al., 2017; Quesnel and Riecke, 2017; Chirico et al., 2018). VR consists of a computer-generated immersive virtual environment, where the user may interactively act upon the environment and objects within it. Well-designed VR can help an individual become immersed in what feels like a believable experience akin to reality. Places and experiences that would be otherwise impossible, are made to feel possible, like time travel (Friedman et al., 2014) and visual reorientation illusions experienced by astronauts (Mast and Oman, 2004). There are core features that allow for this; immersion, interactivity, and presence, the latter a sense of "being there" in a virtual environment. Immersion is a sense of existing in a virtual environment, due to vividness and a sense of depth that a 3D environment enables, along with a breadth of provided information through multisensory cues, such as image, audio, olfactory signals, and tactile sensations (Ryan, 1999). With added interactivity, an individual can modify their environment so their actions have consequences, with the degree of interactivity being variable (Steuer, 1992). Immersion and interactivity alone are not responsible for subjective presence, as research has demonstrated that affective VR content influencing emotional intensity has an effect on levels of presence felt and adds relevance to the experience (Baños et al., 2004; Riva et al., 2007). While VR as a technological environment itself may not lead to elicitation of specific emotional states, Diemer et al. (2015) provide evidence that when participants feel emotionally affected, the overall level of presence increases. This can be achieved through the use of narrative and aesthetics (Bouchard et al., 2008; Gorini et al., 2011; Felnhofer et al., 2015; Triberti and Riva, 2016). Studies tend to focus on the general change in emotional state of a participant, opposed to elicitation of a specific emotion like awe, so more research is needed in exploring how VR features affect emotional specificity. This current study was designed to be a step toward addressing this gap.

Research on Virtually Induced Awe

In psychology research, VR has advantages over other commonly used media stimuli: (1) environment can be personalized for the participant; (2) experimental control over the stimulus can be maintained; (3) high naturalism/believability due to its being a multimodal sensory device, which can lead to realistic behaviors (Wilson and Soranzo, 2015). Previous studies have explored the role of immersive video, virtual and mixed reality in eliciting awe. These include a mixed-reality Cave Automatic Virtual Environment (CAVE) by Gallagher et al. (2015), designed to elicit the Overview Effect; immersive 360 degree videos were used by Chirico et al. (2017); and interactive virtual environments with a VR headset (Chirico et al., 2018). These studies used surveys for assessing awe, with participants rating high levels of awe. Researchers have also used VR to investigate participant's perceptions: Rauhoeft et al. (2015) used a VR environment with landscapes to explore perceived 'vastness' and found that terminology describing awe actually lead to unreliable survey data; this can occur when a definition of 'vastness' is interpreted by the literal visual perception that the area is big and open, opposed to an individual's self-concept of feeling in the presence of something greater than themselves. Rauhoeft et al. (2015) study demonstrates easily understood definitions and terminology for awe and self-transcendence is important, since there are many ways the experience can be subjectively and empirically described.

Research on awe with virtual environments has combined self-report data with psychophysiological measures to capture the full awe experience. For example, Gallagher et al. (2015) collected self-report, physiological, and neurophysiological measures with the finding that differences in EEG brainwaves exist between the groups of awe-experiencers, and non-awe experiencers. With the human autonomic nervous system responsible for many of our critical body processes like the "fight or flight" response, it is interesting to learn that it also reacts to awe experiences in a unique, powerful way. With awe, we see this through sympathetic nervous system withdrawal and/or increased parasympathetic activation (Shiota et al., 2007, 2011), a phenomenon involving the vagus nerve often regarded as the "tend-and-befriend" response. Chirico et al. (2017) used Skin Conductance Response (SCR), Blood Volume Pulse (BVP), and surface electromyography (sEMG) and found that parasympathetic activation occurred with awe induced using immersive videos compared to 2D videos. It could be that the parasympathetic activation and "tend-and-befriend" response is connected to the reported wellness benefits recorded from awe experiences, with more psychophysiological studies needed to explore this deeper.

Learning From VR Induced Perspective Shifts

While empirical studies exploring virtually induced awe are emerging, they are still few today. Meanwhile, we can look to studies that explore transformative potential of VR not exclusively related to awe, such as elicitation of perspective shifts. Since awe is thought to generate a shift in self-concept in how a person sees themselves in the world, exploring shifts in self-concept generated through a virtual environment may provide helpful frameworks. Work by Ahn et al. (2014) demonstrates that VR environments, principally the feeling of 'embodiment', can result in short and long term behavioral changes through a shift in perspective. Similarly, embodying a superhero in VR increases prosocial behavior, presumably through a shift in self-concept (Rosenberg et al., 2013). In addition to self-report measures, these two studies also added behavioral measures that provided further evidence toward support of a perspective shift. Since induction of such positive emotions and improvement to attitudes are possible through VR (Riva et al., 2016), the implications for changes to an individual's well-being are encouraging. Several VR environments have been created in the past several decades that may be categorized as a form of "positive technology" with wellness outcomes, and researchers together with designers are exploring this maturing area (Riva et al., 2012; Riva et al., 2016; Baños et al., 2017; Gaggioli et al., 2017; Kitson et al., 2018).

Regarding multimodal sensory devices, VR allows for more than the passive display of audio and visual stimuli. VR becomes active through interaction, which is important since natural body movement in an environment has been positively associated with reported presence levels (Slater et al., 1998). Subjective presence is relevant because the feeling of 'being there' (place illusion), and maintaining the illusion that events occurring in the virtual environment are real (plausibility illusion) can lead to realistic behaviors in participants (Slater, 2009, 2011). By enabling the participant to manipulate their environment with body position and interfaces, they may self-select where to navigate. We propose that these actions in the virtual environment feel as though they may be real, leading to authentic experiences and emotions. Furthermore, the use of interactivity may enable more self-relevance and generate awe experiences that have a higher degree of presence than immersive video alone. Thus, interactivity and embodiment could play an important role if we were to use behavioral measures with virtually induced awe.

Evaluation and Validation of Awe Experiences

Awe experiences and their effects should be carefully evaluated. In lab environments, awe is challenging to elicit, because data is often collected with retrospective self-report methods requiring the participant to constantly self-monitor. If biosensors and monitoring equipment inherent in lab setups are also used, these wearable sensors could be distracting along with the need to self-monitor, potentially lowering the intensities of awe (Benedek and Kaernbach, 2011; Silvia, 2012; Silvia et al., 2015). Questionnaires are also subjective and therefore vulnerable to biases and a participant's desire to be compliant may affect reliability (Paulhus and Vazire, 2007). Participants may have difficulty finding words to describe a complex event of awe, making thematic interpretation of their experiences challenging; a phenomenological approach may be more favorable (Pearsall, 2008). Likewise, knowing that awe occurred as an overall emotional state doesn't tell researchers much about the specific elicitors that led to awe, i.e., was there a moment or rush of awe, inspired by seeing a specific aesthetically beautiful scene, or from hearing a crescendo of music/inspiring dialog? These moment-to-moment indications of awe and emotion are important in understanding how to design an awe-inspiring environment.

Empirically, there is evidence that awe can be elicited in the lab through a variety of stimuli. Music and video are highly effective and are often accompanied by chills/goose bumps (Panksepp, 1995; Nusbaum and Silvia, 2011; Maruskin et al., 2012; Wassiliwizky et al., 2015; Colver and El-Alayli, 2016; Schoeller and Perlovsky, 2016; Schubert et al., 2016). Video games elicit these emotions (Lazzaro, 2009; Perron and Schröter, 2016), for example, the video game "Journey" (2012) uses perceptual vastness and a sense of awe to encourage players to connect and have emotional exchanges (Ohannessian, 2012; Isbister, 2016).

As mentioned, self-monitoring can interfere with the ability of the participant to be immersed in the experience, thus reducing the intensity of emotion (Potter and Bolls, 2012). This means that self-reports (through surveys) alone may not sufficiently capture the emotional experience. On the other hand, continuous physiological instruments do not require the participant to self-monitor and may complement introspective self-report data. To validate the presence of specific emotions, researchers have been developing psychophysiological sensors and affective correlates specific to the individual participant (Picard, 2010). If we understand the moment-to-moment attributes of awe, psychophysiological data collection methods of body events via instruments can provide objective, real-time insights. Psychophysiological data complements and enhances the use of traditional self-report psychology methods, particularly when evaluating responses to media forms such as passive video, audio, and interactive games. As non-intrusive data, this helps with ecological validity (Potter and Bolls, 2012), which is important if researchers aim to create virtual experiences that have positive benefits similar to real-life awe-inspiring experiences. There are measures and instruments specific to awe; Grewe et al. (2009) provide solid evidence that the sensation of "chills"/"shivers" are connected to the physiological response of goose bumps as emotional 'peak' experiences of awe. In measuring 'peak' experiences, Grewe et al. (2009) collected both physiological and real time self-report data to explore physiological correlates of emotion. Novel instruments have been designed to capture fleeting "peak" experiences, such as a video camera for recording goose bumps used by Benedek et al. (2010). Benedek and Kaernbach (2011) found goose bumps are correlated with high emotional arousal, specifically the "being moved" characteristic of awe. Further studies using music and video stimulus with this camera instrument also found goose bumps correlated with "being moved" and a "peak" experience (Sumpf et al., 2015; Wassiliwizky et al., 2017). Schurtz et al. (2011), and Silvia et al. (2015), found goose bumps were correlated with awe; Keltner and Haidt (2003), Campos et al. (2013), and Maruskin et al. (2012) also describe goose bumps with awe-inspiring stimuli. In what may be an ultimate awe-inspiring experience, astronauts have reported goose bumps and chills from seeing the Earth from Space in the Overview Effect. NASA flight engineer and mission specialist Kjell Lindgren describes this:

> "I saw this really bright white light coming through the small windows of the Soyuz capsule. I took a peek and saw the beautiful blue and whites of the Earth below, and the curvature of the horizon. Getting to experience the whole disk of the Earth from that point of view, truly for me, it was this breathtaking experience. I got goosebumps." – in an interview with The Week (Hullinger, 2016)

The connection of chills and goose bumps to moving, awe-inspiring experiences has been observed by artists and designers over the decades, with distinctions noted between (a) regular chills and goose bump episodes: the feeling of shivers and presence of goose bumps due to cold and thermoregulation; and 'aesthetic chills': (b) pleasurable non-thermoregulatory shivering and presence of goose bumps (Schoeller, 2015; Schoeller and Perlovsky, 2016). Aesthetic chills are also cited as 'frisson', with these terms interchangeable (Sloboda, 1991; Colver and El-Alayli, 2016). It is important to note the differing terms for the same phenomenon, because awe can be very subjective and described in multiple ways, with more than one concurring emotion present. For example, similar to a "peak" experience, being profoundly "moved" is also correlated with shivers/chills (Blood and Zatorre, 2001; Mori and Iwanaga, 2017) and goose bumps (Seibt et al., 2017). To illustrate this, **Figure 1** presents how the experience of awe, the feeling of being profoundly "moved," and a "peak" experience commonly overlap with one another and physiological correlations; as shown in the literature, there have been multiple ways of describing this phenomenon that potentially share epistemic traits. In an effort to accurately validate emotions, physiological instruments like a goose bump recording instrument and other sensors can be used with the artificial intelligence to differentiate awe and other concurring emotions (Quesnel et al., 2017). As reported in literature, some individuals haven't actually experienced goose bumps in response to an emotional or aesthetic stimulus (Goldstein, 1980; Sachs et al., 2016; Neidlinger et al., 2017). Additionally, there is mixed evidence regarding the potential role of gender for episodes of goose bumps/chills/shivers: While most studies involving goose bumps/chills/shivers do not report gender as a factor, two previous studies have shown that both male and females have equal episodes of goose bumps/chills/shivers (Goldstein, 1980; Grewe et al., 2009), whereas two other studies observed gender effects, in that females showed more episodes of goose bumps/chills/shivers than males (Panksepp, 1995; Benedek and Kaernbach, 2011). However, a limitation of these studies is that females might be more likely to report chills in a group/social setting as per Panksepp (1995) study, and there was a significant disproportion of 43 female to 7 male participants in Benedek and Kaernbach (2011) study. To address these issues in the current study, we used individual post-experimental interviewing to avoid potential group effects and aimed for a gender-balanced participant sample.

For our study, we placed importance on collecting physiological data in the form of goose bumps that may illustrate the moment-to-moment experience of awe and collect self-report questionnaire data and interview data to provide further insight into the phenomenon.

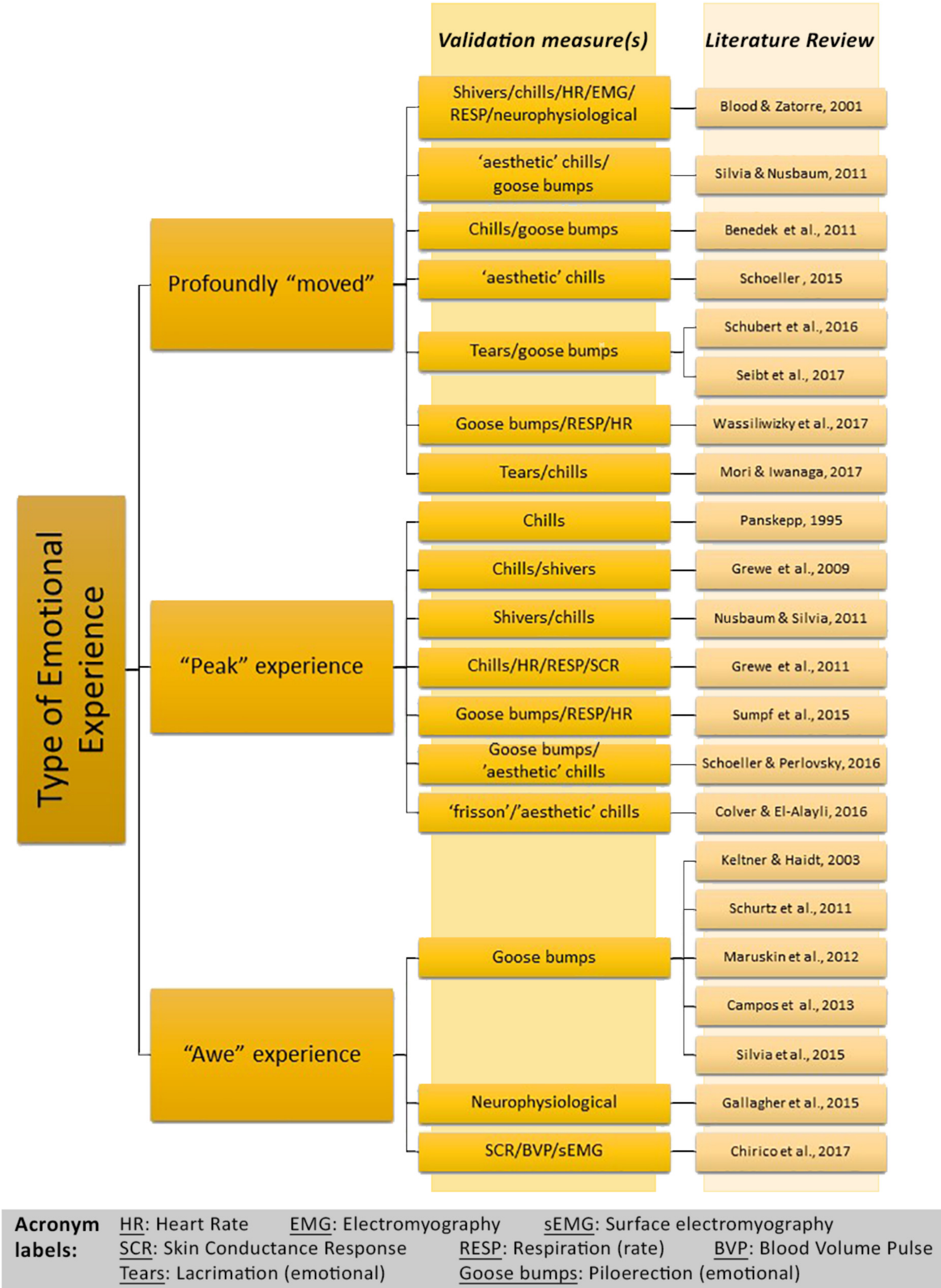

FIGURE 1 | The ways in which awe has been phrased by participants in literature, with the corresponding physiological subjective, and objective validation measures.

RESEARCH QUESTIONS

This study was designed to provide insight into three research questions (RQs):

(RQ1) To what degree can interactive VR generate subjective and physiological goose bump experiences of awe? and;
(RQ2) What effect(s) do the traits of aesthetic beauty/scale, familiarity, or personalization of the environment have on awe experiences?

While the findings of (**RQ1**) are quantitative and measured through physiological goose bump readings and awe ratings in self-report questionnaires, the findings for (**RQ2**) are more qualitative in nature, requiring analysis of interview data. (**RQ1**) informs us about whether our selected emotional validation measures are specific to VR induced awe, and (**RQ2**) informs us how the VR might be awe-inspiring and comparable to real-life awe experiences. It should be noted that it is not an objective of the study to compare different virtual environments for awe elicitation, but rather investigate individual traits of the environments. Through qualitative exploration, we analyze the individual participant statements to explore whether specific features such as vastness, beauty, scale, and familiarity are correlated with self-reports of awe and/or physiological goose bumps.

We also explore possible relations between personality traits and potential experiences of awe, as there is a question of whether personality factors are predictors for awe experiences. "Openness," one of the domains used to describe personality in the Five-Factor Model, has been found to be connected to profound emotional responses over the other personality factors of Agreeableness, Conscientiousness, Extroversion, and Neuroticism (Silvia et al., 2015). Studies have shown "Openness" to be correlated with lab-induced awe (Bride, 2016), and Openness correlating with "frisson"/"chills" from music (Nusbaum and Silvia, 2011; Colver and El-Alayli, 2016). Cultural differences, physical location, daily stressors, willingness to participate, and education level may influence personality traits, which in turn may impact ability to experience awe. As a result, correlations between personality traits and awe may not have good generalizability. In our study, we explore whether personality factors predict awe experiences.

While the measure of 'absorption' is often collected in studies (Silvia and Nusbaum, 2011; Elk et al., 2016), we opted to use a comparable measure specific to passive and interactive media: Immersive Tendencies Questionnaire (ITQ: Witmer and Singer, 1998). Items on the ITQ are similar to those on the Tellegen Absorption Scale (TAS: Tellegen and Atkinson, 1974). The TAS and ITQ both utilize data on how likely participants are to be absorbed or immersed, to lose track of time, and to be so involved they are unaware of things happening around them (Parsons et al., 2015). We explore correlations between higher scores in Immersive Tendencies and increased awe ratings or goose bumps.

Previous studies found that experiences in nature and with art (museums, music) can be awe-inspiring (Keltner and Haidt, 2003; Shiota et al., 2007); these studies identified aesthetic beauty/scale as awe elicitors, yet there is a question of how familiarity and personal relevance are factors of an awe experience. Therefore, we propose a qualitative exploration of aesthetic beauty/scale, familiarity, and ability to personalize an environment as potential awe elicitors. It is unknown how many awe elicitors are in a VR experience, so we explore introspective interviews for any arising themes. We look to this introspective data for themes concerning the usability of VR, as the technology itself and its navigation interface may affect awe.

To explore if females would report more goose bumps/chills/shivers as reported in some studies (Panksepp, 1995; Benedek and Kaernbach, 2011) but not others (Goldstein, 1980; Grewe et al., 2009), we included a research question **(RQ3): what effect does gender have on ratings of awe, and rates of goose bumps?** We predicted that if there was an effect, females should show higher incidences of goose bumps/chills/shivers.

MATERIALS AND METHODS

Participants

Sixteen participants, 10 males and 6 females, a mean of 27.3 years of age, were recruited from undergraduate programs at a Canadian University and through a local VR meetup. All participants voluntarily took part in the experiment, and student participants received course credit. None were monetarily reimbursed. This study was carried out in accordance with the recommendations of the 2nd edition of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2), through Simon Fraser University Office of Research Ethics (ORE). The protocol was approved by the Simon Fraser University ORE prior to data collection (REB #2012c0022), with all consent forms, procedures, and methods compliant to the 2nd edition of the TCPS 2. All participants gave written informed consent in accordance with the Declaration of Helsinki and received identical instructions.

