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Insights in digital mental health: 2021

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Heleen Riper — VU Amsterdam, Netherlands

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Digital Health Literacy About COVID-19 as a Factor Mediating the Association Between the Importance of Online Information Search and Subjective Well-Being Among University Students in Vietnam

Linh Hoang Thuy Nguyen[1,2], Man Thi Hue Vo[3], Lien Thi Mai Tran[2], Kevin Dadaczynski[4,5†], Orkan Okan[6], Linda Murray[7] and Thang Van Vo[1,2†]*

[1] Institute for Community Health Research, University of Medicine and Pharmacy, Hue University, Hue, Vietnam, [2] Faculty of Public Health, University of Medicine and Pharmacy, Hue University, Hue, Vietnam, [3] Division of Public Health, Global Health Entrepreneuship Department, Tokyo Medical and Dental University, Tokyo, Japan, [4] Public Health Centre, Fulda University of Applied Sciences, Fulda, Germany, [5] Centre for Applied Health Science, Leuphana University Lueneburg, Lueneburg, Germany, [6] Interdisciplinary Centre for Health Literacy Research, Bielefeld University, Bielefeld, Germany, [7] School of Health Sciences, College of Health, Massey University, Wellington, New Zealand

Introduction: Digital health literacy (DHL) has recently been proposed as a means of enabling healthy decisions for protective behavior, preventive measures, and adherence with COVID-19 policies and recommendations especially in the era of the "infodemic". This study aimed to (1) identify COVID-19 related DHL and its association with online information seeking; (2) to elucidate COVID-19 related DHL as a mediator predictor between the importance of online information search and its association with subjective well-being among Vietnamese university students.

Methods: A cross-sectional web-based survey was used to elicit the responses of Vietnamese students over 2 consecutive weeks (from April 25 to May 9, 2020, $n = 1{,}003$, 70.1% female students, mean age 21.4 ± 3.1). The online survey questionnaire collected data on the sociodemographic characteristics of participants, DHL about COVID-19, information seeking behavior, and subjective well-being. Mediation analysis was conducted using the importance of searching COVID-19 related information as independent variables, subjective well-being as a dependent variable, and DHL as a mediator variable.

Results: Among 1,003 students, the mean (SD) of DHL related to COVID-19 was 2.87 ± 0.32. In the survey, 87.2% of the students reported sufficient well-being, while almost 13% reported low or very low well-being. The findings also indicated that search engines were the most popular platform for information seeking by Vietnamese students (95.3%) and 92.8% of participants had searched for information related to the current spread of COVID-19. Not searching for hygiene regulation as part of infection control and an average level of information satisfaction were associated with limited DHL ($p < 0.05$). The importance of online information searching related to COVID-19 increased

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Heleen Riper,
Vrije Universiteit
Amsterdam, Netherlands

Reviewed by:
Gallus Bischof,
University of Lübeck,
Lübeck, Germany
Paul Best,
Queen's University Belfast,
United Kingdom

***Correspondence:**
Thang Van Vo
vovanthang147@hueuni.edu.vn

†ORCID:
Kevin Dadaczynski
orcid.org/0000-0002-7367-5362
Thang Van Vo
orcid.org/0000-0003-2018-0371

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the subjective well-being of students significantly and limited DHL ($p < 0.05$). DHL was found to mediate the relationship between the importance of online information searching and the subjective well-being of students.

Conclusion: The finding provides insight into DHL about COVID-19 among university students, and their ability to find, understand, appraise, and use online health related information during lockdown throughout the first COVID-19 pandemic wave. DHL should be highlighted as a mediating factor that enhances the positive effect of the importance of information seeking on psychological well-being. However, further studies are needed to better define the mediating role of DHL across other factors.

Keywords: COVID-19, Vietnamese students, digital health literacy, subjective well-being, mediator

INTRODUCTION

A novel coronavirus (COVID-19) was identified on December 31, 2019, in Wuhan, China (1) and has spread to most of the countries worldwide. The WHO has identified more than 174 million confirmed COVID-19 cases, and as of June 09, 2021, 3.7 million related deaths had been reported. Among these, 224,894 cases and 3,757 deaths have been documented in Vietnam as of August 10, 2021 (2–6). In May 2021, a new COVID-19 outbreak with a new variant occurred in Vietnam, with community transmission in many provinces and cities, and lockdown measures were reinstituted throughout the country. By August 8, 2021, ∼10% of the population in Vietnam had received at least one dose of a COVID-19 vaccine (4).

Vietnam has progressively implemented strict lockdown measures since the first wave of the COVID-19 pandemic in January 2020 until the recent waves, including social distancing, travel bans, screening at ports of entry, a 14-day self-isolation requirement for all international arrivals, school closures, and public event cancelations. From March 16, 2020, the wearing of masks at public venues was strictly enforced, and non-essential services were shut down nationwide at this time (7).

In response to COVID-19, the universities were closed, and face-to-face learning was pivoted to online lectures and delivered through web-based platforms and online meetings. The majority of university students have been increasingly turning to the Internet to search for health-related information, but many of them found it challenging to deal with the vast amount of COVID-19 related information (8). Digital health literacy (DHL) has been defined as "the ability to seek, find, understand, and appraise health information from electronic sources, and apply the knowledge gained for preventing, addressing, or solving a health problem" (9). Several studies before this pandemic have found that the vast majority of university students lack sufficient skills for DHL (10). For example, a moderate and low self-perceived level of DHL has been reported for nursing, medical, and health sciences university students, respectively (11–13). Up to 77% of pharmacy students were unable to evaluate the quality of the health resources they found online (14). Thus, it can be assumed that searching for COVID-19 related information through the Internet and making health decisions is challenging for many of them (15).

The quality of online information available has played a crucial role in health promotion during the pandemic. However, this has occurred in a context of an overabundance of true, false, and mixed information, including on COVID-19 diagnosis, treatment, protective behavior, preventive measures, dashboard statistics, and public health recommendations. This phenomenon has been entitled the "infodemic," which spreads faster than the pandemic itself, especially through online social media platforms (16). This "information overload" may lead to feelings of confusion and stress (17). Hence, a sufficient ability to search for and appraise health-related information can be expected to have positive effects on the health behaviors in preventing diseases and mental health outcomes, such as well-being (9).

The health-related consequences were manifold and the pandemic, in particular, caused mental health problems and health communications problems with adverse effects on the mental health of the population. A recent study in the United States reported that 31% of adults had symptoms of anxiety or depression during the pandemic (18). These surging issues are related to the spread of myths and misinformation about this epidemic and associated fear and stress (7, 9, 10).

COVID-19 control measures such as social distancing measures, school closure or decreased physical activities, fewer locations visited, and increased smartphone use seemed to have an immediate negative affect on the emotional well-being of university students, characterized by increased anxiety and depression (19, 20). Furthermore, there were many social factors associated with the subjective well-being of university students that were affected by the pandemic, including family income, which may have become more unstable due to job loss during the pandemic, having a relative or acquaintance infected with COVID-19, and delays in academic progress (20). Health literacy has been identified as one factor associated with subjective well-being among adults (21). However, evidence about the role of DHL as a mediating factor between the importance of online information search and mental health among students is scarce in the context of the COVID-19 pandemic.

Most of the studies published to date have separately analyzed the predictors and outcomes of health literacy, while only a few have evaluated the possible role of health literacy as an intermediate pathway that affects the relationship between potential determinants and well-being (22). To date, it is

unknown whether health literacy mediates the association between the quality of information searched on the Internet and subjective well-being and this is the main reason why we might explore to what extent DHL mediates the association between the importance of online information as perceived and subjective well-being during the COVID-19 pandemic in Vietnam.

This study aimed (1) to investigate COVID-19 related DHL and its association with online information seeking; (2) to elucidate if COVID-19 related DHL plays a mediating role in the relationship between perceptions about the importance of online information searching and subjective well-being among Vietnamese university students.

METHODS

Study Design

This was an online cross-sectional survey. Participation was voluntary, with participants answering once and during a 2-week period (from April 25 to May 9, 2020).

Study Procedures

This research is part of a large-scale COVID-Health Literacy (HL) research network that was launched in mid-March in 2020 and now includes around 50 countries worldwide (23). Data collection in Vietnam was conducted through an online survey hosted by a secured website (Microsoft Forms online). The COVID-HL questionnaire [23] was adapted to the local Vietnamese context. The process of adaptation included a translation from English into Vietnamese, a pilot test with 10 volunteers, and refinement based on the results of the pretest before official use. The whole questionnaire took approximately 10–15 min to complete. The recruitment was the official dissemination of the survey invitation to Vietnamese university students *via* various social media platforms. All participants took part in the survey on a voluntary basis, could withdraw without justification at any point, and their confidentiality and anonymity were fully protected. The online questionnaire was kept open for 2 weeks only. The study participation was voluntary and before accessing the questionnaire, the participants provided consent. The study was approved by the Ethical Review Committee of Hue University of Medicine and Pharmacy, Vietnam (No. H2020/050 dated April 20, 2020).