Stimuli and Apparatus

Provided that the most common awe elicitors are found in nature scenes and as visuals of the Earth from space (Keltner and Haidt, 2003; Shiota et al., 2007; Grewe et al., 2011; Gallagher et al., 2015; Silvia et al., 2015; Yaden et al., 2016; Gordon et al., 2017), we opted to use a VR environment that allows for the appraisal of the Earth's landscapes, cityscapes, and a view of the planet from Earth's orbit. Each of these environments incorporates some of these awe elicitors, which were determined by participants in our pilot study, and while we do not aim to compare environments as more or less awe-inspiring from one another, we do intend to provide a qualitative analysis exploring moments within the environments that may indicate awe. To evaluate the full capacity of VR in eliciting awe, our stimulus also included interaction with the environment. For the most accurate and high-resolution representation of the Earth that also involves interactive modes, the application "Google Earth VR" was selected as the stimulus.

The application features thousands of locations in stereoscopic 3D, with imagery displayed in real-time (Käser et al., 2016; Käser et al., 2017). The stimulus is interactive through tracked head position and two handheld controllers, allowing the user to fly through the environment (**Figure 2**). As an existing system, Google Earth VR was selected for this study because we required a complete, "whole" Earth model of excellent resolution that enabled participants to recognize landmarks, and to get close to destinations of the user's choice. At the time of this study, no other Earth model in VR reached the level of realism and resolution that Google Earth VR could. The navigation via hand controller as input device worked by using a trigger button (right hand) to point, select, and drag the environment; a touch pad enabled forward and backward movement (right hand); and a touchpad (left hand) enabled a vertical or horizontal orientation on the Earth. At the time of execution, Google Earth VR had only been publicly available for 7 days, and none of the participants had tried it.

Virtual Environment Locations and Order

There are four environments: (i) Non-interactive Color Tour; (ii) interactive Vancouver, Canada; (iii) interactive Mount Everest, in the Himalayas; (iv) interactive place of the participant's choosing (self-selection). Participants experienced all four environments for 5 min each, in the same fixed order:

(i) Color tour

A 5-min tour by Google Earth VR's development team acclimatizes the immersant to VR, and doesn't require hand controllers- an immersant may look around but they cannot navigate; no navigation skills needed. Potential awe-elicitors: Locations may have aesthetic beauty and scale effects, like colorful natural landscapes, and vibrant buildings; some may be familiar to participants (**Figure 3**).

(ii) Vancouver, Canada

Potential awe-elicitors: In addition to its aesthetic natural beauty, Vancouver was selected to provide familiarity, since this experiment was physically situated in the Vancouver area. The familiarity enabled participants to be able to navigate easily (**Figure 4**).

FIGURE 2 | A participant from the pilot experiment (who does not contribute to this studies' dataset) is wearing the VR headset and navigates Earth with handheld controllers. Informed and written consent was obtained from the pilot participant depicted in the photo.

FIGURE 3 | Color Tour environment, as seen on the external monitor of the VR display.

(iii) Mount Everest, in the Himalayas

Potential awe-elicitors: Aesthetic supernatural vista and beauty and scale/vastness effects may be present with the participant positioned at summit. This vantage point was not familiar to participants in the pilot study and required more navigation skills (**Figure 5**).

(iv) A place of the participant's choosing (self-selection)

Any location of the participant's choosing; Teleportation navigation was activated, enabling travel along the ground

FIGURE 4 | Vancouver, Canada environment, as seen on the external monitor of the VR display.

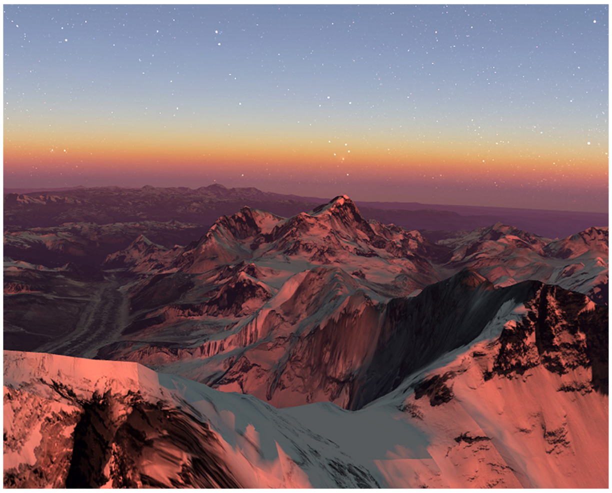

FIGURE 5 | Mount Everest environment, in the Himalayas, as seen on the external monitor of the VR display.

or orbiting the Earth, requiring more navigation skills than previous environments. Participants were free to do whatever they liked during this final personalized aspect of the study. Potential awe-elicitors: aesthetic beauty, scale/vastness, familiarity/personalization, or emerging traits (**Figure 6**).

All environments included views of the Earth from Space, if the participant chose to orbit during navigation.

We opted to have the participants undertake the four virtual environments in a fixed order due to observations in our pilot study with 11 participants. We initially introduced the environments in a counterbalanced order, however, participants that didn't experience the controller-free Color Tour first struggled considerably with getting used to simultaneously wearing the VR equipment, being in a VR environment, and coordinating the hand controllers. Three of these participants mentioned mild motion sickness in the first minutes of being in VR, explaining that it happened when they "lost control" of their locomotion ability. Pilot participants who undertook the Color Tour before the other environments appeared to 'ease' into the more interactive environments with fewer reported mistakes with the interfaces. The other issue with a counterbalanced order of four environments is that the qualitative data collection in this study was extensive, and time constraints limited the number of participants that could be used. Instead of utilizing a large sample size, we opted to use a smaller sample size and focus in depth on the details of these participants' experiences. We chose to present the Vancouver scene second as it was more familiar and thus harder to get lost in than the subsequent Everest scene. Based on pilot testing, we expected the self-selected scene to require the most navigation skills, and consequently presented it last to reduce usability issues.

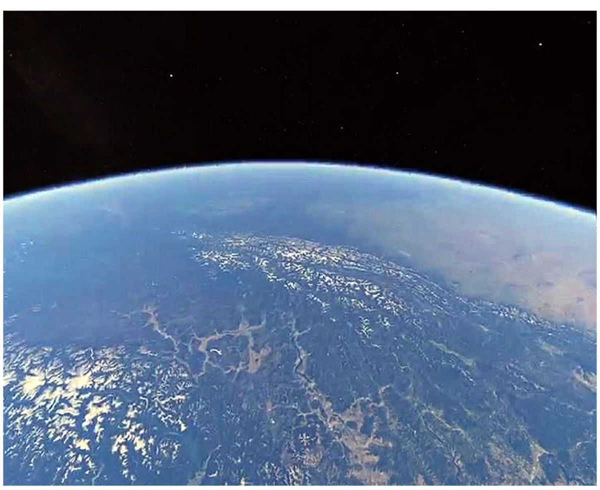

FIGURE 6 | A self-selected environment where the participant orbits the Earth from Space, as seen in the external monitor of the VR display.

Settings and Equipment

Each environment lasted 5 min. Participants could explore as they chose in all but the Color Tour. The choice to remain where they were and not explore was open to them. The stimuli contained 3D audio and instrumental musical score. An audio track through noise-canceling headphones was intended to block out outside sounds from the lab setting and enhance sensory immersion, and to provide continuous music. We disabled the "comfort mode," a feature designed for reduction of motion sickness through blurring of the peripheral vision while moving. The overall scale of the environment was set to "human scale."

The stimulus was presented stereoscopically on a 2016 model HTC Vive VR system consisting of a head-mounted display (2160 × 1200 total resolution, 1080 × 1200 per eye, 90 Hz refresh rate at 110-degree diagonal field of view), with cables to the headset draped overhead to avoid drag on the participant's head. Audio was presented on Sennheiser noise-canceling headphones. The computer contained an Intel i5 6600 CPU and a GeForce GTX 970 graphics card.

Measures

Goose Bump Recorder Instrument

In exploring (**RQ1**), we determine the frequency of goose bumps for each participant. To record these, we designed an instrument adapted from Benedek et al.'s (2010) 'goosecam' consisting of a Logitech HD C270 webcam. The focus ring was modified to allow macro recording of a 5 cm × 5 cm patch of forearm skin, with 3 LEDs at a 15-degree angle to cast unidirectional light onto the skin (**Figure 7**). This angle captured changes to skin texture. The camera was fixed onto curved fiberglass with soft foam on the skin side. Two elastic straps secured the instrument in place on the non-dominant arm. The instrument was designed to accommodate VR hand controllers. Video from the camera was analyzed via high-contrast filters to determine the presence of goose bumps on the skin. Video was synced to a screen recording of the participant's VR headset output (via Open Broadcaster Software). To view the videos side by side, the videos were imported into Adobe Premiere and observed on a timeline. Through syncing the instrument recording to the VR

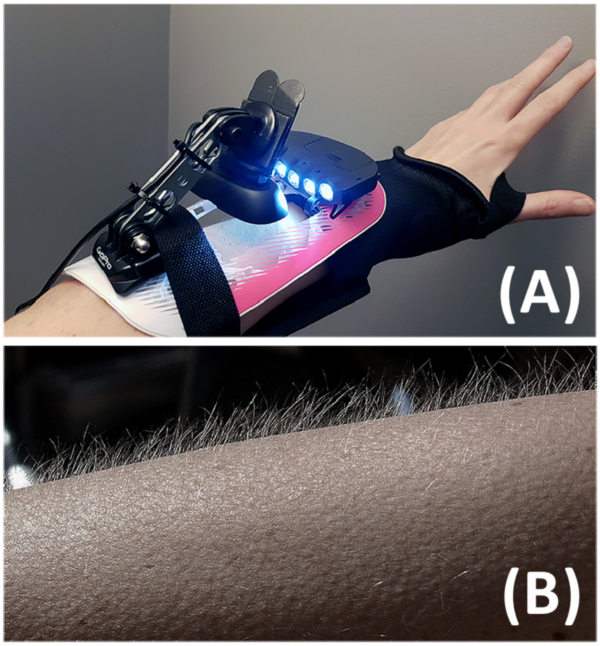

FIGURE 7 | Image **(A)** depicts a model wearing the Goose Bump Recorder Instrument on the arm; **(B)** depicts a typical presentation of the models' goose bumps.

screen capture as time series, we see the "moment-to-moment" temporal correlations in the participant's VR view, and any goose bump episodes that may occur. This allows researchers to directly see and evaluate both the stimulus and participant's response.

Questionnaires

Experience questionnaire

To address (**RQ1**), we designed a post-treatment questionnaire ("Experience Questionnaire") to collect participants' awe ratings of the VR experience. Participants were asked to rate their experience on a visual analog scale of 0–100 across all four environments (the overall VR experience) with respect to awe, wonder, curiosity, and humility, with definitions for each provided by Gallagher et al. (2015), as seen below:

Awe. A direct and initial feeling when faced with something incomprehensible or sublime. Specification: Captured by view/ drawn to phenomenon; elation; experience-hungry, overwhelmed, scale effects, sublime, surprise.

Wonder. A reflective feeling one has when unable to put things back into a familiar conceptual framework. Specification: Inspired; Perspectival shift; Nostalgia; Unity with whole; Unity of external; Responsibility.

Curiosity. Wanting to know, see, experience, and/or understand more. Specification: Interest/inquisitiveness; Experience-hungry; Intellectual appreciation.

Humility. A sense one has about one's relation to one's surroundings or of one's significance. Specification: Responsibility; Unity with whole; scale effects.

Participants were presented with the definition and question about their experience on this questionnaire:

> "Please note the following definition- When we use the word AWE, we mean: a direct and initial feeling when faced with something incomprehensible or sublime." "Did you feel AWED by the experience?"

A visual analog scale was presented from "0" (Not at all awed) to "100" (Definitely awed).

To explore the potential role of personality and immersive tendencies on the experience of awe in VR, we use additional questionnaires:

Personality traits questionnaire

The 44-question Big Five Inventory of personality, or BFI (John et al., 2008) consists of questions with a five-point Likert scale, with the minimum score possible being 44 points, and maximum possible being 220 points. Questions were broken into 5 traits: Agreeableness (9 questions for a maximum total 45 points), Conscientiousness (9 questions for a maximum total 45 points), Extroversion (8 questions for a maximum total 40 points), Neuroticism (8 questions for a maximum total 40 points) and Openness (9 questions for a maximum total 45 points).

Immersive tendencies questionnaire (ITQ)

The immersive tendencies questionnaire (ITQ) is an 18 question survey, presented on a 7-point Likert scale (Witmer and Singer, 1998). It consists of the subscales: "Involvement," the tendency to become involved in activities; "Focus," the tendency to maintain focus on current activities; and "Games," the tendency to play video games.

Demographics questionnaire

To learn more about our sample population we used the following general demographics questions:

1. how many times the participant experienced VR before the experiment (as a number);
2. the participant's experience with 3D games as a visual analog scale from 0 (no experience) – 10 (expert);
3. age in years, and;
4. gender.

Introspective Open-Ended Interviews

To explore (**RQ2**), we used qualitative methods of open-ended interviews and observations of the participants during the experiment. With an experience of awe being complex, and awe elicitors in a VR environment largely unknown, we opted to use the most detailed descriptions of awe-inspiring experiences in the literature. These descriptions were the analysis of astronauts' awe experiences placed into 34 consensus categories by Gallagher et al. (2015). Participant interviews were transcribed and statements from the interviews were matched within four definitions of awe, wonder, curiosity, and humility, and are found within the 34 consensus categories. To explore how the environment might affect awe experiences and include specific awe elicitors, we looked for repeating categories and statements that occurred during the virtual environments. We recorded themes around the usability of the VR system and navigation interface to better understand the role of interactivity and usability on experiences of awe. Finally, we specifically looked for participants' referring to their personal history: these statements may provide insight to their ability to become awed or not.

A video camera with audio recording capability was used to capture the participant's experimental session and interview.

Procedure

Participants signed informed consent, then were briefed that they would experience VR. They were shown the goose bump recording instrument and told that they may ask questions. The facilitator took care to avoid stating expectations around the VR stimuli. Participants completed the 44-question personality traits evaluation (BFI: John et al., 2008). Next, participants were told that they would enter Google Earth VR, which began with a 5-min tour with VR hand controllers not needed. They were shown and taught the VR headset and controllers before beginning the 5-min tour. This allowed them to seamlessly enter the next environment without the facilitator disrupting their experience.

The goose bump recording instrument was placed on their non-dominant arm. Participants were fitted with the VR headset and headphones, with adjustments made by the facilitator for comfort (**Figure 8**). The presentation of the stimuli then began with the Color Tour. Once the tour was finished, participants were handed the controllers and began their exploration in Vancouver. Upon completion of 5 min in exploring this environment, participants went to Mount Everest for 5 min. After this third environment, participants were told to navigate to a destination of their choosing, anywhere in the world, for a final 5 min.

FIGURE 8 | The VR equipment setup with headset, noise-canceling headphones, and goose bump recording instrument. Informed and written consent was obtained from the participant from the pilot experiment depicted in the photo (who does not contribute to this studies' dataset).

Once their self-selected environment was complete, VR equipment was removed, and participants were given the Experience Questionnaire, followed by the demographics questionnaire, and final questionnaire on their Immersive Tendencies (ITQ: Witmer and Singer, 1998). Upon survey completion, an open-ended interview was conducted. Questions directed at participants included an indirect inquiry about the participant's sense of time ("You've spent 20 min in VR today, how do you feel?"), a question directed at their experience ("was there anything you'd like to talk about from that experience?"), a question about anything that stood out ("did anything stand out to you?"), and a question directed at their self-selection ("What is the significance of the place you chose to travel to?"). No other specific questions were asked, instead the interview was open-ended so the participant could talk about their feelings in the moment. The facilitator added these responses to observations made during the participant's session, such as whether they turned around and utilized the full 360 degrees of the headset, how they handled the controllers (with ease, or not at ease), how vocal the participant was, and how enthusiastic/animated the participant was before, during and after the experiment. The entire experiment lasted 60 min.

RESULTS

All effects are reported at a 0.05 level of significance. Parametric statistics were used for all quantitative analysis. Unless specified, assumption of normality is confirmed.

Subjective Awe Levels

Overall across the four environments, participants rated their emotional engagement for feeling awe, wonder and curiosity fairly high (averaging above 70 on a 0–100 scale), as summarized in **Figure 9**. To support this finding, we use a threshold of 10–100 for determining heightened emotions, as per Gallagher et al. (2015, p. 91).

Overall ratings of awe were high across all individuals ($M = 79.7$, $SD = 17.1$). Although females ($M = 84.0$, $SD = 11.7$) reported slightly higher awe ratings than males ($M = 77.1$, $SD = 19.7$), this trend did not reach significance, $t(14) = -0.78$, $p = 0.449$, $d = 0.43$.

Similarly, females showed a non-significant trend toward higher ratings of wonder ($M = 81.3$, $SD = 14.3$) than males ($M = 67.6$, $SD = 23.5$), $t(14) = -1.28$, $p = 0.221$, $d = 0.70$.

Humility ratings were overall a bit lower than the other ratings ($M = 58.1$, $SD = 33.2$), with males showing a non-significant trend toward lower humility ratings ($M = 50.7$, $SD = 32.5$) than females ($M = 70.5$, $SD = 33.3$), $t(14) = -1.17$, $p = 0.261$, $d = 0.60$.

Finally, curiosity ratings were overall high ($M = 91.7$, $SD = 12.1$), with males showing slightly higher curiosity ratings ($M = 95.1$, $SD = 9.3$) than females ($M = 86.0$, $SD = 14.8$). Again,

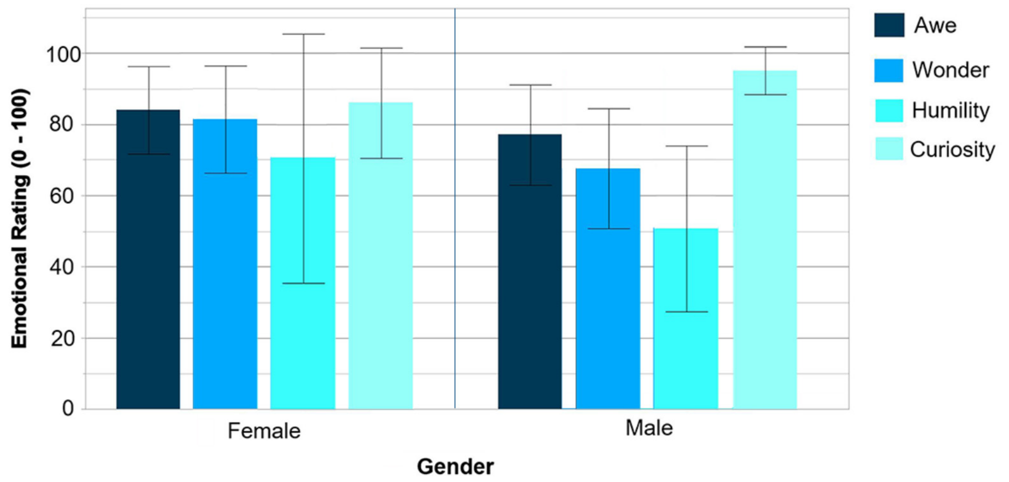

FIGURE 9 | Emotional ratings across all four environments by gender. Each error bar is constructed using a 95% confidence interval of the mean. For females: awed (*M* = 84.0, *SD* = 11.7), wonder (*M* = 81.3, *SD* = 14.3), humility (*M* = 70.5, *SD* = 33.3), and curiosity (*M* = 86.0, *SD* = 14.8). For males: awed (*M* = 77.1, *SD* = 19.7), wonder (*M* = 67.6, *SD* = 23.5), humility (*M* = 50.7, *SD* = 32.5), and curiosity (*M* = 95.1, *SD* = 9.3).

this trend did not reach significance, $t(14) = 1.52$, $p = 0.152$, $d = 0.74$.

Using bivariate correlation analysis, results indicated that participants whose rankings of humility were high, also had closely correlated high rankings of awe ($r^2 = 0.41$, $F(1,14) = 9.6$, $p = 0.008$), see **Figure 10**. None of the other ratings were correlated. The positive correlation between awe and humility is of interest when we explore the qualitative findings, specifically the concept of '*small-self*' / diminished perceived size as a self-transcendent quality (Bai et al., 2017).

To summarize the subjective awe findings, we did find support for our (**RQ1**) in that the four different interactive VR environments yielded an average awe rating of 79.7 out of a 0–100 scale, indicating that interactive VR can indeed induce awe.

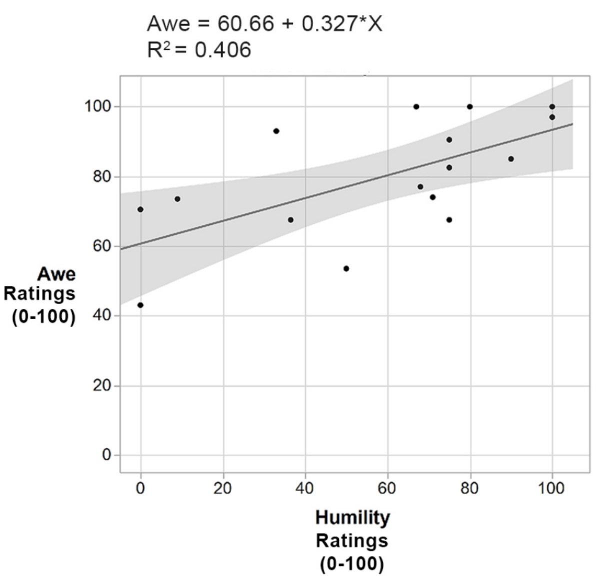

FIGURE 10 | Awe and humility ratings correlational diagram.

Goose Bumps Occurred in Almost Half of the Participants; Most Occurred in the Final Self-Selection VR Environment

43.8%, or 7 of the 16 participants experienced goose bumps as detected by our goose bump recording instrument throughout the four environments, which is consistent with previous research (Benedek and Kaernbach, 2011; Sumpf et al., 2015; Wassiliwizky et al., 2017). With equal variances confirmed and using a *t*-test, there was a significant trend for females experiencing more goose bump occurrences ($M = 1.3$, $SD = 1.4$) than males ($M = 0.3$, $SD = 0.5$) $t(14) = -2.21$, $p = 0.04$, $d = 1.0$. This finding demonstrates that females are slightly more likely to have goose bumps than males (**RQ3**).

Interestingly, 64% of the goose bump occurrences from all participants occurred in the final self-selection VR environment, where participants traveled to a location of their choosing. The qualitative interviews provide more specifics into this finding and are discussed in detail in the Section "Most Goose Bumps Occurred During the Self-Selected Environment."

Awe Ratings Were Positively Correlated With the Occurrence of Goose Bumps

To explore the relationship between the occurrence of goose bumps and awe ratings, participants ($N = 7$) who had goose bumps were sorted into a "Goose bump experiencers" group, and those who did not have goose bumps ($N = 9$) were sorted into a "Non-Goose bump experiencers" group. When the goose bump-experiencers were separated from non-goose bump experiencers, there a significant effect of the presence of goose bumps on the ratings of awe, see **Figure 11**. Awe ratings were significantly higher for goose bump experiencers ($M = 90.9$,

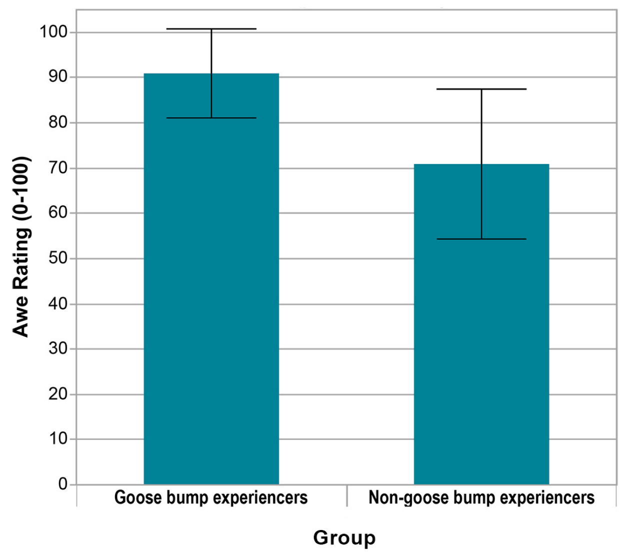

FIGURE 11 | Awe ratings between the groups 'goose bump experiencers' ($N = 7$, $M = 90.9$, $SD = 9.8$), and 'non-goose bump experiencers' ($N = 9$, $M = 70.9$, $SD = 16.6$).

$SD = 9.8$) than for non-goose bump experiencers ($M = 70.9$, $SD = 16.6$), $t(14) = 2.82$, $p = 0.01$, $d = 1.42$. This indicates a correlation between the occurrence of goose bumps and higher awe ratings and supports the literature that goose bumps are a probable physiological indication of awe (Keltner and Haidt, 2003; Schurtz et al., 2011; Maruskin et al., 2012; Campos et al., 2013; Silvia et al., 2015). This means that use of a goose bump recording instrument may be valuable in collecting data on moment-to-moment indications of awe.

To summarize the findings for (**RQ1**), data indicate that the interactive VR stimuli generated subjective (through awe ratings) and physiological (through goose bumps) indications of awe. This finding suggests there is merit in collecting both subjective ratings and physiological data for the evaluation of awe, as both methods demonstrate valuable insight into the awe phenomenon; ratings represent an 'overall' sense of awe, and physiological goose bumps show 'moment-to-moment' indications.

Personality Traits Are Not Clearly Correlated to Goose Bump Occurrences and Subjective Awe Ratings

Prior evidence has demonstrated that Openness as a trait may be correlated with a higher incidence of awe (Silvia et al., 2015; Bride, 2016), and awe with goose bumps/chills (Silvia and Nusbaum, 2011; Colver and El-Alayli, 2016). Here, bivariate analysis was used to test if the BFI personality traits significantly predicted participants' ratings of awe (see **Figure 12**). However, we found no evidence that Openness as a trait predicts higher **awe ratings** in this study. Openness, Agreeableness, and Conscientiousness showed non-significant negative correlations with awe ratings (all p's > 0.05). Extroversion was found to be slightly but not significantly positively correlated with awe ratings, ($r^2 = 0.150$, $F(1,14) = 2.48$, $p = 0.138$). However, Neuroticism had a slight positive correlation with awe ratings ($r^2 = 0.325$, $F(1,14) = 6.73$, $p = 0.02$), but the medium effect size indicates limited linear relation between the two variables.

No correlation between **goose bump counts** and any of the BFI personality traits were found (all p's > 0.05).

No Correlations Between Immersive Tendencies and Goose Bump Frequency or Subjective Awe Ratings

Correlation analyses showed that immersive Tendencies scores did not appear to have any effect on **high responses of awe** or physiological **goose bump incidences** (all p's > 0.05). Thus, participants with higher Immersive Tendencies didn't appear to be more likely to experience higher awe in VR, at least not in the current study with the small participant sample.

Introspective Open-Ended Interviews Show Specifics of Experience

To address (**RQ2**), we used introspective data from the interviews to gain a deeper understanding how the traits of aesthetic

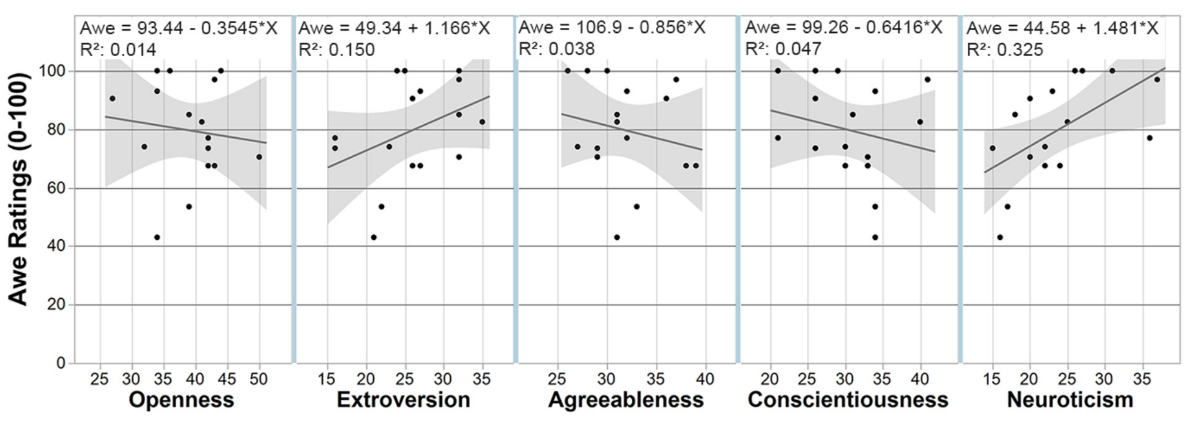

FIGURE 12 | Personality traits vs. awe ratings correlational diagram.

beauty/scale, familiarity, or personalization of the environment relates to the participants' experience. Statements were classified into categories of awe and usability of technology by one trained researcher who also conducted the open-ended interviews, using pre-defined coding units and themes. Awe categories were obtained, and validated from Gallagher et al. (2015, p. 29).

Participant Statements Within the Categories of Awe

All participants had at least two statements during the interviews that could be categorized into one of Gallagher et al. (2015) consensus categories of awe. Given that the categories were generated based on astronauts' experiences in space, and since we used a VR environment that allowed for viewing Earth from space and Earth at ground level, we anticipated some similarities between statements. However, as the astronauts' experience of viewing the actual Earth from space is a considerably powerful experience involving specialized training and danger, we expected participants to report less intense experiences than the astronauts. **Figure 13** summarizes the categories and frequency of statements by participants.

Although Gallagher et al. (2015) determined 34 categories of awe and wonder based on descriptions by astronauts, we found that our participant statements fit into a subset of just 12 of these 34 categories:

(1) Aesthetic Appreciation
(2) Captured by the view / drawn to the phenomenon
(3) Connectedness (feeling connected with something without losing distinctness)
(4) Dream-like experience (feeling of unreality, abstract feeling)
(5) Elation
(6) Nostalgia
(7) Overwhelmed
(8) Perspectival shift (internal change of [moral] attitude)

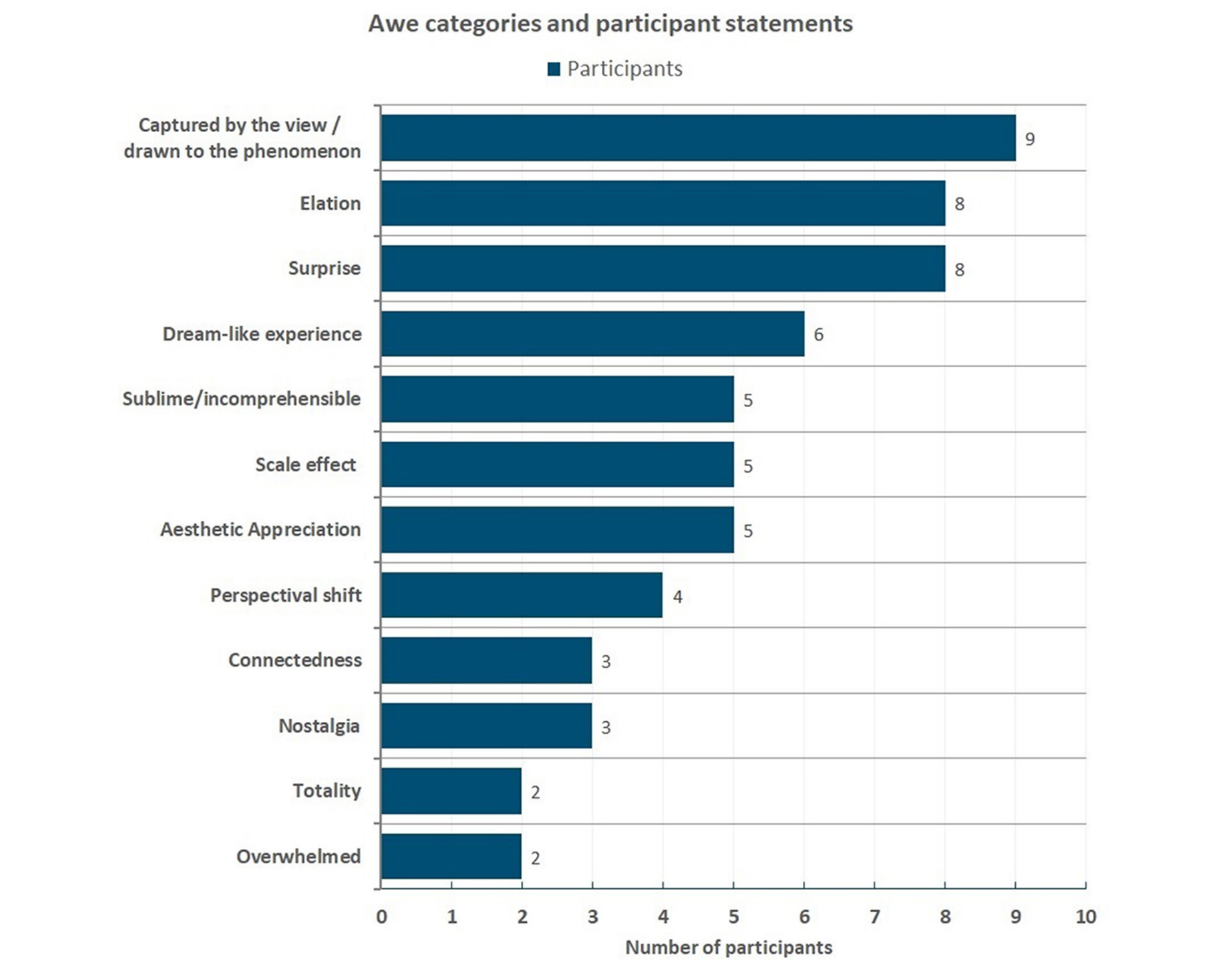

FIGURE 13 | 12 categories of astronauts' awe experiences based on Gallagher et al. (2015) textual analysis. Participant statements are sorted into the awe categories, with the frequency of participants noted who made statements in each category.

(9) Scale effect (feelings of the vastness of the universe or one's own smallness/ insignificance)
(10) Sublime/incomprehensible
(11) Surprise
(12) Totality (wholeness of what is experienced; big picture)

It is possible that a broader participant sample and a more comprehensive interview technique, such as neurophenomenology or micro-phenomenology would have enabled us to dig deeper into the experiences and associate participant statements into more categories. For the style of open-ended interviews that we used for the current study, however, our participant interview statements did not fit into any of the remaining categories defined by Gallagher et al. (2015):

(13) Change (internal or bodily change)
(14) Contentment (tranquility, feeling relaxed or at peace)
(15) Disorientation
(16) Emotional (general emotional feeling or arousal)
(17) Experience-hungry (wanting more of a particular experience)
(18) Exteroceptive intensive experiences (sensory overload, silence)
(19) Floating (bodily, feelings of weightlessness)
(20) Floating in void (not related to weightlessness)
(21) Fulfillment
(22) Home (feeling of being at home)
(23) Inspired
(24) Intellectual appreciation (for order, analysis, complexity)
(25) Interest/inquisitiveness
(26) Interoceptive intensive experiences
(27) Joy (feeling of happiness)
(28) Perspectival (spatial) change
(29) Peace (conceptual thoughts about)
(30) Pleasure
(31) Poetic expression
(32) Responsibility (toward others)
(33) Unity of external (earth, universe, people on earth, interrelatedness)
(34) Unity with whole (feeling of oneness with; holistic feeling)

We wish to note that category #5 "Elation," #16 "Emotional (general emotional feeling or arousal)," #27 'Joy (feeling of happiness)," and #30 "Pleasure" overlap each other considerably. All four categories describe a particular positive affect, or overall emotional state. While some participant statements did reflect these three categories, we chose to focus on #5 "Elation" which tended to be more specific. Because of the overlap, we took a conservative approach to the analysis of under-categorizing, opposed to over-categorizing statements, thus helping to avoid potential mis-categorization.

As illustrated in **Figure 13**, the most common statements fit into the category of "Captured by the view/drawn to the phenomenon," mentioned by 9 of the 16 participants (56%). This isn't surprising given part of the operational definition of awe contains the specific categories of: Captured by view/drawn to phenomenon; elation; experience-hungry, overwhelmed, scale effects, sublime, and surprise. Some examples of feeling captured by view/drawn to phenomenon were spoken by participants as they were in the VR environment:

> "*I feel like superman, flying above Earth and seeing all these cool things! I'll never get enough of this view! Look!*" P08, female

On the other hand, some participants went to places they would be traveling to in real life and treated the VR environment like a preview. One participant describes being captured by the view:

> "*I'm going to London and Japan soon, so I thought I'd enjoy what it will be. London has a lot of landmarks that look really great to see. Japan though, has some natural sights I now want to visit. It draws you right in, to see that. I feel like my eyes were locked on that.*" P15, female

Another participant describes the difference between a photo of a place, and feeling like they are there in VR while being drawn in:

> "*If I saw a photo, I wouldn't care... But this made me feel it was just real enough to sort of be there, and want to go there more. I felt drawn to that place.*" P14, female

Feelings of elation and surprise were also common among the participants interviews (8 of 16, or 50% of participants for both). Two participants described how the experience could be mood altering:

> "*I don't know what I would feel like (after), but I felt totally happy. Like, nothing can disappoint me now today.*" P05, female

"*This was so amazing. I feel like my week is going to be a lot less stressful. Whenever I think of all the things I have to do, I'll think of this and how fun it was.*" P14, female Some participants described the delight and elation of seeing familiar places in a new way:

> "*This is totally outrageous. I can't believe what I am seeing... Actually I can. I am seeing my planet but from a totally different way. I can go anywhere, I love this.*" P06, male

> "*That was so cool. I could do that forever. It makes me really happy to be able to go home, whenever I want. I'm a small town kid and there's comfort in that, in seeing it this way, you know?*" P13, male

It should also be noted that these four above statements may also be categorized as #16 Emotional (general emotional feeling or arousal), #27 Joy (feeling of happiness), and #30 Pleasure.

There was some overlap between elation and surprise, with many statements indicating both happened in parallel:

> *"I liked the beginning of the experience a lot." ... "Because I didn't know those places, that they existed. Couldn't wait to see what was next. They are beautiful. I am really surprised."* P04, male

Several participants (6 of 16, or 38%) made note that the experience felt dream-like, or like drifting through unreality. One participant voices how he lost track of time:

"*Time just stopped. It felt like daydreaming, when hours pass but it feels like just minutes.*" P09, male

Aesthetic appreciation frequently was heard, with many participants stating their environments were "breathtakingly gorgeous," "really nice to look at," and with "lots to see, very beautiful." Likewise, many statements indicating feelings of sublime/incomprehension were mentioned:

"*I can't believe what I am seeing. Is that real? It feels real.*" P08, female

Feeling overwhelmed wasn't commonly reported, but in the two instances it was stated was in the context as being positive:

"*. . .the type of feeling, of being overwhelmed when seeing earth from high up, is really neat.*" P11, female

Five participants mentioned scale effects, describing the visuals as perceptually vast or large, like massive oceans and coastlines. Two participants mentioned feeling both perceptually and conceptually small compared to the environment:

"*I don't feel very significant right now. I mean that's ok, I just feel like there's a big planet full of people and things out there, and I am just one. It means my problems are actually smaller than I think, in reality.*" P08, female

"*I can't believe this can exist. It feels much greater than me.*" P01, male

These two comments may be indicative of the '*small-self*', or diminished size phenomenon in an awe-inspiring experience (Piff et al., 2015; Campos et al., 2013; Elk et al., 2016; Bai et al., 2017).

Some participants stated a feeling of connectedness, and a yearning to connect (3 of 16, 19% of participants). We can see with the following statements some examples:

"*That's my home. That's my old home, where I grew up. I was. . . I left when I was nine, I haven't seen it since. That fence, it is still there, same fence. Can I see a person? Maybe she is there?*" (participant speaking aloud to themselves during the experiment, with "she" later revealed in the interview to be a grandmother). "*I think I need to. . . I haven't talked to her, my sister, or grandmother in a long time. They are there still. I should talk with them, over video, you know?*" (stated during the interview). P02, male

"*I feel like I could do this for a long time, and just get lost in it. Imagine if you could connect with other people there, like we do in a dream, people you know. I feel like sharing that.*" P16, male

Relating to connectedness was some statements around experiencing nostalgia. Three participants mentioned nostalgia in their interviews, and each participant experienced nostalgia when looking upon a childhood and ancestral home, like the following:

"*It doesn't look like much changed, from the photos. It's very nostalgic.*" P10, male

Few participants appeared to have statements that could be categorized as perspectival shifts. Included among the four participants who mentioned potential changes to their moral attitude we see: one possible change to how they perceive the environment; one perception that problems may be small in proportion to others; and two perceptions that individuals in other places have a challenging way of life that should elicit empathy.