Sample Size and Sampling

For this study, a convenience sample with a snowball approach was used: the more university students that completed the online questionnaire, the more widespread it became, as participants were asked to share the survey web link with their friends and relatives. A link to the survey was included in the invitation of the study objective and participation.

Data were analyzed for respondents who met the following inclusion criteria: (1) being at least 18 years old, (2) Vietnamese citizens who understood the Vietnamese language and resided in Vietnam at the time of the study, and (3) being a university student and searching for COVID-19 related information during the first wave of the COVID-19 pandemic in Vietnam. The final sample for analysis included 1,003 university students from 1,055 responses (52 participants who did not meet the inclusion criteria listed above were excluded). Most of the participants were studying at Medical or Health Science Universities (83.1%), 70.1% were female students, and the mean (SD) age of this sample was 21.4 (±3.10).

Variables

The variables include sociodemographic information, such as gender (male/female/diverse), age (continuous in absolute numbers), study program (bachelor/masters/other), anxiety about the future, personal health status, online information seeking behavior, and the importance of searching for information. All of these variables and their measurements were well-described in the survey guidelines of the international COVID-HL network (https://covid-hl.eu/) (24).

Online Information Seeking Behavior

This included different online sources for information searching, different topics that were searched for with regard to COVID-19, the language of the information searched, and satisfaction with the information found.

A list of 10 online sources for searching information on COVID-19 and related topics were used e.g., search engines (Google and Yahoo), websites of public institutions, Wikipedia, and social media platforms (Facebook, Instagram, and Twitter). These items could be answered on a four-point scale ranging from 1 (don't know) to 4 (often). These variables were recoded and classified as "yes," which included "often/sometimes," and "no," which included "rarely," "never," and "don't know."

Regarding COVID-19 related topics, a list of nine topics was provided, with a possible response of "yes" or "no." This list included, e.g., the current spread of COVID-19, transmission routes, symptoms and protective measures, assessment the of current situation, restrictions, economic and social consequences, and dealing with psychological stress.

Participants were also asked about their level of satisfaction with the information they found on the Internet about COVID-19 and related topics. Questions were answered on a five-point Likert scale ranging from 1 (very dissatisfied) to 5 (very satisfied).

The Importance of Searching Information Related to COVID-19

The importance of searching information related to COVID-19 was measured using six items which were introduced with "How important is it to you that…?" and included six dimensions of information importance: (1) being updated; (2) verified; (3) quickly learning the most important things, (1) information from official sources, (5) represented different opinion, and (6) dealt with comprehensively. All items could be rated on a four-point Likert scale ranging from 1 (not important at all) to 4 (very important).

Digital Health Literacy

Digital health literacy was measured using an adapted and translated version of the Digital Health Literacy Instrument (DHLI). The DHLI tool is an instrument that proved to show as acceptable to good reliability in several previous studies (25–27).

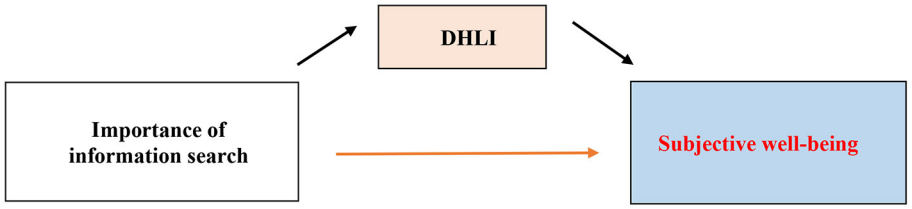

FIGURE 1 | The conceptual framework of study.

For the context of this study, all items were adapted to the specific context of COVID-19, and previous studies from the COVID-HL network could show this adapted tool to be valid and reliable for capturing DHL in university students during the pandemic.

For the context of this study, the items were adapted to information about COVID-19. The original instrument included 21-items assessing seven DHL skill dimensions: (1) information searching, (2) adding self-generated content, (3) evaluating reliability, (4) determining relevance, (5) protecting privacy, (6) operation skills, and (7) navigation skills. For this study, we included five skills (1–5) with each dimension containing three items which could be answered on a four-point response scale, ranging from 1 (very difficult) to 4 (very easy), with higher scores representing higher DHL (e.g., when you search the Internet for information on COVID-19 or related topics, how ease or difficult is it for you to …) or from "never" to "often" for questions related to protecting privacy (e.g., when you post a message about the COVID-19 or related topics on a public forum or social media, how often…). The internal consistency of the overall DHLI score was acceptable (Cronbach's alpha = 0.77) and the subscales reached acceptable to excellent reliability scores (0.71 < Alpha< 0.95). After recoding all items (with higher values indicating a higher DHL), the mean values for each subscale and the DHLI scale were created. With regards to the statistical analyses, we dichotomized the general DHL using a median split (0 = sufficient DHL, 1 = limited DHL).

The Subjective Well-Being of University Students

The subjective well-being of university students as a dependent variable was measured using the WHO-5 well-being index (28). This instrument included five items that could be answered on a 6-point Likert scale ranging from 0 ("at no time") to 5 ("all of the time"). According to the scale developer, the raw score for each item has been multiplied by 4, resulting in a transformed scale from 0 (lowest well-being) to 100 (highest well-being). The subjective well-being scale reached excellent reliability (Alpha = 0.91). The existing cut-off points suggest a low well-being for score ≤ 50, while values ≤ 28 indicate symptoms of depression (very low well-being) (29).

Data Analysis

The descriptive statistics were presented as mean ± SD for continuous data, while the categorical variables were presented as percentages. The associations between the independent variables and the dependent variable "limited DHL" were investigated with bivariate analysis (chi-squares and *t*-tests). Regarding the effect size, we calculated the Cramér's V (for chi-square test) or Cohen's *d* (for *t*-tests) (30). For Cramér's V, the effect was small at ≥0.1, medium at ≥0.3, and large at ≥0.5. For Cohen's *d*, the following effect was ≥0.2 (small), ≥0.5 (medium), and large at ≥0.5 (30). With the statistically significant differences in this study, the value of Cramér's V and Cohen's *d* were more than 0.1 and 0.2, respectively. A multivariable logistic regression model was used to analyze the association between the limited levels of DHL and associated factors after adjusting for sex and age. This form of regression analysis was chosen because there are no predefined cut-off values for the dependent variable resulting in an empirical division of low vs. high DHL (using a median split). In the next step, the mediation analyses were conducted to test the direct effects of the predictor as an independent variable (importance of information search), on well-being as the dependent variable, and the indirect effect through the mediator (DHL). According to the mediation model as discussed by Baron and Kenny (31), we explored DHL as a mediator of the association between the independent and the dependent variable (as shown in **Figure 1**).

The mediation model was tested separately following the procedure outlined by Haye et al. (32), using the modeling tool PROCESS (version 3.5) for SPSS. A Bootstrap approach (using 1,000 resamples) was utilized to assess the statistical significance of the mediation by means of the confidence

TABLE 1 | Digital health literacy (DHL) related to COVID-19 and the subjective well-being (n = 1,003).

	*n**	M (SD)*	%*
Digital health literacy			
General digital health literacy (DHL)		2.87 (0.323)	
Subscale			
Information searching		3.06 (0.438)	
Adding self-generated content		2.25 (0.877)	
Evaluating reliability		2.73 (0.492)	
Determining relevance		2.89 (0.404)	
Protecting privacy		3.41 (0.709)	
Subjective well-being		71.44 (±18.92)	
Sufficient well-being	873		87.2
Low well-being	92		9.2
Very low well-being	36		3.6

**M, mean value; SD; n, frequency; %, percent.*

TABLE 2 | COVID-19 related information-seeking behavior and attitude toward COVID-19 related online information searching among Vietnamese university students by DHL.

Variables	General digital health literacy (DHL)						*P*
	Sufficient		Limited		Total		
	N	%	*n*	%	*N*	%	
Sources used for online COVID-19 information seeking (often/sometimes)							
Search engines	476	49.8	480	50.2	956	95.3	0.649
Websites of public bodies	388	51.2	370	48.8	578	57.6	0.168
Wikipedia and other online-encyclopedias	322	49.7	326	50.3	648	64.6	0.825
Social media	462	49.8	465	50.2	929	92.6	0.804
YouTube	390	50.3	386	49.7	776	77.4	0.719
Blogs on health topics	267	50.1	266	49.9	533	53.1	0.923
Guidebook-communities	268	53.5	233	46.5	501	50.0	0.025
Health portals	376	52.7	337	47.3	713	71.1	0.006
Websites of doctors or health insurance companies	282	51.6	264	48.4	546	54.4	0.24
News portals	467	50.8	452	49.2	919	91.6	0.07
Topics searched for in the context of the COVID-19 (yes)							
Current spread of the COVID-19	478	50.3	473	49.7	951	94.8	0.397
Transmission routes of the COVID-19	351	50.1	342	49.4	693	69.1	0.508
Symptoms of the disease COVID-19	414	50.5	406	49.5	820	92.8	0.471
Individual measures to protect against infection	417	50.8	404	49.2	821	81.9	0.258
Hygiene regulations	320	52.5	290	47.5	610	60.8	0.048
Current situation assessments and recommendations	320	51.5	301	48.5	621	61.9	0.202
Restrictions	324	50.5	317	49.5	641	63.9	0.616
Economic and social consequences of the COVID-19	289	51.2	276	48.8	565	56.3	0.388
Dealing with psychological stress caused by the COVID-19	200	52.9	178	47.1	378	37.7	0.145
Information satisfaction							
Dissatisfied	33	52.4	30	47.6	63	6.3	<0.001
Average	180	41.1	258	58.9	438	43.7	
Satisfied	288	57.4	214	42.6	502	50.0	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Importance of searching information related to COVID-19	3.66	0.316	3.61	0.33	3.64	0.333	0.023*

**t-test for compare means.*

interval around the "indirect effect estimate." Bootstrapping is a robust non-parametric technique for hypothesis testing and effect size estimation without making the assumptions of normal distribution.

The statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). In all the analyses, $p < 0.05$ was regarded as indicating statistical significance.

RESULTS

Table 1 shows that mean of DHL was 2.87 ± 0.32. The students reported most difficulties in the DHLI dimension "*adding self-generated content*" had the lowest mean (2.25 ± 0.88), while for *protecting privacy,* the highest mean values could be observed (3.41 ± 0.71). As for subjective well-being, 87.2% of the participants showed sufficient well-being (50 scores), while almost 13% reported low or very low well-being.

Table 2 shows that search engines were the most popular sources used for online information seeking on COVID-19 related topics (95.3%), followed by social media (92.4%) and news portals (91.6%). With regard to the topics, 92.8% of participants searched for information related to the current spread of the coronavirus, while 37.7% of participants searched for information about dealing with psychological stress caused by COVID-19. Guidebook communities (e.g., poster, brochure, and guidelines in communities), health portals (e.g., ministry of health website) in sources of information seeking, "hygiene regulations" among searching topic and information satisfaction showed significant differences according to DHL level ($p < 0.05$). In addition, the mean score of the importance of seeking information related to

TABLE 3 | Association between DHL and information seeking behavior among Vietnamese university students.

		Limited DHL			*P*
		AOR*	95% CI		
Sources used for online COVID-19 information seeking					
Guidebook-communities					
	No	1.000			
	Yes	0.807	0.622	1.047	0.106
Health portals					
	No	1.000			
	Yes	0.722	0.543	0.961	0.025
Topics searched for in the context of the COVID-19					
Hygiene regulations					
	Yes	1.000			
	No	1.347	1.041	1.743	0.023
Information satisfaction					
	Dissatisfied	1.325	0.778	2.255	0.301
	Average	1.898	1.459	2.468	<0.001
	Satisfied	1.000			
Importance of searching information		0.635	0.431	0.936	0.022

**AOR, adjusted odds ratio (adjusted for gender,age).*

TABLE 4 | Digital health literacy as a mediator of the relationship between the importance of searching information and subjective well-being.

Mediator model	Beta (95% CI)			*P*
General DHL as dependent variable				
Importance of searching information	0.127	0.066	0.189	<0.001
Outcome model				
General DHL	7.083	3.473	10.692	0.0001
Importance of searching information	5.708	2.321	9.495	0.0013
	B	95% CI		*P*
Total effect	6.811	3.229	10.392	0.0002
Direct effect	5.908	2.321	9.495	0.0013
Indirect effect	0.903	0.3267	1.6881	

COVID-19 differed significantly by DHL level ($P < 0.05$), i.e., the respondents with limited DHL also attached lower importance to information search.

In particular, in **Table 3**, the participants who did not search for information on "infection control" had an increased odds ratio (*OR*) of having a limited DHL compared with those respondents who searched for information on this topic (*OR* 1.35, 95% *CI* 1.04–1.74). As for the relationship between information satisfaction and DHL, the students with average information satisfaction had an increased *OR* of having a limited DHL (*OR* 1.90, 95% *CI* 1.46–2.47).

The mediation analyses suggest that DHL partially mediated the relationship between the importance of searching for information and subjective well-being. The "indirect effect" of the importance of searching for information on psychological well-being through the DHL mediator was 0.90 (95% $CI = 0.3267$–1.688). The direct effect on subjective well-being remained significant [5.91 (95% $CI = 2.321$–9.495)] and was increased with the mediator input (DHL) to 6.81 (95% *CI* 3.229–10.392) (as shown in **Table 4**; **Figure 2**).

DISCUSSION

Our study findings indicated that Vietnamese university students have a considerably high overall DHL score (2.87 ± 0.323), which is comparable with the results of a previous report among the university students of Pakistan (33). Search engines were utilized as the most popular platform for information seeking, followed by social media. The majority of the participants looked for information about the current spread of COVID-19. A lack of content for "infection control" during information searching, in particular, not searching for hygiene regulation, and an average level of information satisfaction were associated with limited DHL. Interestingly, DHL was found to mediate the relationship between the perceived importance of searching for information and their subjective well-being.

Search engines and social media were the most popular sources for health information seeking for Vietnamese university students. According to the Global Digital suite of reports in 2018, 64 million out of 96 million Vietnamese people were online, and 89.1% of online users are active social media users (34). Besides that, during the COVID-19 breakout, the Vietnamese Ministry of Health has utilized social medial channels as an additional way to share well-timed information about COVID-19 to the population (35). Therefore, the government can make use of social media by integrating the official health news into social media platforms popular in Vietnam (Facebook, Youtube, etc.) in future outbreaks in a timely manner.

Regarding the effect size which measures the strength of the relationship between the two variables, in all the statistically significant differences, the value of Cramér's V and Cohen's *d* were more than 0.1 and 0.2, respectively. The results of this effect size were acceptable to determine the difference is real (30). Research design, sample size, type of measurement, etc., could influence the effect sizes (36). Therefore the magnitude of effect size, which was detected to be significant in our study, should be considered in relation to the research design. In this regard, our effect size showed a rather positive association between searching for online information and DHL, next action research (community intervention or randomized controlled trial) in which online information-based intervention is expected to improve better subjective well-being through increased DHL is quite feasible.

As there has been widely shared disinformation on the social platforms during the pandemic, DHL of university students is affected when students cannot properly appraise the quality of information on COVID-19 and are manipulated by false information. The overabundance of COVID-19 related information could bring about negative mental health consequences to those who are not able to critically evaluate the information they read (37), as disinformation and fake news could lead to confusion and increased stress (38, 39). As the

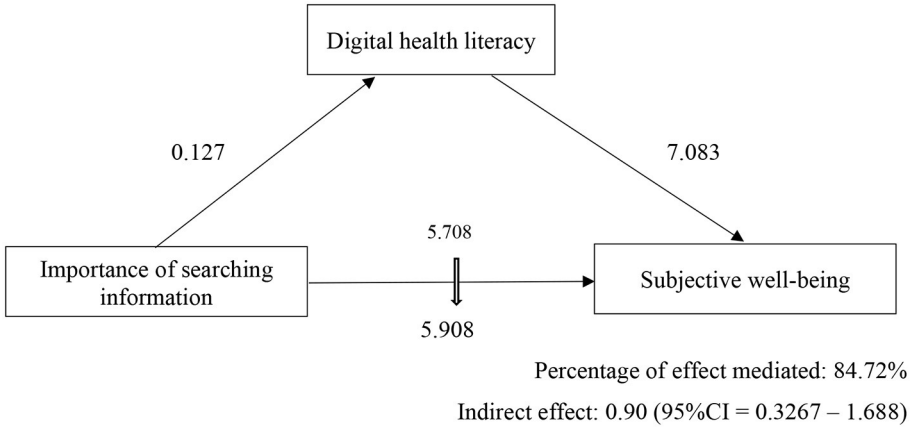

FIGURE 2 | Digital health literacy mediates the relationship between the importance of searching information and subjective well-being (n = 1,003).

Internet and digital platforms have become the major sources of health information regarding COVID-19, it is important to strengthen the DHL of students. However, there is a clear lack of interventions that strengthen DHL for young adults so far.

The importance of information content while searching, as well as information satisfaction, was presented by their relationship with general DHL. The students with average information satisfaction were more likely to have limited DHL compared with those who were satisfied with the information obtained. This might be because the higher levels of DHL require one to critically choose and evaluate available information on the Internet (40). DHL is also considered to involve various different types of literacy, such as health literacy and information literacy (41) that may enhance the confidence of participants in accessing the information and in turn, their satisfaction. This finding also corresponds with a previous study that health literacy could be a contributing factor to information satisfaction (42) when lower health literacy is associated with less perceived information provision and less satisfaction with the information.