Totality was mentioned just twice in the interviews, but both related to the sight of seeing Earth from space:

"*It was amazing to see the whole planet from this perspective, makes feel free, and able to see the whole of everything.*" P14, female

The lack of comments attributed to totality may be because most participants opted not to orbit the Earth, but rather looked for more familiar features closer to ground level.

Most Goose Bumps Occurred During the Self-Selected Environment

Most of goose bumps occurred during the final self-selection phase of the experiment (64%), with the most common self-selected destinations, as explained by the qualitative data, being participants' hometowns where family and friends are, or places participants wished to visit (**Figure 14**). Familiar environments appear to draw an equal amount of awe-inspiring feelings as environments that are unfamiliar. In allowing the participant to personalize their experience, our aim was to enable the participant with agency and ownership of their experience, a capability many participants stated they enjoyed. Personalization of an experience and its correlation to awe is compelling, with many participants stating this was an overwhelmingly positive experience; additional introspective findings as seen in the interview excerpts also reveal themes of social connection during the self-selected environments.

Controller-Based Interaction May Impede Usability and Immersion in the VR Environment

While participants had a positive experience with the VR stimuli, there were diverse comments about the usability and intuitiveness of the navigation interface/interaction paradigm. While several commented that they enjoyed the intuitive ability to kneel at ground level, to turn their body around physically, or to look around the environment in 360 degrees, several participants spoke about and were observed to have difficulty with the controllers. Participants mention that seeing the graphical interface of the controllers was distracting and impeded immersion, with a more natural body-based interface desired:

"*Seeing the controllers took me out. I looked down at them too much, relied too much. If I could not see them and just know how to use them, or maybe if there is another way for me to*

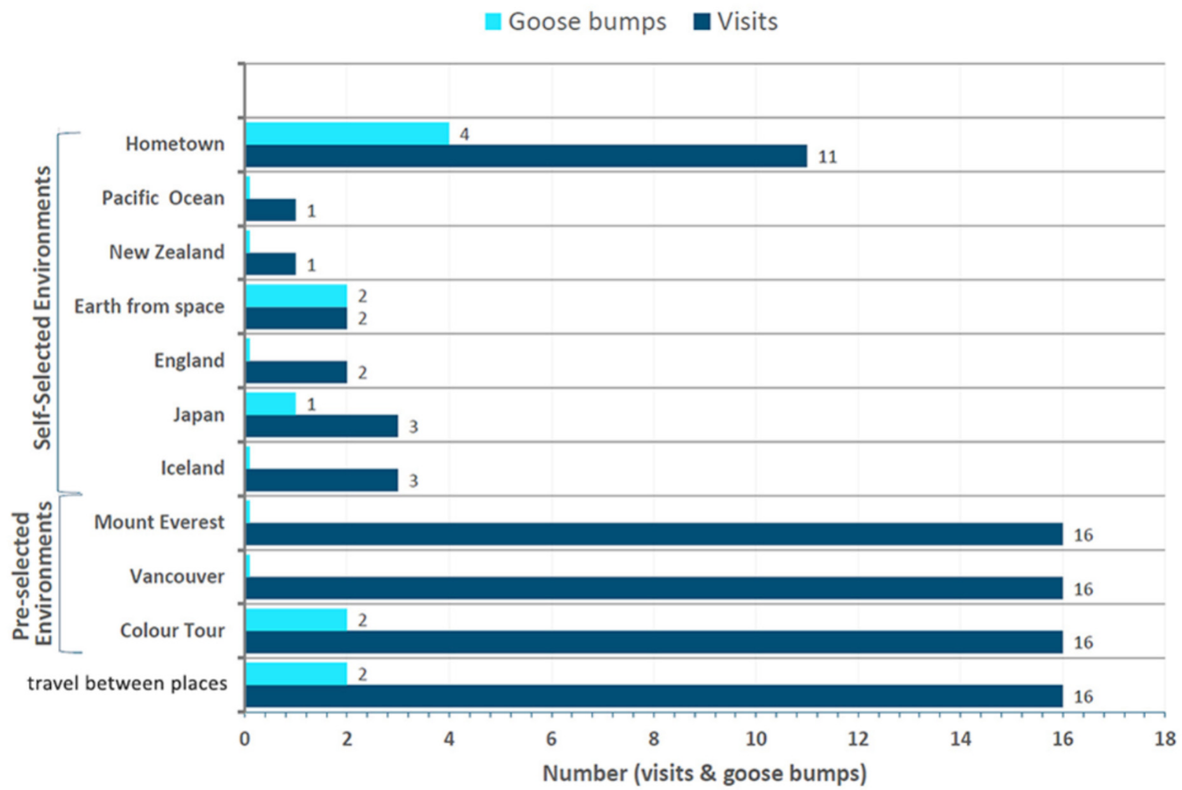

FIGURE 14 | The total number of visits to each place inside the VR environments across all participants, and the total number of goose bump occurrences (if any) for each place. Please note that all participants experienced the pre-selected environments of Color Tour, Vancouver, and Mount Everest; all participants engaged in travel between places by navigating from place to place and around the environment. Some participants elected to travel closer to the ground, while others orbited above Earth. Some participants experienced more than one occurrence of goose bumps during the experiment.

move and choose where I want to go without my hands, I'd really like that." P04, male

"*It was hard to be immersed when the controllers were needed. The interface was on screen so I kept seeing it, and it took me out a bit each time... body tracking, that would be more intuitive.*" P09, male

Another participant mentions the controllers didn't feel easy to use, yet observational data demonstrates the participant appeared to get immersed in the environment by visibly flinching when virtual objects came near:

"*It was hard learning the controllers. I wanted to explore, but I had to keep looking at them to make sure I touched the right buttons.*" P08, female

Participants turned their head to look behind their peripheral vision an average of six times per experimental session; only one participant made a full physical circular turn with their body.

To summarize, the qualitative findings provide insight into the following research question (**RQ2**) "What effect(s) do the traits of aesthetic beauty/scale, familiarity, or personalization of the environment have on awe experiences?" For aesthetic beauty/scale, statements fitting into 'Captured by the view/drawn to the phenomenon' awe category were most numerous (9/16 participants). Given that notable awe-inspiring places share attributes of vastness, scale, and beauty (Keltner and Haidt, 2003; Shiota et al., 2007), the VR stimulus of the Earth fits this description well and is likely very captivating to observe. 'Scale effects' of perceptual vastness or largeness were mentioned by several, and while it isn't a consensus awe category, the 'small-self', or diminished size phenomenon was mentioned in the scale effects context. 'Aesthetic appreciation' was mentioned by 5/16 participants, with comments reflecting their pleasure of seeing beautiful landscapes. With respect to 'familiarity', we see in the data that participants often chose familiar locations as their self-selected environment, such as hometowns and places family and friends reside. It is particularly interesting that hometowns are the most popular of all destinations participants visited, and it produced the most goose bump occurrences of all locations. Likely related to this finding is 'personalization', with most goose bumps occurring during the self-selected environment. We can determine from these findings that aesthetic beauty/scale positively influences awe, and familiarity/personalization of the environment leads to personal relevance that also positively influences awe.

Of all the categories, #3 "Connectedness (feeling connected with something without losing distinctness)" could potentially be the most interesting because "connectedness" statements indicated that participants might incite change because of their experience in VR. They used language such as "I should," "I feel like I could, and "I think I need to," which implies consideration of a possible real-world action once the VR experience is over. Finally, we see from the qualitative findings that usability challenges of the VR interface to navigate impeded some participants' ability to become and stay immersed. From the statements, it is interesting that several participants intuitively knew their needs for a positive experience, as they identified potential benefits to a hands-free interface and no on-screen UI graphical elements. This is consistent with Slater et al. (1998) argument that natural, full body movement influences subjective presence, and in turn, immersion.

DISCUSSION

Overall our study showed that immersive interactive VR can indeed generate subjective experiences of awe and physiological goose bumps in many participants (**RQ1**): four different interactive VR environments yielded an average awe rating of 79.7 (on a scale of 0–100). Our goose bump recorder instrument could indeed detect and record goose bumps, although we hope to automate goose bump detection in future design iterations. 43.8% of the participants experienced goose bumps, consistent with the ratio of goose bumps using stimuli in lab settings (Benedek and Kaernbach, 2011; Sumpf et al., 2015; Wassiliwizky et al., 2017). Also, awe ratings were positively correlated with the occurrence of goose bumps. Most goose bumps were experienced in the final self-selection VR environment. Personality traits yielded no clear correlation to awe ratings. While females had a higher incidence of goose bumps (66.7%, 4/6 females) than males (30%, 3/10 males), there was no difference between genders when it came to self-report ratings of awe. Our finding that females are more likely than males to experience goose bumps (**RQ3**) corroborates findings from two earlier studies that used only audio as stimulus (Panksepp, 1995; Benedek and Kaernbach, 2011), with a difference that our own study used audio and video as VR stimulus.

The observed positive correlation between ratings of humility and awe in our study is intriguing, since this same correlation was found by Gallagher et al. (2015) with participants that experienced awe also reporting higher humility. This may be related to the perception of a "*small self*" which is a shift in self-concept, the diminished size, that occurs during and after an awe-inspiring experience (Campos et al., 2013; Piff et al., 2015; Elk et al., 2016; Bai et al., 2017). This concept of small-self generated through awe is connected to feelings of humility, with humility often leading to improved feelings of social connectedness and well-being (Stellar et al., 2017a). As seen in the introspective interviews, we discovered participant statements that are illustrative of the small-self phenomenon, which may provide insight into the correlation between awe and humility ratings in the quantitative data.

In exploring (**RQ2**), we learn that aesthetic beauty/scale and familiarity/personalization of the environment positively influence awe. 12 categories of astronauts' awe experiences based on Gallagher et al. (2015) were matched to participant interview statements. These ranged from impressions around the **aesthetics** being beautiful and awe-inspiring, to thoughts and feelings about **scale**. The scale comments involved both perceptual ('the ocean is massive') and conceptual impressions ('it feels much greater than me'). In exploring the effect of **familiarity** and **personalization** (through self-selection of locations and agency) on awe, we found most goose bumps occurred during the final self-selected environment. **Figure 14** displays the environments explored, and real-time occurrences of goose bumps. Many participants visited multiple places in the self-selection phase, since they were not limited to just one place. Iceland and Japan tied as the most visited with three visits each; respective participants stated they had never been to those places but always wondered what they would be like to travel to. Two participants opted to get an overview of the Earth from outer space as their self-selected option. Notably both those participants experienced goose bumps. Eleven participants used the self-selected environment phase to search for their hometown, place of birth, or ancestral home. These places weren't always familiar to participants; in three cases, participants found the locations from their memory of photographs and descriptions. Of the eleven 'home-traveling' participants, three spoke of experiencing nostalgia. The elicitation of nostalgia has been correlated with maintenance and enhancement of a sense of meaning, or existential function (Routledge et al., 2011) and these are traits frequently seen in astronauts' descriptions of the Overview Effect and awe (White, 2014). The nostalgic attributes demonstrated by some of the participants in our present study may reflect this previous research, with the feeling of curiosity to visit new places likely less indicative of awe. In terms of the selected height during navigation, five participants spent over half of their time orbiting space and taking an overview perspective of the Earth while trying to get from place to place, while the other eleven participants mainly stayed close to ground level, closer to airplane height.

Introspective data revealed that interactivity and allowing participants to navigate themselves had benefits, such as free movement and a feeling of agency, but also detriments, such as difficulty using controllers. This motivated us to create hands-free, leaning-based interfaces in our own design of awe-inspiring virtual environments (Quesnel et al., 2018). When looking at the participant's demographic questionnaire details, several participants had experience with 3D games, but not VR systems. It is possible that the forward seated position of looking at a screen while playing games translates into a forward-facing habit in VR, with reliance on hand controllers to turn and navigate opposed to using the head and body. Indeed, the most experienced participants with VR tended to physically move their bodies the most on up/down, sideways, on rotation, and forward/backward. More exploration is needed in the use of interfaces that may be more universally intuitive or natural, such as leaning (Riecke et al., 2005; Kruijff et al., 2016; Kitson et al., 2017).

To summarize, these findings demonstrate that (1) interactive VR has an excellent capacity in eliciting awe, and if we regard goose bumps as a reliable indicator of awe, then familiar, self-selected environments are particularly effective; (2) physiologic goose bumps can be collected using a goose bump recorder instrument for non-intrusive, reliable indications of awe; (3) care must be taken to not impede awe and immersion or create distraction through appropriate design and intuitive, uncomplicated interaction interfaces; (4) While personality traits are not clearly correlated to awe ratings, goose bumps were experienced more frequently among females.

Limitations and Future Directions

While our present study was able to explore the participants' experience in considerable detail, the small sample size of 16 participants reduces the statistical power and opportunity to find significant effects. Additionally, we did not have an equal number of females to males, which is an improvement to be made in the next studies. This may have impacted the findings for (**RQ3**), where a higher percentage of females than males experienced goose bumps. Regardless, an equal proportion of males to females in addition to a larger sample size may yield more conclusive results. Based on pilot testing results as described in subsection "Virtual Environment Locations and Order," we chose a fixed instead of counterbalanced or Latin Square order of the four scenes. Thus, order was a potential confound, and the finding that self-selected environment (also the last environment) provided the most goose bumps might change if order was balanced, which future research should investigate. Nevertheless, the qualitative data indicated that the self-selected environments had personal and emotional relevance for many participants, which seems less likely to be affected by order effects.

A limitation may be the use of one researcher to conduct interviews and analyze the qualitative open-ended, semi-structured interviews. To guard against subjective idiosyncrasies and promote rigor and justification of claims, it could be advantageous to utilize two or more researchers for the qualitative analysis. Since the categories of awe were provided via Gallagher et al. (2015, p 29) with comprehensive examples of category statements provided in text, we feel confident that statements were classified to the best of the researcher's ability and acknowledge that the categories may in fact evolve as our understanding of awe increases. Gallagher et al. (2015) framework is thoughtful and clearly strives for validity, and to understand the complexity of the framework it took considerable time for our researcher to apply and check the accuracy of the framework. Training of more researchers in understanding the process could build more rigor.

Through semi-structured interviews, a predominant usability concern voiced by participants was with the operability of the VR hand controllers. Ten of the sixteen participants were observed to struggle with the controllers during the experience (seen in interactions where the controllers led to participants getting "stuck" in place while flying through the VR environment through incorrect button pushing, or gesturing). Researchers also noticed participants had high reliance on the controllers in navigating the virtual environment and did not use their head position or body position changes to look around the environment. With their gaze largely directed at the on-screen controls, and not constantly at the environment itself means the controllers themselves may have broken the level of presence and immersion, illustrated by participant comments like "it took me out." The lack of physical body turning (as in, rotating the body to change orientation) from participants should also be taken into discussion, since this is a frequent and debatable point in creation of cinematic VR content; where and how do we direct the gaze, and prompt emotional moments? Covert and overt orienting are often embedded within a VR narrative to direct attention, with immersive audio (Jerald, 2016). Given the Google Earth VR environment is open and exploratory, it would be beneficial to explore directed narratives as stimulus for covert and overt orienting. Provided that awe contains two key features, "vastness" and the "need for accommodation," Cohen et al. (2010) investigated differences between narratives on profound beauty (as aesthetics) and spiritual transformation narratives (as natural phenomenon, relationships, sacredness) and discovered that transformative narratives seem to produce long-lasting change over aesthetic narratives. For future directions with VR content on eliciting awe and transformative emotions, guided narrative could be compared with an open-world environment.

Usability concerns and user interface (UI) distraction points to limitations with a commercially available application (Google Earth VR) not purpose-built to induce awe. Remarkably, while not an intentional design feature, elicitation of the Overview Effect through Google Earth VR has been experienced by some (Podwal et al., 2016). This points to how VR as a nascent medium can produce surprising, unintended positive effects with opportunities to explore dedicated design for awe and the Overview Effect.

Interestingly, two participants described the passive 5-min Color Tour at the start of the experiment to be their favorite environment. This introduces the potential for limited-interactivity VR to potentially be more effective in allowing concentration on aesthetics and the experience of 'being there'. Once hand controllers are used, focus may shift to completing tasks (flying, or searching) rather than simply "being there." It is worth investigating how navigation interfaces with different modes of interaction impact awe and embodiment. Intuitive navigation interfaces like leaning and gestural motion tracking should be explored; our recent study using leaning-based interaction in a VR environment designed to elicit awe and wonder suggests that providing embodied navigation and eliminating hand controllers may reduce breaks in presence (Quesnel et al., 2018). In future studies, avoidance of interactions that may prevent awe from occurring through a loss of presence or concentration could provide evidence of new typologies of virtually induced awe.

In exploring a potential relationship between the small-self, humility and awe-inspiring experiences, a formal measure could be used such as the Perceived Self-Size Scale (Bai et al., 2017). Likewise, the relationship between experiencing awe and feeling a desire to socially connect was illustrated in some of the qualitative themes of this study, and a measure such as the Inclusion of the Other in the Self Scale (Aron et al., 1992) to collect data on social connectivity may be valuable. With these scales, it may be possible to investigate if the VR environment and interaction with it can impact a participant's perception of themselves and connection to others. As immersion and presence might be important factors enabling awe experiences, presence and immersion questionnaires could be used such as the Presence Questionnaire (PQ) by Witmer and Singer (1998) or Slater-Usoh-Steed (SUS) questionnaire by Usoh et al. (2000). A possible circular effect exists of emotions in the VR environment influencing presence levels that in turn influence emotions felt (Riva et al., 2007; Diemer et al., 2015), so data on presence correlating with emotions could be valuable.

Through additional physiological data, we may better understand patterns in the experience of awe. Biosensors, like SCR and Electrocardiogram (ECG) worn in addition to the goose bump instrument may provide real-time data demonstrating a relationship between processes of the autonomous nervous system. Through triangulation of data, it may be possible to differentiate between awe and frequently concurring emotions, like fear, and recognize emotions in order to provide biofeedback into a VR system (Quesnel et al., 2017). Other studies exploring markers of health and awe demonstrated that a tendency to feel awe predicts lower levels of pro-inflammatory cytokines compared to other emotions (Stellar et al., 2015). Inflammation is attributed to negative cardiac health and numerous auto-immune conditions, so investigating if awe in VR can lead to similar findings for improved wellness would be compelling.

CONCLUSION

Despite the limitations on the controller-based navigation interface and common personality tests unable to predict awe, results from this study demonstrate that immersive VR can be effective in eliciting awe, measured through physiological and self-report data. With immersive VR increasingly recognized for its potential to evoke shifts in a user's beliefs and values, future experiments could use high-quality multisensory VR stimuli to maximize emotions and engagement. Findings encourage exploration of VR stimuli and interaction paradigms for awe experiences and self-transcendent emotions that potentially lead to lasting, positive well-being and social implications. For further insight into awe experience, we will conduct future studies with custom-designed VR content and interfaces as a Positive Technology for awe elicitation, and will complement the goose bumps measure with additional physiological instruments.

AUTHOR CONTRIBUTIONS

DQ and BR conceived the main idea of the article. DQ collected data, conducted statistical and qualitative analysis, and wrote the first draft of the manuscript. BR provided guidance on the data analysis and rhetoric, and supervised the entire work. All authors contributed to the manuscript, read, revised, and approved the final version.

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Space—A Virtual Frontier: How to Design and Evaluate a Virtual Reality Experience of the Overview Effect

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A select small group of people have an amazing opportunity to see the Earth from a unique perspective—from space. The effect this experience has on an individual has been described as extraordinary and profound, consisting of a cognitive shift in worldview that leads to a deeper understanding of the fragility and vulnerability of our planet, and an increased feeling of connectedness. This experience, termed the "Overview Effect," has been reported by many space-travelers. Its key outcome—an enhanced feeling of interconnectedness—contributes to both one's well-being and the sense of responsibility for the Earth. If this profoundly positive experience could be made accessible to more people than just space-travelers, this might ultimately contribute to a healthier and more caring society, where more individuals deeply feel the interconnection of all living beings and responsibility for our collective future. Given virtual reality (VR) technology's potential to induce experiences affecting an immersant in a similar way as a real experience, we see an opportunity to leverage this technology to attempt to elicit the Overview Effect as a virtual experience. Through a virtual installation, the experience could be made accessible to people around the world, and for researchers to study this otherwise rare phenomenon. This article builds the case for VR as a tool for inducing and studying the Overview Effect. It reviews the psychological research on the Overview Effect and awe, and proposes guidelines for: (1) the design of VR experiences to elicit an Overview Effect and (2) evaluation methods for assessing if, or to what degree, the experience was achieved. Finally, we discuss existing implementations of the Overview Effect in VR. Thus, we are making an applied contribution in the form of design guidelines, and contributions to knowledge in the form of a review of research related to the Overview Effect. We invite researchers and VR creators to utilize and expand on the guidelines proposed in this paper to design transformative VR experiences that induce positive change, and promote a feeling of connectedness and care for each other, and our Spaceship Earth.