However, the students who were dissatisfied with the information obtained also had a higher adjusted odds ratio (AOR) for a limited DHL, but this association was not statistically significant in our data analysis. It may also be that low satisfaction can be attributed to respondents being more critical of available information, indicating a higher DHL. This might be especially true for people with chronic diseases who reported lower satisfaction with COVID-19 information in a Chinese study (43). Therefore, it will need further investigation to clarify this finding. Similar findings were also shown in the recent studies in Germany and Portugal, on the association between DHL and information found online and on social media (8).

Despite the fact that the prevalence of low and very low subjective well-being among our study participants was found to be lower than the findings of a study among preclinical medical Vietnamese students (44), our model revealed the mediating role of DHL in the relationship between the perceived importance of COVID-19 related information search of students and their subjective well-being. In particular, DHL could constitute an important pathway by which the importance of information searching on COVID-19 improves the subjective well-being of students. Regarding the association between online seeking behavior, DHL, and well-being, the results of our study are in line with the scientific pre-pandemic evidence (45, 46). In particular, the effect of the importance of information searching on COVID-19 on subjective well-being was enhanced with DHL. As information seeking was seen as purposeful and driven by personal need (47), it is possible that the individuals who perceive searching for COVID-19-related topics as important are more likely to actively seek this information than the individuals who do not. Consequently, this provides them richer knowledge of online health information and in turn, positively affects well-being through improving the health knowledge and self-care skills (48, 49). Furthermore, health literacy, as a basic component of DHL, is associated with frequent online information search (50), and also with better health behaviors (51), which in turn enhance the well-being of an individual (52), which can be the explanation for the indirect effect of the importance of COVID-19 information searching on subjective well-being through DHL during the pandemic in our study.

Considering the tightening of the pandemic measure due to the serious re-emergence of COVID-19 in Vietnam since late April 2021 [47], the findings from this study are meaningful for informing future research, where DHL is included along with other established mediators that link other factors to well-being, such as mental, physical, and social health–the commonly known combination of well-being in a time of virtual information during the pandemic. Apart from deepening the research concerning these underlying mechanisms, the mediating role of DHL may have important implications for health promotion interventions, as DHL can be improved more easily with the change in positive perception about the importance of COVID-19 related information search. Consequently, in the digital era, it is well-noted that online health resources should be designed in a way that fits the literacy levels of the target

users. This is especially crucial during pandemics when online health information does not only provide users with useful information but also can help to enhance the health and well-being of individuals.

Our study has some limitations that should be acknowledged. First, our data cannot be considered representative of all university students in Vietnam and the results cannot be generalized due to the use of convenience sampling. The more university students completed the online questionnaire, the more widespread it became, as participants were asked to share the survey web link to their friends and relatives. The recruitment was used and went out from our medical university; therefore, it could be that medical and health science students with their dominant samples (83.1%) have a higher DHL level as they have more background information and scientific expertise. Second, the cross-sectional design does not allow us to interpret causation but is a useful first step for developing a research hypothesis. As the survey used self-reported data, recall bias could have occurred. Last, as social media were used as part of the recruitment strategy, this could have led to the selection bias excluding the number of students without access to digital media during the COVID-19 pandemic. We also expect that the DHLI-Covid tool has proven to be valid and reliable and that a Vietnamese validation study is on its way and will be hopefully published soon (48, 49).

CONCLUSIONS

This study has provided insightful evidence about the DHL of Vietnamese students, and their ability to properly find, understand, appraise, and use online health related information during the COVID-19 epidemic. Moreover, the results suggest that DHL during the pandemic may serve as a pathway by which attitudes toward information searching bring a positive effect on subjective well-being in the digital era. However, as there is limited research on the topic, future studies that take into account the possible effect of DGL, other potential moderators, and specific health outcome measures are needed to define the role of DHL in mediating model in a more comprehensive way. The efforts of governments to improve health literacy based on the digital platform can significantly contribute not only to COVID-19 prevention and control but also increase the well-being of students.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethical Review Committee of the University of Medicine and Pharmacy, Hue University, Vietnam (No H2020/050 dated 20/04/2020). Anonymity and informed consent were ensured *via* online registration in our survey during the COVID-19 pandemic.

AUTHOR CONTRIBUTIONS

TV, LN, OO, and KD contributed to the study design and conceptualization. LN, LT, MV, and TV did the statistical analysis, interpretation, data, and drafting of the initial manuscript. LN, LT, and TV coordinated the questionnaire adaptation and data collection. TV, LN, LT, MV, KD, OO, and LM critically revised the draft manuscript. All authors have read and approved the final manuscript.

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frontiers in Digital Health

REVIEW
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Technological and Digital Interventions for Mental Health and Wellbeing: An Overview of Systematic Reviews

*Nele A. J. De Witte, Steven Joris, Eva Van Assche and Tom Van Daele**

Expertise Unit Psychology, Technology & Society, Thomas More University of Applied Sciences, Antwerp, Belgium

Background: Research increasingly shows how selective and targeted use of technology within care and welfare can have several advantages including improved quality of care and active user involvement.

Purpose: The current overview of reviews aims to summarize the research on the effectiveness of technology for mental health and wellbeing. The goal is to highlight and structure the diverse combinations of technologies and interventions used so far, rather than to summarize the effectiveness of singular approaches.

Methods: The current overview includes reviews published in the past five years with a focus on effectiveness of digital and technological interventions targeting mental health and wellbeing.

Results: A total of 246 reviews could be included. All reviews examined the effectiveness of digital and technological interventions in the context of care and welfare. A combination of two taxonomies was created through qualitative analysis, based on the retrieved interventions and technologies in the reviews. Review classification shows a predominance of reviews on psychotherapeutic interventions using computers and smartphones. It is furthermore shown that when smartphone applications as stand-alone technology are researched, the primary focus is on self-help, and that extended reality is the most researched emerging technology to date.

Conclusion: This overview of reviews shows that a wide range of interventions and technologies, with varying focus and target populations, have been studied in the field of care and wellbeing. The current overview of reviews is a first step to add structure to this rapidly changing field and may guide both researchers and clinicians in further exploring the evidence-base of particular approaches.

Keywords: digital applications (apps), digital mental health, wellbeing, technologies, interventions

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****Correspondence:***
Tom Van Daele
tom.vandaele@thomasmore.be

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INTRODUCTION

Within the broad field of healthcare and welfare a wide range of services are offered which are aimed at promoting the wellbeing and mental health of individuals. While the context and target populations can vary substantially, professionals in this field share many interventions which often rely on face-to-face interactions. However, digital technologies can also support these services, either stand-alone or in combination with an existing service offer. New technologies can allow for more flexibility, can offer interventions in the natural context, can reach a larger population without risk of stigma, and can be more cost-effective as compared to existing services (1, 2). Research increasingly shows how selective and targeted use of technology can have a meaningful impact on the quality of care and the role users can take in the organization and delivery of services (3). For example, users may be able to have more control over their care, especially in the context of chronic illness (4).

Nevertheless, there is a sharp contrast between what is technically possible and the amount of research that has actually been done so far. As a result, there are an overwhelming number of options, which hampers overview. To address this, attempts have already been made to structure parts of the field, for example for specific technologies, e.g., internet-supported mental health interventions (5, 6), smartphone apps (7) or for particular domains, e.g., for emotion regulation in clinical psychology (8). The current overview of reviews aims to extend those previous endeavors by expanding the scope to all technologies applied to the broad domain of mental health and wellbeing. The goal is to structure existing technologies and interventions which have been the focus of reviews, rather than to summarize the effectiveness of singular approaches. By summarizing the large body of research to date and by highlighting both similarities and differences across approaches and settings, we hope to further structure this domain and to inform about gaps in research that currently still exists.

MATERIALS AND METHODS

This review was preregistered in the Open Science Framework as part of a larger study (https://osf.io/hdxky).

Search Strategy

The databases Scopus and Web of Sciences were searched on 4 January 2021 for reviews written in English and published in the past five years with a focus on effectiveness of digital and technological interventions in the field of care and welfare. A combination of two sets of search terms was used, one with a focus on technological interventions and the other on wellbeing. The search string was as follows: (websites OR "smartphone app*" OR wearable OR "virtual reality" OR "augmented reality" OR "immersive technology" OR platform OR mhealth OR "mobile health" OR ehealth OR "e-mental health" OR e-health OR internet OR mail OR chat) AND ("mental health*" OR "mental wellbeing" OR "social support" OR "psychological support" OR psycholog* OR psychiatr* OR "mental illness" OR "mental disorder" OR "quality of life").

Inclusion and Exclusion Criteria

Articles were included if they were systematic reviews, meta-analyses, scoping reviews, or overviews of reviews with an exclusive focus on the efficacy of technological tools or interventions in the context of mental health, wellbeing, or quality of life. No limitations were placed on the setting, control condition, or population, which could consist of participants of all ages of the general population, at-risk groups or individuals with underlying conditions. Studies were excluded if the focus was on strictly medical applications, lab research, assistive technology for disability, mere feasibility of technology, and if research took place among low- and middle-income countries.

Literature Screening and Data Extraction

The online review platform Covidence (https://www.covidence.org) was used, which aims to facilitate screening and data extraction with multiple reviewers. Titles, abstracts and full texts were screened by two independent reviewers in each phase. Conflicts were resolved through discussion. A data extraction template was designed to extract the characteristics of each included study. Reviews were categorized regarding:

(1) Focus: prevention, treatment, or relapse prevention.
(2) Target population, or the intended audience of the reviewed interventions: general population, at-risk population, somatic disorders, pain or neurological disorders, substance use, mental illness, or other.
(3) Age: children and young adults, adults, or elderly.
(4) Setting: home, outpatient, or residential.
(5) Integration with conventional care: online, blended.

The included reviews were also labeled according to the intervention(s) and implemented technology(/ies) through inductive qualitative analysis with the goal of creating a taxonomy. Three authors independently developed an intervention and technology taxonomy based on 50 included reviews. These categorizations were subsequently compared, and the final matrix combining interventions and technologies was developed through discussion. All reviews were subsequently labeled according to these taxonomies. A review could load on multiple interventions and technologies simultaneously. After data extraction was complete, each entry was checked for errors in extraction by the first author.

For a number of combinations of interventions and technologies a review was selected and its focus described, to briefly illustrate what each combination might. Three criteria for selection were put forward: (1) the review is the most recent available, (2) the review is of high-quality, as determined by the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses [a maximum of four negative evaluations; (9)], and (3) the review focuses on the combination of a single methodology and technology.

RESULTS

Study Identification

The systematic search strategy yielded 6,113 results. The selection process is visually summarized in a PRISMA flowchart (10) in **Figure 1**. A total of 246 reviews could be included. All reviews examined the effectiveness of digital and technological interventions in the context of care and welfare. The reviews were diverse in scope and the quality of the studies they retrieved varied greatly (cfr. supra, review illustrations). Each review included an average of 16 studies, with outliers ranging from 1 to 111 studies.

Characteristics of Reviews

A detailed overview of the characteristics of each review can be found in **Supplementary Table 1**. Results show that most reviews focused on treatment ($N = 196$). Prevention was also fairly common ($N = 107$), but only a limited number of reviews examined applications for relapse prevention or maintenance of treatment effects ($N = 20$). In line with the focus on treatment or, in this context, psychotherapy, the largest subset of reviews had an (exclusive) focus on individuals with mental illness ($N = 142$; **Figure 2**). This was followed by the general population ($N = 58$) and somatic conditions ($N = 56$). The "other" category of **Figure 2** consisted of informal caregivers ($N = 22$) and perinatal women ($N = 9$). A third of the studies focused on more than one target group in their review (e.g., both general population and at risk populations). In terms of age group, most studies focus primarily on adults ($N = 203$). However, there are also several studies that focus on children to young adults ($N = 81$). The age group that is currently understudied in systematic reviews is the older population ($N = 23$). Since most reviews do not clearly indicate the setting in which the studies took place (e.g., outpatient or residential), it was not possible to formally categorize reviews on this behalf. In general, however, many interventions were offered in the home setting. Additionally, interventions also took place in outpatient care, residential care, school/university setting, and the work context. Finally, there

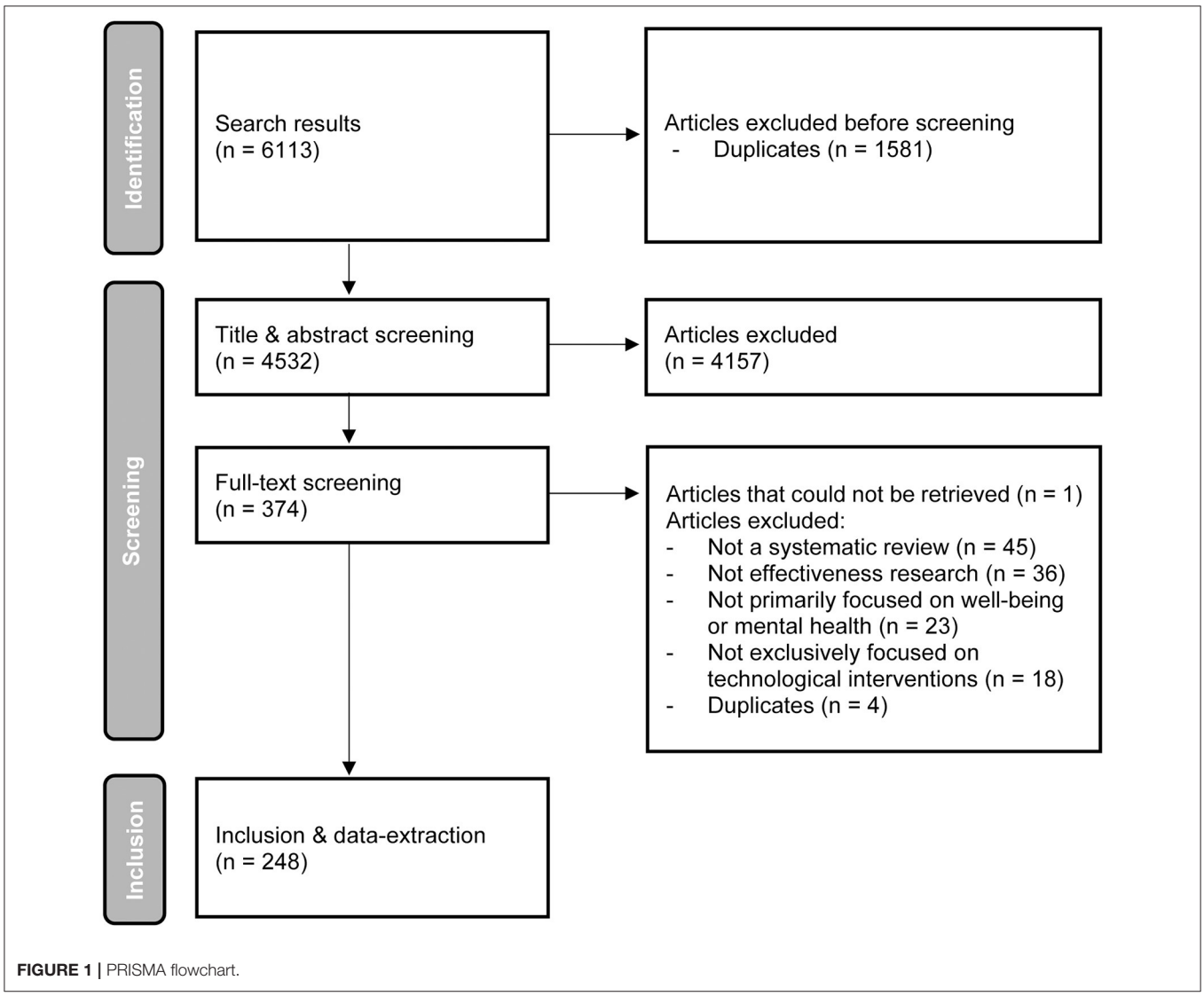

FIGURE 1 | PRISMA flowchart.

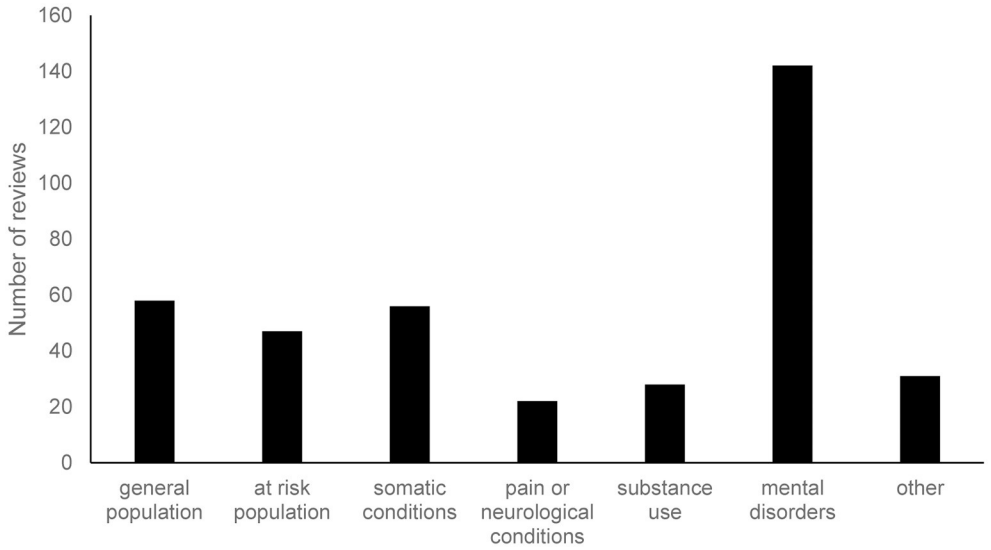

FIGURE 2 | Target groups of the included reviews. Each review could be assigned multiple categories.

were only three reviews that clearly and explicitly examined blended care (a combination of online and face-to-face contact). Most reviews examined interventions that were entirely digital or did not clearly report whether complementary face-to-face contact was provided.