Keywords: virtual reality, overview effect, transformative experience, design guidelines, cognitive shift, interconnectedness, awe

1. INTRODUCTION

Our world is facing a lot of challenges in the domains of the environment, climate change, sustainability, over-consumption, and social stability. While these challenges require complex solutions, still, on an individual level, there are some well-known small steps each person could take to help protect the environment and minimize social tensions. Despite this intellectual awareness, many people still neglect to take the required action. It seems that many people may not perceive the connection between their individual actions and the global processes in the world (Blumstein and Saylan, 2007). If we could promote the feeling of connection within individuals, that could support the development of a more global consciousness, which may, in turn, assist with more people caring and taking responsibility for the collective future of our planet. Additionally, we are observing growing rates of mental disorders, such as depression (Whiteford et al., 2013; World Health Organization, 2017). People often feel isolated and lack profound social connections, which can contribute to increased depression and detachment. Despite rapid developments of technology designed to facilitate communication and connection between people, such technology is often (although not always) associated with the opposite effect of increased loneliness and depression (Kraut et al., 1998; Kross et al., 2013).

Thus, experiences that can promote the feeling of connection are very valuable as a step toward a healthier, happier and more caring society. So how can we promote the feeling of connectedness? One inspiration may come from a rare but powerful experience that appears to have this exact effect: it's the experience that astronauts have when they see the Earth from outer space. In his book "The Overview Effect: Space exploration and human," White (1998) analyzed reports of astronauts about this experience, and introduced a term for it—the "Overview Effect" (OE). Micheal Collins, a space pilot, described the importance of the OE:

> *"I think the view from 100,000 miles could be invaluable in getting people together to work out joint solutions, by causing them to realize that the planet we share unites us in a way far more basic and far more important than differences in skin color or religion or economic system."*
>
> (White, 2014, p. 109).

The OE has been shown to have lasting positive effects both on individuals (Ritsher et al., 2005; Suedfeld et al., 2012) and society, as evident from a lot of astronauts joining humanitarian and pro-environmental movements after returning from space (Ihle et al., 2006; Garan, 2015). Nezami (2017) has also explored the OE's potential for psychological therapy and well-being. The findings show that the OE is a profoundly positive experience that can improve an individual's wellness, and promote awareness, pro-social and pro-environmental attitudes in society. If we could provide more people with a similarly profound experience as the astronauts fortunate enough to have experienced it, we may contribute to a healthier and more connected society where taking care of each other and the planet would seem obvious and natural instead of an extra burden. Yet, it is not feasible to send large numbers of people into space with the sole aim of having a profound emotional experience, especially given the high cost, risk, environmental footprint, and physical demands of spaceflight. However, if we better understand what are the key triggers of the OE, we might ultimately be able to simulate this experience on Earth.

This presents a perfect opportunity for Virtual Reality (VR) technology to provide the researchers and designers with a means to study this rare, profound phenomenon, and develop virtual experiences for positive change. The immersive powers of VR allow the immersant to experience being in distant places and be affected by that experience without actually going there (Sanchez-Vives and Slater, 2005). This technological breakthrough is providing us with an opportunity to make the OE more accessible to researchers and the general public. While VR probably won't be able to provide an experience as powerful as the OE experienced by space-travelers, recent research shows that it has the potential of eliciting at least some aspects of the OE (Chirico et al., 2018; Quesnel and Riecke, 2018; Stepanova et al., in press), supporting its potential to inviting at least a smaller degree of the OE in participants on Earth. However, the extent to which VR technology would be able to elicit a transformative experience such as the OE remains an open research question.

In order to build the case for VR being a tool capable of eliciting the OE, this paper first summarizes the relevant research suggesting that VR technology is capable of inducing an experience that could lead to a positive change. Since OE is a rare and complex phenomenon, there is little academic research on this topic. Some important steps toward building an understanding of its effects, components, triggers and progression have been taken (Gallagher et al., 2015; Yaden et al., 2016; Nezami, 2017), however a lot more research needs to be done before we can develop a complete understanding of the phenomenon. The primary focus of this paper is to analyze existing research and reports of the OE, and extract specific design guidelines from the research for the creation of a VR experience that could elicit a transformative experience similar to the OE. Secondly, we are suggesting evaluation methods on whether/to what extent the VR experience was able to induce the OE, and methods for studying this transformative phenomenon elicited in VR.

To achieve these two goals, we are analyzing the space-travelers reports described and summarized in White (2014) and Gallagher et al. (2015) books on the OE, as well as the scientific research investigating this phenomenon (Yaden et al., 2016). We also draw from theories about transformative experience design (Gaggioli, 2016; Kitson et al., 2018; Stepanova et al., 2018). As such, this paper presents a focused psychological review on positive transformative experiences and proposes specific guidelines that can be implemented by VR developers. Therefore we are making applied contributions to the design field by providing research-based guidelines for the design of a positive transformative VR experience of an OE, as well as some contributions to knowledge within the field of psychology in a form of a review of the research and methods related to studying the OE (**Figure 1**).

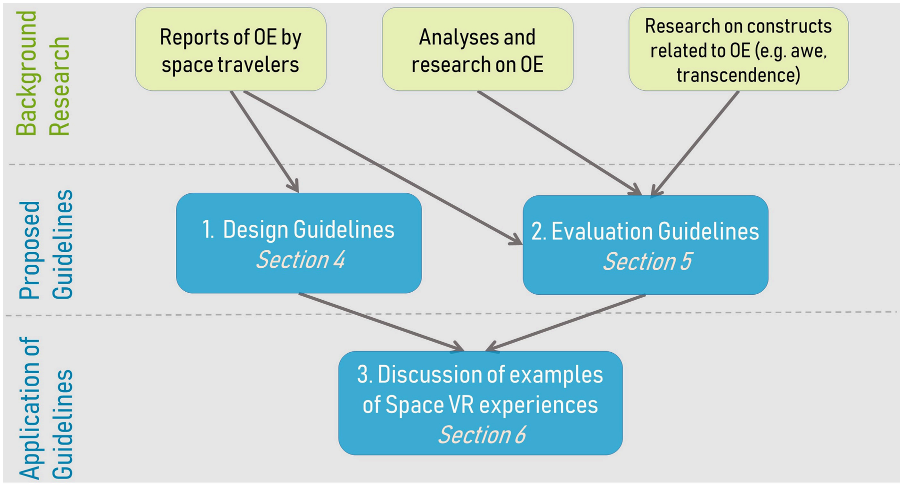

FIGURE 1 | The diagram illustrating the general structure of the current paper and its contributions.

Finally, we discuss some of the existing VR applications inspired by spaceflight experiences, and make a tentative comparison between them and our guidelines. We applied some of the proposed design guidelines ourselves by iteratively designing a prototype of an immersive experience inspired by the OE (Quesnel et al., 2018b), which we evaluated in a study using some of the methods proposed in this paper (Stepanova et al., in press); however, comprehensive discussion of this prototype is outside of the scope of this paper and can be found in the above mentioned publications.

2. VIRTUAL REALITY FOR POSITIVE CHANGE

In recent years, VR technology is rapidly becoming more capable, affordable, and accessible to people, which has prompted the scientific community to explore its potential to be used for research, and for improving human lives.

2.1. The Mechanism of How VR Can Influence Individuals

First, it's important to discuss the theoretical assumptions that lead us to believe that VR technology can have a strong effect on an individual's cognition and behavior. When analyzing the effects of VR, we need to be aware of the assumptions of the psychological theories that this field is grounding itself in.

Our worldview is based on our experiences: through sensory systems, we observe events in the world, and build a cognitive model that can account for these experiences. However, the sensory information we are receiving from the world is often incomplete and in certain cases could be conflicting. To deal with this, our cognitive system relies on multi-sensory integration to register an event. In case of a conflict between multiple sensory inputs, we tend to be biased toward the senses that are stronger, or have higher acuity in humans (Welch and Warren, 1980). For instance, a visual stimulus will usually dominate auditory stimuli as famously observed in the McGurck effect (McGurk and MacDonald, 1976) and ventriloquist illusion (Bonath et al., 2007). Moreover, this effect is prominent even with large conflicts between stimuli that can't be merged into a single event perception: with repeated exposure to conflicting stimuli, our cognitive system adjusts and forms a biased perception. For example, a repeated conflict between visual feedback for a pointing task and spatial memory will bias our spatial perception for all future stimuli by the length of the discrepancy between the received feedback and the memory of the position of the target (Lipinski et al., 2010). Anecdotally, everyone can observe this phenomenon of learning through sensory integration when they step on a non-moving escalator and feel unbalanced and disoriented.

In the context of VR, this effect of multi-sensory integration has been studied in relation to the body ownership illusion (the illusion of experiencing an artificial or virtual limb as a part of one's own body) (Maselli et al., 2016), suggesting that the visual input received through a VR head-mounted display indeed integrates with other sensory inputs in a similar manner to a visual input received from the real world. Another example of multi-sensory integration in VR is vection (self-motion illusion) (Riecke, 2010)—the compelling sensation of self-motion induced by the visual or auditory stimulus akin to the sensation experienced when seeing a train starting to move from a window of one's stationary train. This mechanism of our cognitive system makes immersive VR technology extremely potent to create experiences that in effect, might be indistinguishable from real world experiences. We see this in the example of vection, where the illusion of self-motion can no longer be distinguished from actual self-motion (Brandt et al., 1973). A common critique of the potential of VR technology at present is that it doesn't always have comprehensive sensory information, such as haptic, or olfactory capabilities. However, the combination of the multi-sensory integration and a high reliance on visual channel (for human species) provides VR with enough power to create experiences that can affect the structure of our cognitive model akin to real world events. Even when the VR system doesn't produce a perfectly complete experience for all of our sensory channels (e.g., lack of haptic or vestibular input), our mind will fill in these gaps based on the available input (e.g., visual and auditory).

Embodied cognition is another theory that explains how VR experiences can affect our cognition (Bailey et al., 2016). According to this theory, the mind is not "locked" within one's brain, but rather is heavily based on our body (Wilson, 2002). Consequently, an immersive VR experience that engages one's body in the experience will affect cognition on a stronger and deeper level than a solely visual experience in less immersive media. VR tends to elicit more realistic behaviors and reactions due to a feeling of embodiment and use of multisensory input (Slater, 2011; Wilson and Soranzo, 2015).

2.2. Evidence of Transformative Powers of VR

In recent decades, VR technology has been rapidly developing and many researchers have been investigating VR's psychological and societal application and ability to induce positive change in an immersant. An extensive review of VR applications for mental health provided by Riva et al. (2016) and Freeman et al. (2017) shows the growing potential of the technology. Jeremy Bailenson's lab at Stanford University studies the social application of virtual experiences and how it can induce positive behavioral change; for instance, Rosenberg et al. (2013) study observed increased pro-social behavior in participants who flew like a superman around a virtual city. In a different experiment by Ahn et al. (2014), participants performed more pro-environmental behavior after virtually cutting down a tree. Another study with immersive VR have shown learning gains about climate science in 270 participants who took a 'field trip' under water in VR to observe effects of ocean acidification (Markowitz et al., 2018). The type of a virtual body can have an effect on participant's experience of body-ownership and the behavior (Gorisse et al., 2019). These effects of virtually embodying a body other than one's own have been extensively explored: taller avatars would argue more aggressively (Yee et al., 2009), slimmer avatars have smaller body image (Serino et al., 2016); the cognitive effects are shown in increased connection to nature after embodying a cow (Ahn et al., 2016); stereotyping and biases get reduced when embodying an avatar of outer-group (Maister et al., 2015), stereotyping against elderly is reduced when embodying an older avatar (Yee and Bailenson, 2006), likewise embodying an other-race avatar reduces racial biases (Peck et al., 2013; Banakou et al., 2016; Hasler et al., 2017), while having a virtual out-of-body experience reduces the fear of death (Bourdin et al., 2017). Notably, becoming homeless in VR elicits long lasting (up to 8 weeks) positive attitudes toward homeless and increases the chances that participants will sign a petition for affordable housing (Herrera et al., 2018). This compelling evidence from academic research shows that even a few minutes of a VR experience can impact our behavior and worldview, at least for a short-term (immediately after the VR experience, when the measures are taken, or a few weeks after). Specifically, given the previous studies findings on VR eliciting pro-social and pro-environmentalist behavior, and considering the OE is characterized by similar changes in space travellers, we have reason to believe that a well-designed virtual experience of a spaceflight might eventually be able to induce an OE and lead to the cognitive shift and behavioral change associated with the OE. Additionally, it would be important to assess the larger long-term (over a year) effects of such experiences.

3. A SUMMARY OF THE OVERVIEW EFFECT

The term "Overview Effect" (OE) was first coined by Frank White in his book (White, 1998), where he describes this profound experience reported by astronauts who saw the Earth from outer space. White describes it as a cognitive shift, or shift in awareness that resulted in a new worldview leading to an enhanced sense of responsibility for Earth. This effect is reported by most astronauts and space-travelers, but can be described differently by each individual. However, these descriptions have common characteristics that suggest that it is a singular phenomenon. The descriptions start with the admiration of the overwhelming beauty of the Earth and realization of its fragility leading to the feeling and understanding of interconnectedness of all life, and the concern and responsibility for our home planet and its inhabitants.

3.1. Possible Explanations of the OE

Even though OE is a rare phenomenon making it difficult to build a comprehensive understanding of its causes and progression, there are a number of proposed theories that could explain the mechanism of OE, which we will discuss below.

3.1.1. Dissonance

In his foreword to the third addition of Frank White's book (White, 2014, p. xiii), astronaut Ron Garan describes his own experience of OE:

> *"At its core is the contradiction between the beauty of our planet and the unfortunate realities of life on the surface for many of its inhabitants. "*

Ron Garan, author of the book "The Orbital Perspective" (Garan, 2015) identifies the key mechanism through which OE develops to be the emergence of a dissonance between the observed and perceived reality. Our cognitive system strives to be in an equilibrium, thus it adjusts when a dissonance is introduced and the system has to adjust to reduce it. This mechanism, for example, is illustrated in the theory of cognitive dissonance (Festinger, 1962), which explains the alignment of one's mental model and behavior and consequently can be used to modify the behavior or the mental model. The similar process of accommodation explains how the mental model is adjusting to incorporate a new profound perceptual experience, as was described as one of the key processes of the experience of a transformative emotion awe (Keltner and Haidt, 2003) as well as later, more generally integrated in a transformative experience design framework (Gaggioli, 2016). Thus, encountering this new perspective on Earth from space pushes space-travelers to reassess their existing mental model when attempting to assimilate their experience. If this new experience introduces a dissonance into the cognitive model, the model will have to be adjusted to reduce the dissonance and accommodate the new experience, thus producing a cognitive shift, when

> *"the physical and mental realities are brought into alignment."*
>
> (White, 2014, p. 17)

Edgar Mitchell described it as an "aha" experience:

> *"To me the difference between getting and not getting an "aha" experience of it is whether it shifts your structure a bit. Do you get a sense of freedom, of expansiveness, because you've just experienced something that is different from your previous experiences and beliefs"*
>
> (White, 2014, p. 25)

As such, the VR experience needs to be designed with a goal to induce this dissonance and facilitate accommodation, as discussed in Stepanova et al. (2018) and Gaggioli (2016).

3.1.2. Transcendence and Awe

Yaden et al. (2016) analyzed the interviews of astronauts and identified the emotion of *awe* and *transcendent experiences* as key components of the OE. Interestingly, research demonstrates that the traits and effects of both transcendent experiences and awe-inspiring experiences is strikingly similar to that of the OE. However, both transcendent and awe-inspiring experiences include a large spectrum of phenomena (Yaden et al., 2017a; Chirico and Yaden, 2018), and thus only some research from these domains will be relevant to the OE. What complicates this is the lack of consistency in how the terms "awe" and "transcendent" experiences are used: both terms could be used to describe different phenomena, and other terms can be used to describe the same or a similar phenomenon (e.g., "peak experience," "light experience"). Here, we provide a short summary of a few relevant aspects of the research on transcendent and awe-inspiring experiences that can be used for better understanding and designing for the OE.

Transcendent experiences are describing a profound, usually spiritual experience leading to an expanded awareness and dissolution of one's ego and the feeling of global interconnectedness (Levin and Steele, 2005; Yaden et al., 2017a). Although often transcendent experiences are described through a spiritual interpretation, there is a variety of transcendent experiences that are not interpreted with a spiritual lens. Depending on their background, some astronauts may describe their experience of OE as a religious or spiritual experience, feeling connected to God, while others describe the feeling of unity with the world and our planet without spiritual interpretation. Even though the OE is only described as a spiritual experience by some of the astronauts, the description of the effects of the OE and transcendent experiences are fairly similar, so we can use our knowledge of transcendent experience to help understand the OE. Transcendent experiences are described in multiple different contexts, such as: yoga practice and meditation (Berkovich-Ohana and Glicksohn, 2017), flow states during sport and music practices (Csikszentmihalyi and Csikszentmihalyi, 1992), interaction with nature (Williams and Harvey, 2001; McDonald et al., 2009; Powell et al., 2012; Tsaur et al., 2013), near-death experiences (Greyson and Stevenson, 1980; Kohr, 1983) and several others. Yaden et al. (2017a) presents an overview of the spectrum of different self-transcendent experiences, among which awe, peak experiences and mystical experiences are probably the most relevant to the OE. The main characteristic of transcendent experiences is the feeling of oneness with the universe, nature, the divine or God, depending on how it is interpreted by an individual. Other shared characteristics with the OE are an aesthetic pleasure of the experience, restructure of consciousness to encompass the new experience, transcendence of time and space, and positive changes in attitudes and behavior.

Awe-inspiring experiences could account for some of the effects of the OE. Awe is a psychological construct that is considered part of a "self-transcendent" index of emotions, and is characterized by the perception of something vast, followed by a need to accommodate the experience (Keltner and Haidt, 2003). The "vastness" that elicits awe can be both perceptual and conceptual, and as discussed in Yaden et al. (2016) in the case of the OE, astronauts are likely experiencing both perceptual and conceptual vastness when observing our planet floating in outer space. The planet is perceived to look minuscule when compared to the surrounding universe (perceptual vastness), while simultaneously introducing complex ideas like the fragility of life (conceptual vastness).

Additionally, Yaden et al. (2016) explain that while it may be tempting to describe awe as a perceptual or aesthetic emotional experience in the case of viewing the Earth from space, there are a few unique features that factor into how this awe-inspiring experience promotes a feeling of connectedness. Among those is a sense of "totality":

> *"the tendency is, quite literally, to think in global terms, and that the ability to behold all at once the entire domain in which these human themes reside contributes to the overwhelming sense of awe"*
>
> (Yaden et al., 2016, p. 4).

The authors explain that seeing the Earth from above may disconnect an individual physically from their home but helps form an emotional connection that sees humankind as an entirety, connected to one another. A key characteristic of awe is the "small-self" perception, which is a feeling of one's personal identity receding and reducing in significance when faced with an awe-inspiring experience (Piff et al., 2015; Bai et al., 2017), a feeling akin to humility. This is seen in statements such as

> *"I feel the presence of something greater than myself"*
>
> (Piff et al., 2015, p. 6).