Taxonomies

The taxonomy concerning interventions consists of 9 types, which are described in **Table 1** and can be considered as an operationalization of the mental health intervention spectrum of mental disorders, developed by Mrazek and Haggerty (23).

Three broad clusters of technologies can be distinguished: a first is technologies taking conventional care online. A second is technology to be used as (stand-alone) interventions. Finally, there are emerging technologies, on which there may already be substantial research evidence, but which have not necessarily been (frequently) implemented in clinical practice up to now. **Table 2** provides an overview of the taxonomy of technologies.

Technological and digital interventions rely on the combination of a technical component and an intervention. The retrieved reviews can thereby be categorized under several interventions and/or technology forms. The matrix in **Table 3** should therefore not be viewed as an exhaustive overview of possible combinations of interventions and technologies. What can be derived from it are common and less common combinations of technologies and interventions and the relative difference in weight of the various possible combinations.

The overview in **Table 3** shows that the focal point of research into technological and digital interventions for mental health and wellbeing is on interventions offered through computer, smartphone, or a combination of both.

Programs can be offered in the form of mere self-help or can include some form of (mainly digital) support from a professional. **Table 4** provides an overview of the number of studies included in the reviews that discuss pure self-help in relation to studies that (also) include interventions that are supported by a professional. While the majority of studies on smartphone applications are limited to self-help, studies exploring computerized programs do more commonly include professional support. Conventional services delivered online are less represented. In terms of emerging technologies, studies using VR and wearables are most common. When inspecting the interventions, and in line with the predominance of samples with mental disorders, psychotherapeutic interventions are strongly represented in the literature. Supportive interventions are also common and mostly target informal caregivers and individuals with somatic conditions.

Illustrations of Reviews Within the Combination of Both Taxonomies

Discussing each of the 246 studies would lead us to far. To nevertheless offer some insight into both taxonomies, we briefly describe the most common combinations of technologies and interventions. For that purpose, we choose the most frequent combinations within the three technological clusters defined earlier and selected the review meeting all three criteria defined earlier. The JBI quality assessments of all retrieved studies can be found in **Supplementary Table 2**.

Conventional Approach Using (a)Synchronous Technologies

Corry et al. (28) focused on *synchronous technology and supportive interventions*. They conducted a systematic review on telephone interventions delivered by healthcare professionals, for providing education and psychosocial support to informal caregivers of adults with diagnosed illnesses. The combination of *asynchronous technology and psychotherapeutic interventions* was reviewed by Senanayake et al. (29). In text messaging

TABLE 1 | Taxonomy of interventions determined through inductive qualitative analysis, and their description.

Intervention	Description
Preventive interventions	Preventive interventions aim to prevent complaints and problems. Prevention can be aimed at the entire population (universal prevention), at individuals with increased risk (selective prevention), or at individuals who already have symptoms (indicated prevention) (11).
Measurement and follow-up	This includes all forms of measuring variables, whether by a professional, by the user themselves, or automatically. Therefore, this may involve (diagnostic) assessment, consisting of the measurement of the individual's strengths and needs through, e.g., questionnaires (12). In addition, it also involves self-tracking of one's own thoughts, behaviors, bodily sensations and/or emotions as they occur, which can be done through e.g., mood trackers (7). A final group of studies perform passive monitoring or data collection without any effort on the part of the user (13).
Supportive interventions	Interventions can be aimed at supporting the well-being of users. These interventions can use psychoeducation (i.e., providing information about disorders and their physical and mental consequences) which can for instance include a focus on compliance, management of disorders and coping with stress (14). In addition, activating and structurally involving the social network regularly plays a major role in this type of intervention.
Skills training	These interventions focus on mentally or actually practicing skills to build or strengthen a particular competency (12). This can for example consist of training social or cognitive skills. In addition, specific interventions such as biofeedback, i.e., supporting users to gain control over real-time physiological processes to improve their health and performance (15), can also be included.
Behavioral interventions	Interventions focusing on behavior change, trying to reduce risky behaviors or encouraging health-promoting behaviors (16, 17).
Gamified interventions	Interventions can also be offered with game elements. These are called "serious games" or games that actively engage the user and contribute to achieving a particular goal (18). While they are not merely entertaining, a user does not need to be aware of this. These games can for example be aimed at completing certain tasks, problem solving, cognitions, and promoting physical activity [exergames; (19)]
Psychotherapeutic interventions	The encyclopedia of Psychotherapy states that "Psychotherapy, defined within the broader context of the field of psychology, is a skilled and intentional treatment process whereby the thoughts, feelings, and behavior of a person are modified with the intention of facilitating increased functioning and life adjustment (20). Two streams of psychotherapeutic interventions were strongly represented in the literature and were therefore included as separate methodologies (see below).
Psychotherapeutic—Cognitive behavioral therapy (CBT)	CBT is a specific approach in psychotherapy that focuses primarily on the application of experimental methods and principles (such as learning principles) in clinical practice. Specific methodologies included within CBT are behavioral activation and exposure therapy. Behavioral activation consists of identifying, scheduling, and performing activities that are pleasurable or have a positive impact on mood with the goal of promoting or maintaining satisfying and enriching experiences (7). Exposure therapy for anxiety disorders consists of gradually exposing the user in a controlled manner to the stimuli and situations that evoke anxiety in order to reduce anxiety symptoms (21).
Psychotherapeutic—mindfulness & acceptance and commitment therapy (ACT)	Mindfulness and ACT, also called third wave CBT, are psychotherapeutic interventions focused on accepting difficult thoughts and emotions and encouraging behaviors that align with personal values (22).

interventions for the management of depression, texts were being used for various purposes: therapeutic, motivational and supportive.

Programs Supported by Technology

Digital programs were explored in combination with a wide variety of interventions, for example with *preventive interventions* in the context of technology-enhanced youth suicide prevention and interventions (30). Others were combined with *measurement and follow-up*, using digital interventions for routine outcome monitoring (ROM) and measurement-based care (MBC), the routine use of outcome measurement to guide treatment decisions of patients receiving face-to-face psychotherapy (31). Leng et al. (32) furthermore focused on the potential of combing *digital programs and supportive interventions*, more specifically the use of digital interventions to support informal caregivers of people with dementia. Victorson et al. (33), finally, explored the combination with *psychotherapeutic interventions—ACT and mindfulness* when looking into technology-enabled mindfulness-based programs.

Self-help smartphone programs were either most commonly combined with *behavioral interventions* or with *psychotherapeutic interventions*. On the one hand, a systematic review by Milne-Ives et al. (34) focused for example on the effectiveness of smartphone apps for health behavior change, in physical activity, diet, drug and alcohol use, and mental health. On the other hand, Ilagan et al. (35) looked into psychotherapeutic interventions targeting borderline personality disorder (BDP) symptoms like anger, suicidality and self-harm, using smartphone apps. These apps were used to set up safety plans, to help patients track their mood, or to facilitate emotion regulation exercises.

Computer programs often looked into *psychotherapeutic interventions, both general or CBT*, but were also used in the context of *skills training*. Dugdale et al. (36) summarized current evidence on the potential of computer-based treatment programs to reduce symptoms of substance misuse and mental health difficulties in adults with a dual diagnosis. Following an initial screening, users could for example access an interactive coping strategy training, which helped them to address the lifestyle factors which are maintaining their harmful alcohol

TABLE 2 | Taxonomy of implemented technologies, determined through inductive qualitative analysis, and their description.

Type of service	Technology	Description
Conventional, but online	Synchronous media	Synchronous communication implies that the user and professional have real-time contact virtual contact via, for example, video calling or chat.
	Asynchronous media	In asynchronous communication, delayed exchange is expected, as is the case in e-mail conversations.
Programs	Computer or laptop	This consists for example of online platforms or installed software. It can exist in the form of self-help and in combination with support from a professional who (a)synchronously monitors progress and/or provides feedback.
	Smartphone	A second group of interventions is offered mobile via a smartphone application. It can exist in the form of self-help and in combination with support from a professional who (a)synchronously monitors progress and/or provides feedback.
	Digital interventions	This group covers a wide range of mixed digital interventions. In this lump category, reviews were placed that offered interventions that were both accessible via computer and smartphone and/or those that included peer support (e.g., via a forum) in addition to (a)synchronous follow-up from a professional.
Emerging technologies	Extended reality (XR)	Extended reality (XR) refers to virtual reality (VR), augmented reality (AR), and mixed reality (MR). VR refers to the experience of an immersive computer-simulated three-dimensional environment through a headset (24). AR refers to adding virtual elements to the real environment by means of the smartphone or a headset (21). MR involves a blending of the virtual and real worlds but is currently used very little.
	Social media	Social media (e.g., forums, social media platforms) can also lend itself to the provision of methodologies for care and well-being and are primarily used for peer contact and activating the social network.
	Wearables	This term refers to sensors and devices that can be worn on the body and can collect physiological and behavioral data (e.g., heart rhythm, physical activity) in a non-invasive manner continuously throughout daily life (25).
	Other	This includes chatbots, programs that can converse and interact with the user through spoken, written, and visual communication (26). In addition, robots, programmable machines that can perform tasks (semi) autonomously, can also be used for care and well-being. Another emerging technology is digital phenotyping or the use of automatically collected digital (usually smartphone) data to monitor functioning (27). Finally, game consoles and virtual classrooms (online educational spaces in which students and teachers interact) are also placed in this residual category.

TABLE 3 | Overview of the number of studies retrieved in the reviews for combinations of interventions and technologies.

Interventions	Technologies									
	Conventional, but online		Programs			Emerging technologies				
	Synchronous	Asynchronous	Computer	Smartphone	Digital	XR	Social media	Wearables	Other	Total
Preventive interventions			102	28	289	49		15	15	489
Measurement and follow-up	22	9		43	130	69		57	45	375
Supportive interventions	39	15	107	14	659	39	49	56	51	1,029
Skills training			54	22		58			44	178
Behavioral interventions	13		21	58						92
Gamified interventions			30			20		5	17	72
Psychotherapeutic interventions	200	71	399	354	1372	531		221	256	3,350
Psychotherapeutic—CBT	19		520	8	244	15				806
Psychotherapeutic—mindfulness & ACT			97	61	157				33	348
Total	293	95	1330	588	2851	781	49	354	461	6,414

ACT, acceptance and commitment therapy; CBT, cognitive behavioral therapy; XR, extended reality.

consumption. Eilert et al. (37) conducted a systematic review and meta-analysis on the effectiveness of computer-based treatment for generalized anxiety disorder. All but one of the online interventions included some form of human support alongside the intervention and most were primarily based on CBT. To be more specific, interventions relied on (a combination of) psychoeducation, case examples, mindfulness and/or relaxation exercises, notification and/or reminder emails, homework, summaries, and relapse prevention and maintenance. Finally, a scoping review by Zhang et al. (38) assessed the potential of computer-based cognitive bias modification interventions. These interventions, for which evidence initially emerged from experimental psychology, aim to retrain automatic attention to stimuli that are either harmful (e.g., in the context of

TABLE 4 | Overview of the number of studies retrieved in the reviews for combinations focusing on interventions and self-help.

Interventions	Programs			
	Computer	Of which self-help	Smartphone	Of which self-help
Preventive interventions	102	20	28	13
Measurement and follow-up			43	43
Supportive interventions	107	8	14	14
Skills training	54	54	22	22
Behavioral interventions	21	13	58	58
Gamified interventions	30	20		
Psychotherapeutic interventions	399	90	354	279
Psychotherapeutic—CBT	520	10	8	8
Psychotherapeutic—mindfulness & ACT	97		61	34
Total	1330	215	588	471

ACT, acceptance and commitment therapy; CBT, cognitive behavioral therapy.

substance abuse) or threatening (e.g., in the context of social anxiety disorder). In order to do so, participants for example completed online series of modified Stroop tasks. In these tasks, the computer presented them with series of threatening and neutral words, in varying colors. Every time, participants were asked to name the color of these words, while ignoring their semantic content.

Emerging Technologies

XR was most commonly used in combination with *psychotherapeutic interventions—CBT*. Kothgassner and Felnhofer (39) examined the effectiveness of virtual reality exposure therapy (VRET) for the treatment of anxiety disorders in children and adolescents. *Social media*, in turn was most frequently combined with *supportive interventions*. Ridout and Campbell (40) conducted a systematic review on the current evidence base for using social networking sites as a means to deliver mental health interventions for young people up to the age of 25, particularly for sharing knowledge and providing peer-to-peer support. *Wearables* were often used for *measurement and follow-up* and were for example used to unobtrusively measure and monitor depressive symptoms in children and adolescents (41). *Chatbots* were applied in the context of *pychotherapeutic interventions*, for example in the review by Abd-Alrazaq et al. (26) who explored to what extent chatbots might meet the needs of people with mental health conditions, in particular people with symptoms of depression, anxiety and stress and acrophobia. Emerging technologies which are less frequent in current literature are digital phenotyping and robots. Cornet and Holden (13) looked into the potential of *digital phenotyping* for health and wellbeing and found that smartphones were most commonly used to capture accelerometery, location, audio, and usage data, for example with patients with bipolar disorder or schizophrenia. The obtained data were primarily used for unobtrusive monitoring. Finally, Scoglio et al. (42) was the only review with an exclusive focus on *robots*, but found only a very limited number of studies to date.

DISCUSSION

The current overview of reviews on technological and digital interventions in the field of care and welfare shows that there is a large diversity, both in terms of interventions and technologies used. Although the focus is mainly on treatment, a relevant portion of the reviews also consider a preventive approach. Furthermore, both in the case of young people and adults, the reviews focus on a wide variety of target groups. No clear-cut differences regarding these target groups were found amongst the diversity of retrieved reviews, aside from the fact that supportive interventions mostly targeted informal caregivers and individuals with somatic conditions. Technologies most frequently researched are programs, both on computers, smartphones, or cross-platform digital environments (74% of all study categorizations). Not only emerging technologies (e.g., XR), but also technologies that allow conventional therapy to take place online (e.g., video calling) have been the focus of research far less often. Remarkably, an explicit focus on blended interventions is largely absent from the reviews. Combining online and face-to-face offerings is often cited as the most promising avenue for technological and digital interventions in care and welfare (43). However, only three of the 246 reviews appear to explicitly focus on this.

A classification matrix focusing on the type of technology and the content of the activity or intervention was created through qualitative analysis. This proved challenging as many reviews included a wide range of interventions. While the current solution can help to understand the variety of possible interventions and gaps in research and practice, other ways of classification are also possible and have been proposed. The list of treatment elements and definitions for the classification of smartphone apps by Wasil et al. (7) for example demonstrated that psychoeducation, relaxation and medication were the three most common elements in smartphone apps. Since our study goes beyond smartphone apps and focuses on reviews that each include a broad range of treatment elements, a categorization at a higher level was warranted. Fernandez-Álvarez et al. (8) recently made a similar attempt to structure current research on digital technologies for the intervention of emotion regulation, in which a distinction was made between three distinct categories: digital technologies (1) to understand process and outcome (e.g., (bio)sensors, (2) to create new interventions (e.g., bio- and neurofeedback and XR) and (3) to disseminate psychological treatments [e.g., (un)guided interventions and videoconferencing psychotherapy]. Although their categorization is solely focused on emotion regulation, the structuring does show similarities to the current overview of review. However, as our study took a more systematic approach and looked at combinations of technologies and interventions in a broader field, it might offer better insights in current

gaps and potential opportunities. The potential of XR is for example not limited to creating new interventions, but might very well also be used to understand process and outcome. A structuring of the field using the combination of two taxonomies therefore seems to better allow for a flexible categorization of (future) studies.

The focus of future research can be twofold. Firstly, it can further explore novel combinations of interventions and technologies, as combining both taxonomies resulted in a 9 x 9 matrix. This implies that, theoretically, 81 combinations could be made of different technologies and interventions. However, no studies were retrieved for 31 of those combinations (38%). This might lead one to conclude that the different forms of technology have only been used rather one-sided so far. However, not every technology is necessarily suitable for every intervention. Nevertheless, there are various technologies included in the matrix that are still recent: research on these paradigms has therefore only recently started developing. Those emerging technologies have currently been relatively understudied, except for XR, where virtual reality already has an extensive and long-standing research tradition, but is only now gradually making its way into practice. Secondly, even more established combinations need further strengthening, especially those who already see strong uptake in clinical practice. To be more specific, this overview for example shows that (self-help) smartphone apps and programs, which are currently already frequently disseminated in practice, have not been the focus of as much research as often might be thought.

There are also limitations to the current study. Given the broad scope of our overview and the large number of reviews retrieved, we opted to rely on the count of studies within reviews as an indication for the amount of research that has been conducted to date. This obviously does not provide a proper indication of the actual evidence-base for particular combinations of technologies and interventions. We are therefore cautious in our interpretations and see the current overview primarily as a way to provide a structuring of a very broad field, which is currently still in the midst of expanding. Also important to note is that this overview was set up in the context of a broader study on the potential of technological and digital interventions for Flanders, a region and community in Belgium. To assure sufficient local relevance of the literature overview, it was therefore limited to only include reviews with a focus on high-income countries. In the initial abstract screening process several articles were excluded focusing on low to middle income countries. Digital interventions seem (also) most prevalent there as well, although the number of studies specifically taking these contexts into account are still limited (44).

Taken together, the current overview shows that technological and digital interventions in the field of care and welfare can vary substantially in terms of the aims for which they are used, their focus, and target population. Overall, reviews focusing on effectiveness of such applications do appear to have mostly concentrated on psychotherapeutic interventions for mental illness offered through computers and smartphones. Regardless of the underlying rationale, however, adding structure to this diverse and rapidly expanding field helps to offer some insights in current (lack) of evidence-base of certain technologies and interventions that rely on them.