Relating to self-diminishment, an individual may feel the need to assimilate into a social collective, which requires them to set aside their own self-interests and assume the needs of the group (Keltner and Haidt, 2003). In this regard, it should not be surprising that awe is often elicited at collective engagements, like concerts, rallies, and spiritual rituals (Shiota et al., 2004). Compared to other emotions, like pride, that are thought to promote a *desire to belong* to a social collective, individuals who experience awe report a *stronger connection to collectives* (Shiota et al., 2007). Also, awe is different from many positive emotions like joy, which results in self-focused attention (Keltner and Haidt, 2003; Shiota et al., 2007), whereas awe can significantly shift attention away from the self (Stellar et al., 2017). This experience of awe may be why seeing a conceptual wholeness of humanity in the form of the Earth is so profound for astronauts. Profound awe during the OE and its tendency to induce a perception of small-self (self-diminishment) is of great interest when exploring how individuals may feel, and demonstrate connectedness as a result of the experience.

3.2. Negative Psychological Effects of a Spaceflight

The spaceflight experience and the view of Earth from space is not solely described as a positive experience. The "break-off" phenomenon—the feeling of separation from Earth often associated with anxiety has been reported by high altitude jet pilots (Clark and Graybiel, 1957; Sours, 1965), and is sometime mentioned in the context of spaceflight, but is not a well-researched experience for astronauts. Stress and feelings of confinement and isolation (Morphew, 2001) and detachment (Valentine, 2016) can be experienced by astronauts. However, negative effects seem to be predominately associated with the physical stressors and serious dangers of a spaceflight, and thus would be less likely to occur in a VR experience.

4. EXPERIENCE DESIGN GUIDELINES

In this section we extract some common components of the description of the OE by astronauts and propose guidelines for the design of the VR experience for OE, including the setting, pre-VR, and post-VR components of the experience. The proposed design guidelines in this section were identified by a researcher analyzing and coding the interviews with astronauts reported in White (2014) for specific aspects that can be identified as conditions or triggers for the OE experience and transformed into design guidelines. The resulting components and guidelines were reviewed by a second researcher, and partially verified through discussing them with members of the Overview Effect Institute.

For designing a compelling VR experience, many factors need to be considered, including: comfort, presence, agency, immersion, flow, etc. (Stanney and Hale, 2014; Jerald, 2015; Tcha-Tokey et al., 2015; Sherman and Craig, 2018). However, in this paper, we will leave these general factors aside and focus on aspects specific to OE.

4.1. Embodied Experience and Self-Relevance

White discusses that

> *"our 'worldview' as a conceptual framework depends quite literally on our view of the world from a physical place in the universe"*
>
> (White, 2014, p. 1).

Moreover, it doesn't seem to be enough to hear the descriptions or see the images of the perspective; the actual embodied first person experience seems to be crucial for creating this new worldview or mental model. That is, the mere conceptual understanding is not enough to extend one's mental model, when it is not accompanied or elicited by an individual's embodied sensory experience. A number of astronauts were comparing the experience of seeing Earth with the experience of seeing the Grand Canyon:

> *"The first time you look out at the Earth and see that, it's a heart-stopper. I don't care how many pictures you've seen of the Grand Canyon, it's not the same as looking over the side and saying, 'My goodness, it is really that deep'"*
>
> (White, 2014, p. 13).

Similarly, even though the first pictures taken from space after the first space missions left a strong impressions on general public, and, as Joseph Allen put it,

> *"you wouldn't have a gotten a penny for EPA* [Environmental Protection Agency] *before those pictures from orbit"*
>
> (White, 2014, p. 206),

they didn't seem to have been able to induce the OE in the general public. Sandy Magnus, an engineer and astronaut, explains the value of the first person sensory experience:

> *"There is a difference between intellectual knowledge and experience-based knowledge. You know it is hot outside when you hear it is 110 degrees, but you don't really know it's hot outside until you walk out the door and you get blasted with a wall of heat hitting you in the face. It is not an intellectual fact anymore; it is experience that you have connected with that piece of data."*
>
> (White 2014, p. 45)

Even though intellectually astronauts knew, for instance, that there is no dividing boundaries on Earth between countries as we normally see on the globe and maps, seeing boundary elimination for themselves was still surprising, and that experience "provided a crystal clarity," as reported by Edward Gibson (White, 2014, p. 40). Thus, for a VR experience of the OE it is important to go beyond merely presenting the visual perspective of Earth viewed from outer space, but strive to provide the immersant with an embodied first-person experience of them traveling through space. What is crucial for achieving this is designing for the immersant's sense of self-relevance and agency in the environment, which was shown to play large role in virtual body ownership (Ma and Hommel, 2015) and could sometimes be used to explain the sense of 'presence' (Herrera et al., 2006). Presence in a virtual environment has multiple components: place illusion (the feeling of 'being there') needs to be complemented by plausibility illusions (the feeling that events in the virtual environment are real) in order to effect the immersant's behavior (Slater, 2009, 2011). Thus, the virtual environment should facilitate the plausibility illusion and appear responsive to the actions of the immersant. Adding subtle cues on multiple sensory channels could make this first-person embodied sensory experience even more likely to occur. Recent developments of multisensory technologies for VR could aid in supporting embodied experiences: olfactory devices (Morie et al., 2009; Risso et al., 2018), temperature (Ranasinghe et al., 2017), haptic (Pittera et al., 2017; Whitmire et al., 2018). For example, when the sun appears virtually, a heater could provide the experience of warmth coming from the perceived sunlight.

4.2. Privacy and Social Space

> *"The experience is relatively private while the astronaut is in space but becomes highly public on return"*
>
> (White, 2014, p. 12).

The fact that astronauts are being interviewed upon arrival might in fact make them process the experience in a new way. In regards to his experience of the OE, Alan Bean describes how the experience was only contemplated and accommodated upon the media's request for an interview:

> *"You think about it only when people ask you. You were really refining other skills"*
>
> (White, 2014, p. 15).

While the spaceflight experience can often be very social, as usually astronauts work as a crew, the moment of the OE experience is still often described as private. It might be an interesting question to explore whether OE can be experienced and intensified as a virtual shared experience, since sharing an experience with another person can lead to a stronger experience (Boothby et al., 2014). However, given the descriptions of OE we would recommend to start with designing for a virtual OE as a private experience, since it might be important for creating a safe private space where a strong emotional experience can occur. Once we can achieve some level of OE, we can investigate how sharing this experience may amplify it.

While the privacy might have initially allowed for a profound experience to occur in space, the interviews for media upon return might have played a role in accommodating the experience for astronauts. Both stages are likely important for the full processing of the OE, thus the designers of the VR experience will have to face a challenge of creating a space for a very private experience of Earthgazing, while also providing a social space to encourage discussion and processing of the experience after the person exits VR. We propose to introduce a private space for the main VR experience followed by a public space (for accommodation of the experience through sharing and discussion) as a methodological approach to implement this for VR experiences, as it attempts to replicate the real-life accommodation astronauts appear to benefit from.

4.3. Visual Style

4.3.1. Vastness

As discussed above, awe is identified as a key component of OE. Vastness is believed to be the key property of the stimulus capable of eliciting awe (Keltner and Haidt, 2003). Chirico et al. (2016) proposed to use VR to create awe-inspiring experiences, as it is capable of producing vast stimuli, and can induce presence and enhance the ecological validity of the experience. The virtual environment should be designed to highlight the vastness of space and possibly other environments that may be included in the virtual journey to build up the sense of awe. Klatzky et al. (2017) used photographs to analyze which properties of a stimuli would be associated with perception of vastness and found that openness and ruggedness were the predictive parameters, with highly open or moderately open, but rugged images being perceived as vast. However, designing vast stimulus in VR is not as straightforward as it may seem. Besides the technical limitations coming from the current VR headsets still having limited field of view and low resolution, leading to commonly observed distance underestimation in VR (Willemsen et al., 2009), the strategy for design of awe-inspiring vast stimuli is not simple. Rauhoeft et al. (2015) explored the specific properties of a an immersive virtual stimuli that would lead to perception of vastness. They used virtual landscapes that included fields, mountains and forests, and found that even though VR stimuli were successfully able to elicit the perception of vastness, the survey data revealed an open field to lead to the highest reported perception of vastness. This was surprising to the authors, and might be attributed to the definition of 'vastness' used:

> *"A space is vast if it seems to extend without limits away from you, making you feel like a small element within the space"*
>
> (Rauhoeft et al., 2015, p. 52),

thus participants might have conceptualized 'vastness' as a literally open space, rather than being in presence of something greater than themselves. In order to design the vast stimuli that can contribute to the OE, developers need to strive for a combination of perceptually and conceptually vast virtual stimuli that can induce the feeling of presence of something greater than oneself.

4.3.2. Suspending Disbelief Through Aesthetics

Everyone who has seen the Earth from outer space has been deeply impressed by its beauty. The image seems indescribable, like nothing else experienced on Earth. Marc Garneau called his experience a

> *"dreamlike experience, because space is a very magical place to be"*
>
> (White, 2014, p. 218).

These descriptions of the marvelous view of the Earth suggest that the VR experience could be designed in a style of magical realism in order to create a similar dreamlike visual experience. We argue that opposed to hyper-real visual style, magical realism may be more effective at facilitating the suspension of disbelief in the immersant and engaging them emotionally. This would also help to bypass the imperfections of the technology at representing a realistic environment. To illustrate this point we rely on approaches used in art to engage participants and elicit an affective response.

Magical realism is an aesthetic style of art that incorporates a realistic portrayal of our world, with magical or mystical elements fantastical or ambiguous in concept. This style supports positive subjective appraisals of the visual scene while simultaneously experiencing something novel that their imagination can interact with (Faris, 2004). Ambiguity can make interactive systems and artwork more engaging (Gaver et al., 2003) and lead to stronger connection and meaning making between the participant and the installation through the principle of "Beholder's share" (Kandel, 2012), where participant's own experience contributes to the interpretation of an art filling up the gaps left by the ambiguous image. Visuals and art that is too abstract and difficult to understand, or on the flip side, too literal with concrete meaning, tend to elicit less positive emotions (Silvia, 2012). With the example of artist Char Davies 1995 VR installation "Osmose" (1996), we experience abstract visuals that do not directly illustrate, but rather suggest meaning that is open to interpretation in the mind of the immersant, promoting an imaginative and self-relevant experience, which is important for eliciting profound emotions. This might also be related to the 'imaginative immersion' component of the experience (Ermi and Mäyrä, 2005; Vidyarthi et al., 2012).

4.3.3. Clarity and Contrast

The image that astronauts see is very clear and vibrant, as Nicole Stott described it:

> *"dynamic, crystal-clear view that just glows"*
>
> (White, 2014, p. 18).

Often astronauts describe the image they have seen as being in high resolution full of detail. For example the first man in space, Yuri Gagarin says:

> *"The mountain ridges, the great rivers, massive forests, ocean shorelines stood out sharply. I could see both clouds and their faint shadows on the surface of the Earth"*
>
> (White, 2014, p. 27).

The first time the intense clarity of the image of Earth was described, it was interpreted as a hallucination, but later on, it was suggested that vision may indeed become sharper when leaving the atmosphere. This intense clarity my also be an important contributer to the OE (White, 2014, p. 29). This enhanced clarity might be difficult to achieve with the current resolution of VR headsets. However, the perceived clarity of Earth can be achieved through creating a contrast between the images appearing right before the view of Earth is revealed and the image of the Earth. For example, the VR journey could take the immersant through somewhat blurry undefined clouds or asteroids and then reveal a sharp and bright Earth full of vibrant details, and as such, by contrast, appearing impressively clear.

Similarly, the contrast between the Earth and the surrounding hostile space may also contribute to the perception of Earth as a beautiful and fragile living organism. Schweickart reports:

> *"The contrast between that bright blue and white Christmas tree ornament and the black sky, that infinite universe, really comes through"*
>
> (White, 2014, p. 36).

Through defining the contrast between the model of the Earth in VR and its surroundings we can highlight the qualities of our planet admired by astronauts during Earthgazing.

4.3.4. Perception of Earth as a Living Organism

Astronauts highlight how the Earth appears to be a living organism. They describe that it is always changing, you always see

> *"different sides of her face"*

and

> *"different times of the day "*
>
> (White, 2014, p. 1).

We can speculate that in some way the OE is a form of empathy developed toward Earth as a living organism that needs care and protection from its inhabitants. Thus, it is important to put a lot of attention to the development of the Earth model in VR, and ensure that it appears alive and dynamic. In particular, astronauts often describe the ever-changing and moving clouds and distinguishable layers of the atmosphere. Multiple layers of atmosphere and lively clouds are probably the simplest way of creating the perception of the Earth being a living organism.

4.4. Progression of the Experience/Storyline

4.4.1. Earthgazing Moment

The climax of the VR experience would be the Earthgazing moment—when the Earth is revealed and the immersant can admire its beauty. Silvia (2012) explains that a violation of expectations and surprise with an aesthetic experience leads to an increase in curiousity and positive emotion with the subject. In the case of the Earthgazing moment in space, many astronauts are not prepared for the incredible vividness and totality of the sight before them (Yaden et al., 2016). This can be attempted in a VR experience with the sudden appearance of the Earth as an incredibly detailed, three-dimensional, and visually immense object. To get the immersant ready and receptive to the introspective moment of admiring the vast beauty of the Earth, the VR experience should take them through a journey and narrative arc building up to that moment.

4.4.2. Initial Fear

Due to the nature of the spaceflight, the profound OE always follows the frightening experience of being aggressively rocketed into space through the burning of combustive fuel and a volatile atmosphere. As a consequence, each astronaut first has to come to terms with the possibility of death before reaching the point of relief and admiration of the beauty of the Earth.

> *"When a launch is successful, it is a kind of miracle and blessing that one continues to live, especially in having been transported to a new and extraordinary environment"*
>
> (White, 2014, p. 13).

So in some sense the OE could be built on near-death experiences, that are also often found to be transformative (Greyson and Stevenson, 1980). Joseph Allen describes the emotional arc of the journey into space:

> *"the anxious and interminable waiting, the stunning moment of ignition, the thrill of acceleration and the silent surprise of sloe-back space"*
>
> (White, 2014, p. 44).

By designing for a moment of fear and anxious anticipation in the beginning of the VR experience prior to the Earthgazing moment, we may model the emotional arc of the spaceflight journey, and help the immersant to achieve the moment of relief and peace. Since most of the potential participants of the VR experience wouldn't be familiar with an experience of being in a rocket, modeling the take-off might not be the best way of inducing a subtle amount of fear. In fact, when Gallagher et al. (2015) designed a space shuttle countdown and rocket takeoff, participants expected an experience akin to an amusement park ride, and their experiences changed to fit that expectation. A more effective method would be to incorporate into the journey an experience of a familiar event that can induce natural fear, such as a sensation of falling, or of a volatile natural phenomenon.

We want to highlight that by no means we are suggesting to design a virtual near-death experience. The design for an initial fear response should be fairly subtle, as it's important to avoid causing any traumatic virtual experiences or leading to immersants losing trust in the system, and may become disengaged to protect themselves from potential negative emotional experiences. The experience of fear should subsequently be followed by an experience of relief or resolution to ease the initial fear.

4.4.3. Weightlessness

Weightlessness is a significant part of astronauts' experience, that could possibly account for some part of the OE. We can't know how critical the experience of weightlessness is for the experience of OE, as OE is only described in the context of a spaceflight with zero gravity. However, it is difficult to achieve on Earth without expensive equipment. Yet, the designers of a VR experience can *trick* the immersant to experience the sensation of floating, by intelligently creating a transition from one state in the environment to another by changing the soundscape and navigational controls. Let's take a look at how Scott Carprenter described his experiences of silence:

> *"The first thing that impressed me when I got into orbit was the absolute silence. One reason for this, I suppose, was that the noisy booster had just separated and fallen away... But it was also a result, I think, of the sensation of floating"*
>
> (White, 2014, p. 19).

We can speculate that this connection between the sensation of floating and striking silence works in both directions and can be used in design of the VR experience to create experiences akin to floating.

Even though there are number of waterproof VR headsets being developed (e.g., underwater headset for virtual scuba diving (Nagata et al., 2017) that would allow submersion in water during a virtual experience to achieve some sense of weightlessness, this is probably not a very promising direction, as it will significantly complicate the set-up of the experience and increase overall cost and complexity. Thus we propose to focus on designing for the experience of floating without submersing the immersants into water. Moreover, Gallagher et al. (2015) found in descriptions of astronauts' experiences of awe that seeing the Earth from space was more connected to the sight of the Earth, and seemingly not as much to weightlessness. Without being able to replicate a feeling of weightlessness and test its impact in VR, we are unable to empirically determine the strength of its connection to the OE. At best, we should aim to experiment with the sensation of floating felt in meditative or dream-states and assess its role as a contributor for the virtual experience of OE. Experimenting with inducing floating sensation, may allow us to investigate its importance for OE and guide future design.

4.4.4. Personal Connection

Another common theme appearing in the records of Earthgazing, is that at first, before the observer gains a sense of interconnectedness with the whole planet, they start from establishing a mental connection with something familiar, as described by Russel Schweickart:

> *"You finally come up across the coast of California, and you look for those friendly things, Los Angeles and Phoenix and on across to El Paso. And there's Houston, there's home... and you look and sure enough there's the Astrodome—and you identify with that, it's an attachment"*
>
> (White, 2014, p. 9).

When designing a VR experience, the story line should start from establishing a familiar connection for an immersant first, before extrapolating that feeling to the full planet. This connection should not only be established with a location on the globe when Earthgazing, but even earlier, at the initial part of the experience, inviting the immersant to a virtual environment representing a familiar setting, that the immersant can easily associate with and feel *at home*. In our previous studies, we found that the majority of confirmed awe-inspiring moments occurred when immersants had self-relevance, such as when selecting to visit a familiar location that held personal meaning (Quesnel and Riecke, 2018). It is possible that this effect carries into the experience of the OE.

4.4.5. Earthgazing Perspective

Since there are multiple types of space missions, the Earthgazing could happen from three different perspectives: from inside a spaceship, from a spacewalk, and from the surface of the moon. Thus, it poses a design question for the VR experience—from which perspective should Earthgazing happen in VR to have the highest chances of achieving OE? The first scenario of Earthgazing from inside the spaceship has an advantage for a VR simulation, as having the cockpit in the view and serving as a foreground object would increase vection (the illusion of self-motion) (Howard and Howard, 1994). However, the reports of astronauts suggest that a spacewalk environment might be stronger in the ability to induce OE. Jack Lousma describes:

> *"It's like a whole new world out there! Your perspective changes. When you're inside looking out the window, the Earth's impressive, but it's like being inside a train; you can't get your head around the flat plane of glass. But if you stand outdoors, it's like being on the front end of a locomotive as it's going down the track!"*
>
> (White, 2014, p. 40)

The third scenario of Earthgazing from the moon has been experienced only by a few astronauts, and they describe it as a different and stronger experience, as if the magnitude of the OE is proportional to the distances from the Earth. Michael Collins said

> *"There is definitely a different feeling. At 100 miles up, you are just skimming the surface, and you don't get a feeling for the Earth as a whole"*
>
> (White, 2014, p. 183)

Since VR allows us for more freedom in the design of the progression of the experience, we can incorporate any combination of these perspectives, possibly starting from a more familiar orbit perspective and seeing the interconnectedness of all countries, and then extrapolating the effect further while moving away from the Earth and developing a stronger awareness of how the Earth is one living organism. The opposite direction of approaching the Earth from distance can create an alternative narrative, where the immersant first will be introduced to the general idea of the fragility and unity of Earth, and then develop a more detailed and elaborated appreciation of it when Earthgazing from a greater orbital distance and noticing how a lot of the geographical locations are actually closer and more interdependent than we got used to think based on 2D political maps. The choice between these two progressions will have to be determined experimentally through user testing.

4.4.6. Priming and Inducing the Desired State

To implicitly guide the immersant to the desired state, we can include an altered biofeedback that would aim to guide the immersant into a calmer and more introspective state. This approach was found to be effective when participants would hear a modified sound of their footsteps, that would imply that they are heavier or lighter than they actually are, resulting in a corresponding altered perception of their body-weight and an increased motivation to exercise measured through physical properties of their walking activity (Tajadura-Jiménez et al., 2015). In a different study, an altered heart rate as biofeedback in men affected judgment of attractiveness of females in pictures (Valins, 1966). Since outer space is a very quiet environment, the only sounds heard by astronauts (other than from inside the spaceship) are the sounds produced by their own body; as such, we can include a believable soundscape that integrates an altered breathing and/or heartbeat feedback designed to calm or excite the immersant.

4.5. Summary of Design Guidelines

The design of the experience should focus on facilitating a journey for the immersant that gradually prepares them for the climax of the experience and assist with the accommodation and processing of it. The VR creators should think beyond the VR component of the experience and thoughtfully design the pre- and post-VR environments as an essential part of the journey. We summarize the proposed guidelines and present a possible use scenario in **Figure 2**, that a VR developers team could take as a starting point for designing a user journey. The designers would have to work around the technical limitations of the technology, and utilize the scientific knowledge of human perceptual and attentional processes along with artistic intuitions to "trick" immersant's perception and produce a compelling and impactful experience.

5. EVALUATION METHODS DESIGN

One of the challenges that arises when we strive to design a VR experience that could give immersant a glimpse of an OE, is identifying methods that will allow us to determine whether (or to what degree) the created experience was successful in evoking an experience similar to OE. In this section we will analyze the described effects of OE and propose a number of methods that can be used to asses these aspects. This section relies on the aspects of OE and spaceflight identified by Frank White and describes methods that have been used in academic research to measures the constructs related to the components of OE. In addition to OE specific methods, designers of the virtual experience should consider using VR-experience questionnaires to evaluate the general effectiveness of the experience in VR (including presence, immersion, etc.) to ensure that the designed experience is functional and compelling. Some of these questionnaires are summarized in Tcha-Tokey et al. (2016). However for this article, we will focus specifically on the methods that could be used for assessing the aspects of OE.

Since OE is a very complex phenomenon, we propose to design a comprehensive system of multiple evaluation methods combining introspective, physiological, implicit attitudes and behavioral measures. Our transformative experiences framework outlines how a transformative experience such as OE can be assessed at different stages of the experience and what role VR can play in that process (Stepanova et al., 2018). Since our goal is to capture an individual's experience, introspective measures is often our best available option for assessing personal experiences. The researchers aiming to study OE should make use of psychometric measures, such as the awe experience scale (AWE-S) (Yaden et al., 2018), to evaluate the effectiveness of a VR experience at eliciting awe responses, which is a component of the OE. However, in order to be able to connect the individual experience of awe and the OE to the design of the VR experience, we need to use additional methods that can capture the progression of the individual experience through time. To achieve that, we suggest to conduct cued-recall debriefing (Bentley et al., 2005) after the VR experience with the participants, in combination with introspective open-ended interviews to look for constructs similar to the ones that astronauts describe in their interviews and the corresponding design elements of the virtual experience that might have triggered these experiences. Cued-recall debriefing is a situated recall method that captures on video the first-person perspective of the participant's experience in VR, and is often successful in re-immersion that results in reporting of affective states. Phenomenological interviews complement cued-recall debriefing: while cued-recall may provide insight into the moment-to-moment thoughts and feelings during system use, interviews provide more information on the participant's history and overall experience. Below we will outline the constructs to structure the analyses of the interviews as well as non-introspective methods of assessing some of them. We have summarized the proposed relationship between experiential components and correlates, cognitive constructs and outcomes of the OE in the **Figure 3**. The specific research tools proposed in this section are summarized in **Table 1** and organized based on each tool and when to implement it.

When approaching the task of measuring OE, first of all, we need to differentiate between the spaceflight experience and the OE. Even though the OE as a phenomenon in its current description is directly related to spaceflights (or in some cases to jet or plane flights), there is no clear understanding of what experiential aspects of a spaceflight might be related to, or necessary for the experience of OE. Thus, we will analyze these aspects separately.

5.1. Experiential Components of a Spaceflight Experience

Frank White identified four main aspects of the spaceflight experience that we will discuss below: changed perception of time, changed perception of space, silence, and weightlessness (White, 2014, Chapter 3).

5.1.1. Changed Perception of Space

There seem to be two aspects of the changed perception of space: (1) a relative perception of one's individual position in space and (2) an acquired perception of scale and position of the planet in the universe and in relation to other terrestrial bodies, as well as the distances between different locations on Earth. Earthgazing astronauts often report how they notice how different places on Earth seem to be connected and how there are

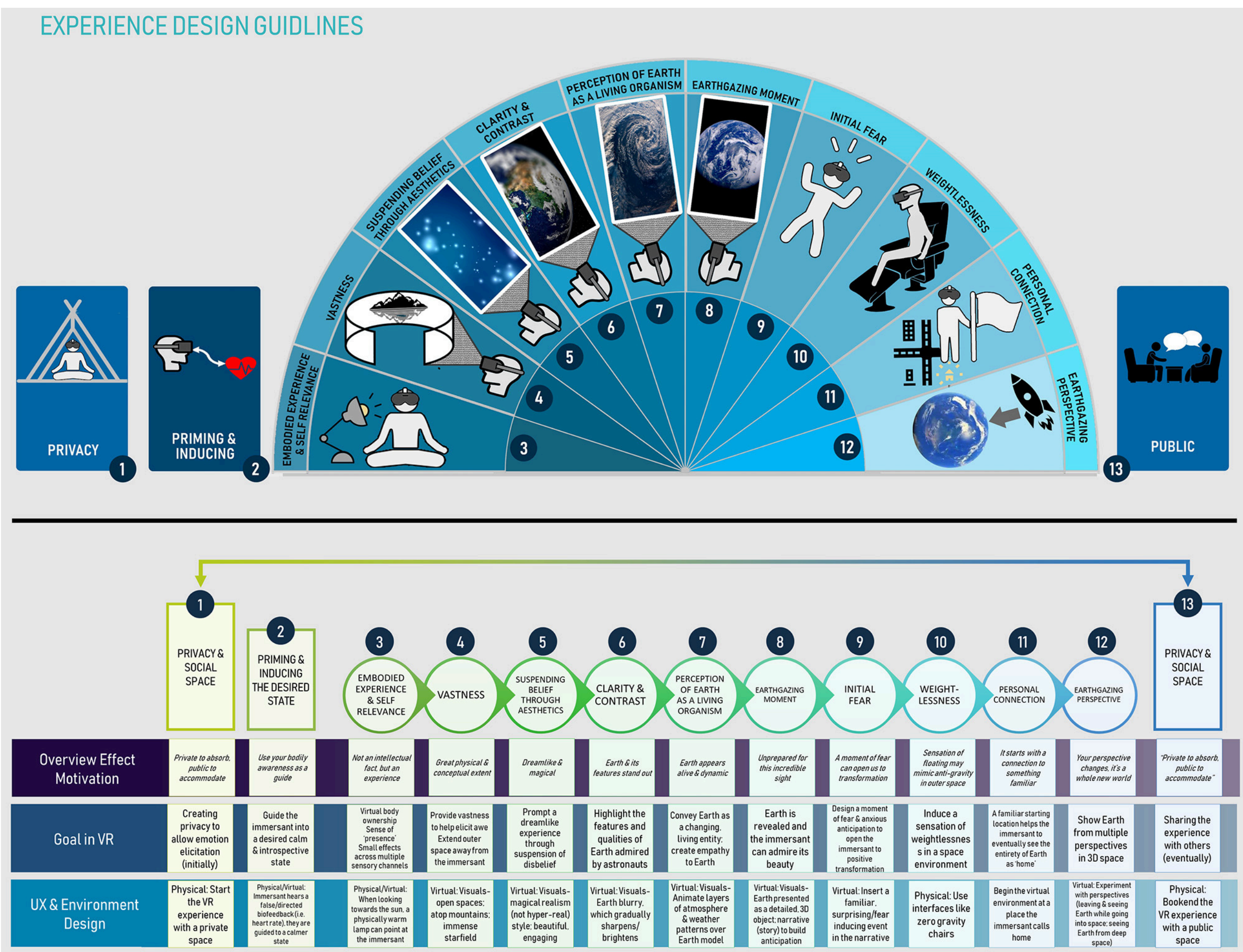

FIGURE 2 | Experience Design Guidelines summarized in a proposed use scenario. Images courtesy of NASA's public domain image library.

no boundaries between countries; we are all neighbors. This effect can be observed in interviews, but also measured quantitatively through implicit measures. Such evaluation methods can be borrowed from studies on the effect of cognitive maps on distance estimation (where a cluttered map would result in longer distance estimation) (Thorndyke, 1981). To adapt this method for our goal in VR, we will ask participants to estimate the distances between different geographical locations, especially between and within a country, before and after the VR experience. We expect the estimation of the distances to shrink after the VR experience if the immersant experienced the OE.

John Herrington described his altered egocentric perception of direction as follows:

> *"I was looking at my hands as I was moving along, looking up relative to the space station, and then instantaneously, I was looking down at the space station, and I hadn't moved. My mind was suddenly telling me I was looking down rather than up"*
>
> (White, 2014, p. 20).

This disorientation can be measured through interviews and cueing the estimated orientation of the participant. It can be induced through interaction of navigation interface and body position and visuals slowly drifting off from each other, like in redirected walking (Zhang et al., 2015).

5.1.2. Changed Perception of Time

Most straightforwardly, time perception is measured through asking participants to report a duration of certain stimuli. Thus, in our case we are proposing to query the participant after the VR experience to estimate how long they have spent in VR. However, there will be two possible explanations for an overestimation of time: the experience was found significant or emotional (Droit-Volet and Meck, 2007), or that it was uninteresting or unpleasant and time "dragged on" (Sackett et al., 2010). These will have to be disambiguated through interview data in order to be understood. Scott Carpenter stated:

> *"I felt a curious compression of time, as if the speed at which I traveled had some effect on the length of the moments I spent there and packed them too tightly on top of one another"*
>
> (White, 2014, p. 178).

Interestingly, the research on the phenomenology of awe suggests that as an emotion, awe often expands individual's perception of available time (Rudd et al., 2012). Rudd's et al. study implements a number of measures of perceived time availability that we can utilize to understand perception of time in VR: (1) The perceived-time-availability index is a short Likert-scale embedded in a longer survey; (2) willingness to commit time to pro-social causes (e.g., volunteering) can be compared to willingness to commit money to the same pro-social causes (e.g., charity); (3) choosing

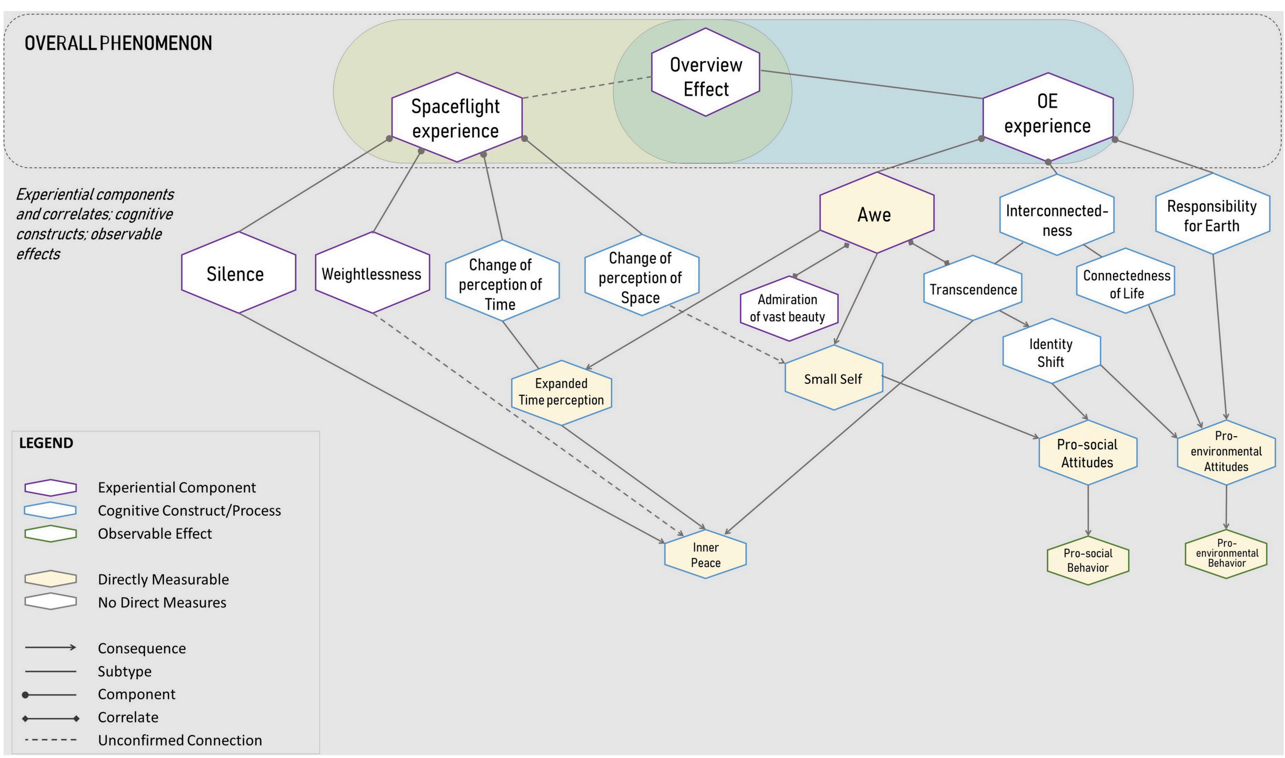

FIGURE 3 | Schematic illustration of the cognitive constructs and outcomes of the Overview Effect. The OE is traditionally described in the context of an actual spaceflight, but the experience of the OE, in principle, might be a phenomenon that could be experienced in a different context as well. Therefor some aspects of a spaceflight might be crucial for the OE experience to occur, while others might be irrelevant.

TABLE 1 | Summary of proposed evaluation methods.

When	Research tool	Analyses	Immediate construct	Who used the tool
Post	Cued-Recall Debrief	Ind. position in space	Changed space perception	n/a
Post	Phenomenological interview	Environmental systems	Global interconnectedness	n/a
		No country boarders		n/a
		Self-identifying	Shift in identity	n/a
		How long was the experience?	Changed time perception	n/a
		Textual analyses	Concepts similar to astronauts	Gallagher et al., 2015
		Linguistic analyses "I" vs. "Us"	Identity shift	Yaden et al., 2017b
Post	AWE-S survey	Awe Factor analyses	Awe	Yaden et al., 2018
Post	Inclusion of Other in Self	Self-other overlap	Connectedness with Others	Aron et al., 1992
Prior & post	Geographical dist. estimation	Shrinkage of dist. est.	Space perception	Thorndyke, 1981
			Global interconnectedness	
Post	Choose prize for a draw	Experiential vs. Material	Changed time perception/awe	Rudd et al., 2012
	Leave contacts for organization	Charity vs. volunteer		
Prior & post	Draw yourself	Relative size	Small self	Bai et al., 2017
During	Wearable camera	Goose bumps	Awe	Quesnel and Riecke, 2017
During	Heart rate sensor	Pattern	Awe	Grewe et al., 2009
			Inner Peace	Peng et al., 2004
During	Skin conductance sensor	Spikes	Awe	Chirico et al., 2017
During	Breathing sensor/mic	Pattern	Inner Peace	Vidyarthi et al., 2012
			Awe	Shiota et al., 2011
Prior & post	Observation	Pattern of movement	Inner Peace	Not found
During	Eye- or head-tracking	attention, dwell time	Admiration of beauty	alike Massaro et al., 2012
		gaze pattern	Inner Peace	Not found
Prior & post	IAT racial bias	Other race and self	Identity shift	Peck et al., 2013
Prior & prost	IAT nature in self	Nature and self	Pro-enviromental attitudes	Schultz et al., 2004
Post	Offer water	Reusable vs. Disposable cup	Pro-enviomental behavior	alike Ahn et al., 2014
	Ask to throw out garbage	Recycling		
Post	"Accidentally" drop pens	RT, and N of picked up pens	Pro-social behavior	Rosenberg et al., 2013

between experiential goods or material goods (e.g., concert tickets over a wrist watch). In Rudd et al. (2012) the measures were all done as a set of hypothetical survey questions, but we propose to modify this method to be presented as real choices to participants through deception: for instance, participants can be informed that they could enter a draw as a reward for their participation and offered to specify a preferred prize out of available material and experiential options; or they can be offered to leave their contact details for either a volunteer organization or a charity.

5.1.3. Silence

The silence experienced by astronauts is hard to achieve on Earth. Earth-bound experiences that would have a similar experiential component of pure silence could be scuba diving, caving (spelunking), and possibly sensory deprivation tanks. If the design of the VR experience strives to induce the experience of silence for the immersant, they can look into the role of silence and its psychological outcomes during caving and scuba-diving experiences to determine the appropriate measures for this experiential component.

5.1.4. Weightlessness

The phenomenology of experience of weightlessness hasn't been receiving a lot of scientific attention, due to the difficulty of achieving the experience of weightlessness on Earth. The closest studied experiences are the ones of flotation tanks. The sensory deprivation of flotation tanks submerse participants in a highly salted water, thus achieving a state close to weightlessness. A meta-analyses of 27 studies of flotation therapy supports its effectiveness for stress-management and well-being (Van Dierendonck and Te Nijenhuis, 2005). Besides most commonly reported relaxation, other effects such as altered state of consciousness, altered time-perception, and out-of-body experiences are also reported by individuals using sensory deprivation tanks (Kjellgren et al., 2008). Since the body of research on psychological effects of weightlessness is fairly limited and its main effects intersect with other effects of OE, for the virtual OE experience we propose to add "weightlessness" as a category for analyses of the interviews of participants, but not add any separate directed measures.

5.2. Experiential Components and Outcomes of Overview Effect

Frank White identifies three main components of the OE:

> *"feeling of awe for the planet, a profound understanding of interconnectedness of all life and a renewed sense of responsibility for care of the environment"*
>
> (White, 2014, p. 2).

We discuss below how different traits of the experience could be evaluated through different methods and at various stages of processing.

5.2.1. Emotional Correlates

5.2.1.1. Awe

Awe has been described as one of the key aspects of the OE. Although emotion research into awe is still in the early stages, there has been progress in determining both constructs and psychophysiological correlates to an experience of awe. Awe is a subjective experience that many individuals find difficult to put into words, which highlights its complexity. However, the body gives some clues as to when awe might occur. Among those clues is the sensation of "chills" (also seen in literature as "shivers," "frisson," "tingles"), and often their concurrence with visual piloerection, or commonly known as goose bumps ("goose flesh") (Keltner and Haidt, 2003; Grewe et al., 2009; Benedek and Kaernbach, 2011; Nusbaum and Silvia, 2011; Stellar et al., 2017). Among the studies by Benedek and Kaernbach (2011), Quesnel and Riecke (2017), Sumpf et al. (2015), and Wassiliwizky et al. (2017), there is overall a 40% rate of goose bump elicitation in participants who watched moving/awe-inspiring videos or VR as stimuli. The consistency of this rate means goose bumps (with concurring chills or not) may be experienced by some people but not others, or that lab-induced stimuli may elicit less-intense awe experiences, theorized by Benedek and Kaernbach (2011), Silvia (2012), and Silvia et al. (2015). Other physiological measures may correlate with goose bump presence, such as heart rate variability (Grewe et al., 2009), and skin conductance (Chirico et al., 2017). The measures can be recorded along with goose bumps, and deep learning can be used to look for correlations and possible patterns of interest among multiple biosignals at once (Quesnel et al., 2018a). Additionally, observational measures of facial expression such as widen eyes and jaw drop, can be complimentary (Shiota et al., 2003), however if the experience is delivered through an HMD, access to visible facial expressions might be limited, as well as effected by the weight and fit of the headset.

Aside from psychophysiological measures, there are several studies that have analyzed awe-inspiring experiences into themes. Among these is the work of Gallagher et al. (2015), who implemented a hermeneutics exploration of syntax and language used by astronauts during the experience of awe as a part of OE. This textual analysis resulted in the creation of 34 consensus categories of awe, wonder, curiosity, and humility described in the texts by the astronauts. Such categories include: "Captured by view/drawn to phenomenon," and "Scale effects (feelings of the vastness of the universe or one's own smallness/insignificance)." In their study, the phenomenological interviews by participants who experienced a space simulation were compared to these categories and descriptions of the OE experience by astronauts, showing a significant overlap of the descriptions of awe. As demonstrated by Gallagher et al. (2015), the use of such categories of the OE and its features of awe and wonder are highly relevant for analyzing the immersant's experience in a VR simulated space environment.

In a recent article Yaden et al. (2018) described the development of a psychometric awe experience scale (AWE-S), that assesses six factors of an awe experience: time perception, self-loss, connectedness, vastness, physiological aspects and need for accommodation. They present a 30 item likert-scale questionnaire assessing these factors, that can be used to provide a quick quantifiable way of assessing the strength of the overall awe experience and each of the six factors following the VR experience.

Another interesting trait of awe is a "small-self" or "diminished self" (Piff et al., 2015; Bai et al., 2017)—which is associated with the trait of humility, an emotion strongly correlated to awe (Stellar et al., 2018). When experiencing awe, one's focus shifts away from themselves, toward a greater collective. The cognitive construct of "small-self" can be covertly measured through asking participants to create a visual representation of themselves in the world, specifically asking them to draw a picture of themselves in a simple environment and then the experimenter can measure the relative size one's self-representation in the relation to other objects in the environment (Bai et al., 2017).

5.2.1.2. Meditative state and inner peace

Edward Gibson described his experience of Earthgazing:

> *"You can see that a lot of things you worry about don't make much difference in an overall sense. The result is that you enjoy the life that is before you; you don't sweat so much about the next milestone... It allows you to have inner peace"*
>
> (White, 2014, p. 41).

This type of description of the OE suggests that the state achieved through experiencing the OE might be in effect similar to the states achieved through transcendent meditation. The inner peace in the moment can be measured through physiological correlates of meditation and relaxation, such as brainwaves (Cahn and Polich, 2013), heart rate variability, and breathing patterns (Peng et al., 2004; Cysarz and Büssing, 2005; Peressutti et al., 2010). We also propose that inner peace can be additionally measured through observations of participants' behavior before and after the experience, and coding the hectic, rushed vs. peaceful, relaxed movement patterns. However, this measure will need to be refined and validated.

5.2.2. Attentional Measures

VR provides the researchers with an easy access to the low resolution gaze data of the participants: even without an eye-tracker, the VR headset itself provides the head movement and position data that gives an estimate of where and how the immersant is looking. Scott Carpenter talked about his experience:

> *"I found it difficult to tear my eyes away <...>Everything is so new and awe-inspiring that is difficult to concentrate for very long on any one thing"*
>
> (White, 2014, p. 29).

By recording the head position data, we can analyze head movements and dwelling in a similar way as attention being measured with eye-trackers. If available to the researchers, then they can use HMDs with built in eye-tracking system for even more precise measure. While normally complicated to acquire in a dynamic environment, attention data comes almost "for free" with the VR technology, however the data can be challenging to interpret as there is no singular interpretation of dwell time, thus additional information will be required for disambiguation of the results, which can come from the interviews. The smoothness of the gaze pattern could also indicate the calmness of the state of the immersant.

5.2.3. Interconnectedness

The feeling of interconnectedness has two components, which can occur together or as independent experiences: the realization of the interconnectedness of life on Earth, and transcendence of one self with the universe.

5.2.3.1. Interconnectedness of life

Don Lind, as many of other astronauts, described:

> *"You can't see the boundaries over which we fight wars, and in a very real way, the inhabitants of this Earth are stuck on a very beautiful, lovely little planet in an incredibly hostile space, and everybody is in the same boat"*
>
> (White, 2014, p. 43).

When seeing the Earth as a whole, astronauts come to realize how all of the living species are interconnected together. We can anticipate that this realization would lead to reduction of racial biases and acknowledging of interdependence of systems and events on our planet.

5.2.3.2. Transcendence

As in transcendent experiences, the OE leads to perceptions of one self's boundaries dissolving and instead one starts associating oneself with the whole world. As described by Russel Schweickart:

> *"And that whole process of what it is you identify with begins to shift. When you go around the Earth in an hour and a half, you begin to recognize that your identity is with the whole thing, that makes a change."*
>
> (White, 2014, p. 9).

We can look for similar statements in the phenomenological interviews of participants' representing what they are identifying with and whether a shift in identity has occurred.

The feeling of connection with others is often measured through the "Inclusion of Other in Self" scale (Aron et al., 1992), that asks participants to pick between a number of venn diagrams representing the 'self'-'other' overlap. Less directly, interconnectedness can be measured through linguistic analyses of the word usage in interviews with participants, e.g., comparing the frequencies of "I" vs. "us" or "everyone" etc. (Yaden et al., 2017b). Another method that can be used for tapping into the cognitive structure is implicit attitude measures (Wittenbrink and Schwarz, 2007). This class of methods is based on the assumption that our cognitive system consists of concepts that when having stronger connections between each other will produce faster responses when triggered one after the other or together. For assessing the interconnectedness experienced as a part of the OE, we can use an implicit association test evaluating the inclusion of nature in self (Schultz et al., 2004). For instance, pre- and post-test IAT was successfully used by Peck et al. (2013) to measure the reduction of racial bias after embodying an other-race avatar, and our pilot study of using the inclusion of nature in self IAT with an underwater VR experience (Stepanova et al., 2017) suggested that it might be a useful measure but it is prone to noise and requires a quiet, distraction-free setting, and as such won't be good a fit for studies run outside a lab environment.

5.2.4. Responsibility for Environment and Earth

Many of astronauts after traveling to space return with a compulsion to take care of our planet and its inhabitants. Edgar Mitchell describes this state as:

> *"having this sort of explosive awareness that some of us had, this abiding concern and passion for the well-being of Earth"*
>
> (White, 2014, p. 39).

The sense of the responsibility for the Earth can be measured through observing pro-environmental behaviors. For example, in Ahn's study of a VR experience promoting understanding of the concern of deforestation, the experimenter was "accidentally" dropping a glass of water and observing how many napkins participants will use to wipe the spilled water (Ahn et al., 2014). Similarly, we can offer the participant a glass of water and observe if they will use a reusable or disposable cup, or kindly ask them to throw out some trash on their way out and record if they went through the effort of sorting the garbage into the recycling bins. These measures will, however, be dependent on individual's beliefs of what constitutes a pro-environmental behavior.

Moreover, given the feeling of interconnectedness associated with the OE, we would expect to observe increased pro-social behavior, that can also be assessed with observational measures. For instance, in Rosenberg's study on inducing pro-social behaviors through flying like a superman in VR, they were observing how quickly participants would reach to help the experimenter pick up the pens that he dropped, and found that both the number of pens was higher and the reaction time was slower on average in the superman condition compared to the control (Rosenberg et al., 2013).

5.3. Considerations to Take When Applying the Measures

5.3.1. Individual Differences

It is important to note that even though the OE experience seems to have common underlying traits, it is being interpreted differently by each individual (White, 2014, p. 11). For instance, Don Lind explained that religious space-travelers often tend to describe OE in religious terms, while people with no religious background interpreted it though different terms, often having nothing to do with spirituality (White, 2014, p. 23). Some astronauts were associating the effect of the spaceflight experience with experience of traveling to foreign countries. Joseph Allen stated

> *"I found that travel in space was a grand extension of the principal that taking a journey was a good thing."*
>
> (White 2014, p. 205)

Understanding whether participants have a substantial amount of traveling experience to extrapolate from will allow us to better interpret their interviews. Thus, for such a complex experience it will be especially important to collect extensive demographic data on the participants in order to be able to interpret their self-report data in the context of their individual background.

5.3.2. Time Required for Accommodation of the Experience

Not all of the astronauts report on having a profound change in their worldview, which could be because not everyone experiences the OE, or some people choose not to discuss it, or it could take months or years to accommodate the experience, as was suggested by Charles Walker and Edgar Mitchell in their interviews with Frank White (White, 2014, p. 41). When taking measures aimed to asses a cognitive shift or behavioral change we need to be mindful that these changes require an accommodation period, which could be different for different people, and, thus, we may miss the positive effect, if we were taking the measures too soon.

5.4. Summary of Evaluation Methods

This section and **Figure 3** illustrates how such a complex phenomenon as the OE requires an elaborate system of various evaluation methods assessing its immediate emotional components (e.g., admiration of the vast beauty of Earth) as well as a more long-term effects such as cognitive shifts (e.g., identity shift, expansion of time perception) and psychological (inner peace) and behavioral (pro-environmental behavior) outcomes. Only by combining multiple evaluation methods assessing different constructs and components of the OE we would be able to develop a comprehesive understanding of the unfolding of the phenomenon. However this conceptual framework illustrated in **Figure 3** will need to be further refined and verified through additional research determining the exact relationships and interdependence of the discussed constructs. The specific methods of evaluation that we have proposed in this section and summarized in **Table 1** can be substituted by alternative methods assessing the same constructs, however we insist that in order to be able to infer that the OE was experienced, the majority of the constructs will need to be assessed individually first and then triangulated. The **Table 1** is structured around the research tools rather than the constructs in order to provide a summary of what each tool can allow to measure.

6. EXISTING IMPLEMENTATIONS

There were a number of attempts to elicit the OE using immersive technology in a research setting, as well as commercial VR games and educational experiences set in space. Commercial simulations include, but not limited to SpaceVR (Holmes, 2018), Overview (Orbital Views, 2018), Apollo 11 (Immersive VR Education Ltd., 2016), ADR1FT (505 Games, 2016), Earthlight (Opaque Space, 2017), and SpaceBuzz (SpaceBuzz Foundation, 2017). These commercial experiences are challenging to evaluate in terms of their effectiveness, as neither of the developers openly report on their methods and outcomes, thus we can only speculate about their potential based on the publicly available information, our personal experiences with the VR titles, and our discussions with some of the developers.

SpaceVR captures 360° video from a camera on a low Earth orbit satellite that one can observe on a cellphone or an HMD, and was even proposed to be used in a flotation tank to support the experience with the feeling of weightlessness during the 2018 Burning Man festival (Bonasio, 2018). SpaceVR was established with a goal of bringing the OE to people on Earth, but we are not aware of how successful it was to this date and whether they are using any evaluation methods to assess the effect of the experience they are providing. Being a 360°video, SpaceVR focuses on providing the most realistic visual perspective of an astronaut, thus it is likely successful at presenting the vastness of our planet and strives to provide high clarity images, while it lacks interactivity and narrative.

Overview provides a view of the whole galaxy striving for the accurate representation of celestial bodies and the relation between them, providing immersants with an opportunity to learn about the Earth's delicate position in the universe. It is designed to induce the change in the perception of space. This experience takes a much larger perspective than any astronaut was able to experience to this day, by providing an educational narrated experience of traveling through solar system and milky way. Even though we don't have any data on the exact effects of this experience, it was voted the best Education Experience on Steam 2018.

Apollo 11 is a VR game reconstructing the Apollo 11 lunar mission. The developers tried to provide an accurate historical replication of the event in the game environment, by reconstructing the interior of the cockpit and using NASA's actual recordings for the audio. Among the VR expereinces discussed here, this is the only one that provides an earthgazing perspective from the moon, and lets the immersants see the Earth as the "blue marble." This game presents a narrated optionally interactive story starting from a rocket launch taking the player to the moon landing. The well developed narrative starting from the initial thrill and fear of the launch seems to elicit some emotional responses in some players including awe and goosebumps based on the reviews on Steam. However, interactivity is limited to only a few instances, that were also deemed frustrating by some players, and as such the level of self-relevancy might be limited in this experience.

ADR1FT and *Earthlight* both are VR games providing an embodied experience of an astronaut on a space station in Earth orbit. While *ADR1FT* is a purely gaming experience, *EarthLight* is developed in collaboration with NASA to provide training opportunities for astronauts for dealing with stressful situations. Both of these experiences have higher interactivity and therefor potential for sense of self-relevance than *SpaceVR* and *Overview*, while they are less likely to provide the sense of vastness and view of the Earth as living organism, as they are task focused with a lot of attention being paid to the details of the spaceship, rather than the view of Earth. Through our own experiences with both titles, we experienced a high degree of excitement and focus on the game tasks, but neither elicited profound positive emotions similar to those within the OE. Notably, neither experience was created with a purpose of reproducing the OE, but they may inadvertently invite the OE experience. Anecdotally, developers of *EarthLight* discussed that astronauts who tried *EarthLight* mentioned that it reminded them of their actual experience in space, and they enjoyed it as a way of re-evoking their experience.

SpaceBuzz is a company in Amsterdam that aims to bring the OE experience to primary school children to educate them about science, technology and sustainability, hoping that this would contribute to forming a future generation with global consciousness. Unlike the experiences discussed above, *SpaceBuzz* is designed as a complex 13 h long experience, where the Virtual and Augmented Reality portion takes 1 h inside a 15 m long rocket and is surrounded with a 6 h pre-flight "astronaut training" and post-flight 6 h of lessons on science and technology. Thus, comparing to the experiences discussed above, *SpaceBuzz* is most likely to prime the participants for the experience and assist with the accommodation of it. After all, for astronauts, OE also spans far beyond the moment of earthgazing, so inclusion of deliberate pre- and post- experience might significantly contribute to the success of the experience. However, its success hasn't been assessed yet, as, to the best of our knowledge, the company is still in the development stage.

Besides commercial companies, the research community has also investigated the potential of VR to induce OE or a component of it, such as awe. Scientific publications provide more detailed information on evaluation methods of the experiences used than commercial games, however, they rarely included trailers of the experiences used, unlike the video games, thus our ability to judge which design guidelines were used might be limited.

For instance, Chirico et al. (2018) investigated how three virtual environments presenting vast stimuli, one of which was the view of Earth from space, are able to induce awe in participants. In this condition participants were able to navigate toward the Earth and watch it rotate. The results indeed show that awe-inspiring virtual environments were more likely to induce awe (measured through self-report Likert-scale questionnaire) than the control environment of a green field. Additionally, they measured the perceived vastness and need for accommodation with a Likert-scale questionnaire and found that the view of Earth was able to elicit higher sense of vastness than the control environment, but no significant differences in perceived need for accommodation was observed. This implementation presented a simple view of Earth with no storyline progression in the experience, and while participants were able to navigate through the environment, it was performed with an xBox controller and their behavior didn't have an effect on the environment, thus the sense of embodiment and self-relevance may have been limited.

Reinerman-Jones et al. (2013) created a mixed reality space capsule through which participants of their experience were passively observing an Earth moving away until turning into a blue marble and a deep space view of a path through stars. The phenomenological interviews showed more experiences of awe in the Earth condition than in deep space, and EEG recording proposed brainwave traces of the experience of awe. Their simulation replicated the narrative observed by lunar mission astronauts, but it was lacking the initial preparation and fear that are an important part of an actual experience of an astronaut. Gallagher et al. (2015) describe a number of virtual simulations of a spaceflight, all aiming to replicate the narrative of a spaceflight. Their resulting textual analyses of patricipants' interviews showed similarities to spaceflight experienced by astronauts. This indicated some effectiveness of inducing an experience similar to the OE. Both of these studies, being a scientific study of OE, inadvertently primed their participants to have the expectation to experience a virtual spaceflight, and thus their discussion of the experience might be based on their preconceptions of what a spaceflight is supposed to be like. For instance, some of the participants in Gallagher et al. (2015) were expecting a more realistic roller-coaster like experience of spaceflight and were underwhelmed by the simulation, while others may have discussed OE in the interviews, because of their prior knowledge about the OE, rather than because of their experience in the simulation.

We have also evaluated the potential of Google Earth VR to elicit awe (Quesnel and Riecke, 2018). Google Earth provides a high resolution model of Earth, that is likely more capable of giving the sense of vastness to the immersants than the models used in the studies discussed above. It also gives immersant a choice of the location on Earth they want to go to, thus supporting the feeling of self-relevance and allowing for a personal connection to get established. We recorded self-reported measures of awe in a form of a questionnaire and an interview, as well as physiological measures in form of goose bumps. Results showed that interacting with Google Earth participants can feel awe, especially when visiting the location of their choice. As we used a commercially available product, that works much like the Google Earth one can explore on their desktop, in this study we didn't have a narrative arc, that can let participants travel through the journey that could assist with the progression of the experience and achieving desired states. It did not simulate the sense of weightlessness or use biofeedback.

In order to facilitate progression to the desired state of OE, in our own implementation, we used an artistic approach to a VR experience inspired by the OE, and created a physical/virtual environment called *AWE* (Quesnel et al., 2018b) that has been demonstrated at multiple conferences and community events, as well as in a series of studies. For evaluation, we used cued-recall, micro-phenomenological and open-ended interviews, as well as goose bumps measures, "small-self" and Implicit Association Test of implicit connection with nature. Early results are encouraging in both *AWE*'s potential to improve well-being, and to induce a cognitive shift toward the sense of global interconnectedness. In addition to components of the OE experience, such as awe and realization of global interconnectedness, we also observed some instances of minor phenomenological experiences of weightlessness, which is a component of a spaceflight experience we didn't think we would be able to replicate. A detailed review of a study with *AWE*, relation of the prototype to the guidelines discussed in this paper and the comparison of the observed results to Quesnel and Riecke (2018) can be found in Stepanova et al. (in press) and forthcoming publications.

All of these implementations show indications that an experience similar to the OE may be achievable here on Earth through immersive technology. However, most of the results can be considered preliminary, and more research and design iteration are required in both how experiences are created, and how they are being evaluated. Simply letting immersants experience a VR environment visually representing outer space is engaging, but doesn't seem to produce a profound experience that could be identified as the OE. A more thoughtful design of the immersant's journey using prerequisites (e.g., privacy) and facilitation of transitions through the stages (e.g., from fear to awe) are necessary. At this moment, we, as a scientific community, are still far from understanding how to induce the OE on Earth. However, inducing some degree of its components, such as awe and interconnectedness, have indeed been demonstrated in some participants.

7. CONCLUSION

The OE is a fascinating, albeit extremely rare phenomenon that has been gaining more public and scientific attention in recent years. Making the OE more accessible to people can allow us to facilitate a restructuring of the value system in individuals and society. It could be an essential step in addressing major social and environmental issues that our world is facing, as well as individual psychological struggles. Even though some fundamental work has already been achieved toward generating an Earth-bound OE, we remain far from bringing an authentic, profound experience of the OE to the public. Several researchers and VR developers have been inspired to try and recreate the extraordinary OE experience in VR, yet, we are not aware of any research-based guidelines for its design being proposed and documented. Even though relevant design guidelines for the design and evaluation can be derived from research on transformative experience design (Gaggioli, 2016) or research on eliciting awe in VR (Chirico et al., 2018), specific guidelines for the design and evaluation of OE in VR have not been proposed before the current paper. This ambitious mission to comprehensively understand and create an OE will require an interdisciplinary team of researchers, VR developers, artists, and clinical psychologists that iteratively develop and study profound immersive experiences, and their effects on people.

In this paper, we explain what the OE is, and how it has been evaluated. With the understanding of the OE's significance in place, we then propose a series of concepts and guidelines for designing and evaluating OE experiences in VR to make this profound experience more accessible to researchers and the general public. As *awe* is a key emotional component of the OE, some of the discussed guidelines that focus on awe and the emotional component of the experience (vastness, accomodation, privacy, etc.) can be utilized for the design of other VR experience that aim to elicit awe in general. Awe is one of the key components of the OE and thus can be considered a necessary, but not sufficient condition for the OE to manifest. Awe has been researched more than the OE, and might be easier to measure through psychometrics (Yaden et al., 2018) and physiological measures (Quesnel and Riecke, 2018) than the other components of the OE—interconnectedness and responsibility for Earth. Therefore, focusing on eliciting awe first would be an important first step in the iterative development of an OE experience in VR. Indeed, in testing our *AWE* prototype we observed several instances of indication of awe experience, and much fewer of cognitive shift and interconnectedness, with no indication of increased responsibility to the environment in the participants (Stepanova et al., in press).

We invite our peers to utilize, explore, and expand on these concepts and guidelines for both the design of the OE experience and the proposed evaluation methods. It is important to recognize the need for these concepts and guidelines to be validated and refined through purposefully designed studies with VR experiences. We encourage the community to become engaged in a dialogue about the conceptual structure and the methods for creating emotionally profound, positive and transformative experiences like the OE on Earth, with the use of modern technology. While VR is likely the most promising tool to give more people access to the OE experience, research is needed to investigate to what extent a simulated experience might or might not be able to achieve anything as profound as the OE.

The OE is an extraordinary and complex phenomenon, but through an iterative collaboration between VR developers and researchers we might be able to recreate and understand it better, making this profound experience accessible to people around the world.

AUTHOR CONTRIBUTIONS

Authors contributed according to their competences and interests. ES and BR conceived the main idea of the article. ES performed the literature review on Overview Effect, and DQ on awe. ES wrote most of the first draft of the manuscript, and DQ added sections on aesthetics, awe and neurophenomenology. BR provided suggestions to the draft and ES and DQ together iterated on the draft to form the final manuscript. BR supervised the entire work. All authors contributed to the manuscript, read, and approved the final version.

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