AUTHOR CONTRIBUTIONS

EV, SJ, and ND created the taxonomy. All authors contributed to the screening process and participated in the data extraction and the writing of the manuscript.

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SUPPLEMENTARY MATERIAL

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Acceptance of E-Mental Health Services for Different Application Purposes Among Psychotherapists in Clinical Training in Germany and Switzerland: Secondary Analysis of a Cross-Sectional Survey

Pia Braun[1], Marie Drüge[2], Severin Hennemann[3], Felix Jan Nitsch[4,5], Robert Staeck[2] and Jennifer Apolinário-Hagen[1]*

[1] Faculty of Medicine, Institute for Occupational, Social and Environmental Medicine, Centre for Health and Society, Heinrich Heine University Düsseldorf, Düsseldorf, Germany, [2] Department of Clinical Psychology/Psychotherapy Research, Institute of Psychology, University of Zurich, Zurich, Switzerland, [3] Department of Clinical Psychology, Psychotherapy and Experimental Psychopathology, Institute of Psychology, University of Mainz, Mainz, Germany, [4] Marketing Area, INSEAD, Fontainebleau, France, [5] Paris Brain Institute (ICM), INSERM U 1127, CNRS UMR 7225, Sorbonne Université, Paris, France

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***Correspondence:**
Pia Braun
braunp@hhu.de

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Background: Despite solid evidence supporting the efficacy of electronic mental health (EMH) services, their acceptance among psychotherapists is limited and uptake rates remain low. However, the acceptance of different EMH services has yet barely been examined in future generations of psychotherapists in a differentiated manner. The aims of this study were (1) to elaborate the intention to use various EMH services for different application purposes and (2) to determine predictors of EMH service acceptance among psychotherapists in clinical training (PiT).

Materials and Methods: Our paper is based on a secondary data analysis of a cross-sectional survey. Respondents were recruited via recognized educational institutions for psychotherapy within Germany and the German-speaking part of Switzerland between June and July of 2020. The survey contained items on the intention to use different EMH services (i.e., guided and unguided programs, virtual reality, psychotherapy by telephone and videoconference) for various application purposes (i.e., prevention, treatment addition, treatment substitute, aftercare). Potential predictors of EMH service acceptance (e.g., barriers and advantages) were examined based on an extension of the Unified Theory of Acceptance and Use of Technology (UTAUT).

Results: Most of the $n = 216$ respondents were female (88.4%) and located in Germany (72.2%). General acceptance of EMH was moderate ($M = 3.4$, $SD = 1.12$, range 1–5), while acceptance of psychotherapy via videoconference was highest ($M = 3.7$, $SD = 1.15$) and acceptance of unguided programs was lowest ($M = 2.55$, $SD = 1.14$). There was an interaction effect of EMH service and application purpose ($\eta^2 = 0.21$). Barriers and advantages both had a uniform influence on EMH service acceptance ($Pr > 0.999$), while impersonality, legal concerns, concerns about therapeutic alliance,

simplified information provision, simplified contact maintenance, time flexibility, and geographic flexibility were significant predictors (all $p < 0.05$). Results showed that the extended UTAUT model was the best fitting model to predict EMH service acceptance ($Pr > 0.999$).

Conclusions: The intention to use different EMH services varied between application purposes among PiT. To increase acceptance of EMH services and reduce misconceptions, we identified predictors that should be addressed in future acceptance-facilitating interventions when educating PiT.

Keywords: acceptance, eHealth, eMental health, psychotherapists, telemedicine, unified theory of acceptance and use of technology

INTRODUCTION

During the ongoing COVID-19 pandemic, common mental health disorders (CMDs) such as depression, post-traumatic stress disorder (PTSD) or anxiety disorders increased tremendously across the globe (1–4). High prevalence rates for CMDs can oftentimes be linked to perceived uncertainty, fear and social isolation measures that come along with this global health crisis (5–7). To offer quick, safe and location-independent help, the World Health Organization (8) has recommended to ensure access to psychosocial support services through digital systems. Consequently, the need for easily accessible, effective and flexible services as alternatives or additions to traditional mental health treatment to support vulnerable populations became even more evident during the COVID-19 pandemic (9).

Electronic mental health (EMH) services are usually internet-delivered services that have proven to be effective in trials on the prevention and treatment of CMDs (10–13), for instance in reducing symptoms of PTSD (14), anxiety (13, 15), depression (16), panic disorder and social anxiety disorder (17). EMH services have been advancing into routine care in developed countries even before the outbreak of the COVID-19 pandemic, as they can complement and improve health care systems (10). Principally, EMH interventions have several advantages over face-to-face interventions such as time flexibility and greater accessibility because they are location-independent and thereby could conquer structural barriers (18, 19). Additionally, EMH services offer a low-threshold, anonymous option for individuals who are afraid of stigmatization (19). Other drivers include perceived acceleration of the treatment process and outcome, simplified contact maintenance (20), improved adherence, health literacy and disease management (21).

Despite these advantages and well documented efficacy of EMH interventions (22–24) the dissemination remains low in many countries at an earlier stage of digital health implementation into healthcare such as Switzerland or Germany (25–27). Efficient implementation of EMH services depends on the utilization and acceptance by potential users and health experts. According to the Unified Theory of Acceptance and Use of Technology (UTAUT), acceptance can be operationalized as the intention to use technology and serves as a direct predictor of the actual usage (9, 28). Thus, low uptake rates can be explained by EMH acceptance being low to moderate among patients (25, 29–31) and health professionals (32, 33). The UTAUT model emerged from eight different acceptance models and was initially developed for the work context (28), but has been successfully validated and adapted to digital health care (9). It is the most frequently used model providing a theoretical framework for potential factors that predict acceptance, including performance expectancy, effort expectancy about the ease to use technical services, social influence by stakeholders and facilitating conditions, as e.g., the extent to which organizational and technical structures support the use of services (34). Performance expectancy is supposed to be the strongest predictor (9), representing beliefs of relative advantage or usefulness of the technical service. Beyond these well documented UTAUT factors, other predictors of EMH acceptance that have been suggested by research, are personal experience with EMH and electronic health (eHealth) literacy (i.e., the ability to find, evaluate, and utilize internet-based health information) (35, 36), knowledge about EMH services (30, 37) and the perceived evidence base on the effectiveness of EMH services (38).

In general, EMH acceptance seems to be even lower among health professionals such as psychotherapists compared to patients (39, 40). Barriers that are perceived by psychotherapists are diverse, including insufficient information (21) concerns about the technology itself (e.g., data security and privacy), lack of clear ethical guidelines and concerns about relational aspects (20, 37, 41, 42). Additionally, a comprehensive legal and regulatory framework for psychotherapists, along with reimbursement schemes, is often lacking even though awareness at the policy level is increasing (43). As health experts are often the primary source of health information or treatment recommendation (44), they supposedly have a large influence on patients' attitude formation and thus on the implementation of EMH services (35). Hence, research should focus on understanding both acceptability and attitudes as determinants of behavioral intentions to use and actual utilization of health experts as negative attitudes can result in slow dissemination or poorer uptake of EMH services (45, 46).

EMH is an umbrella term that includes a wide range of electronic services (e.g., self-help, psychoeducational information, virtual reality, psychotherapy via videoconference,

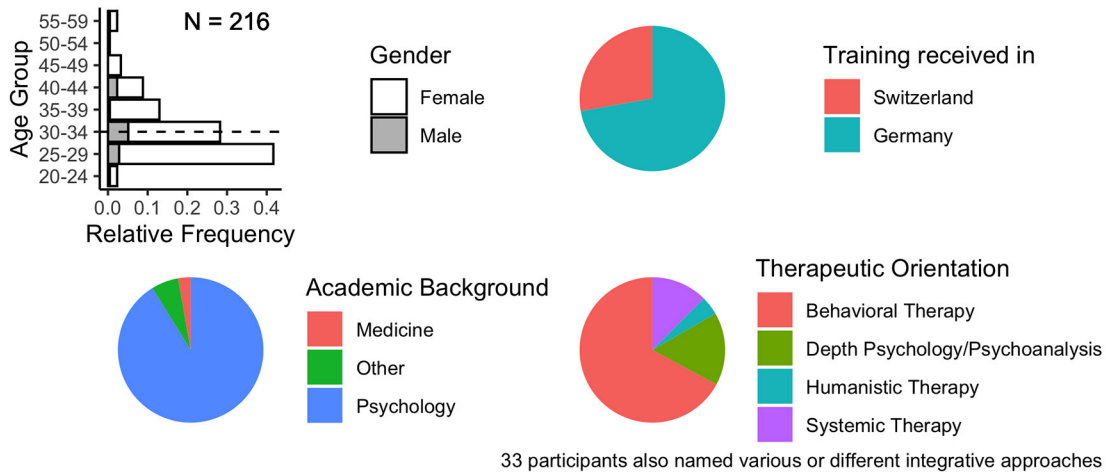

FIGURE 1 | Participant Demographics.

counselling, etc.) which are applied for different purposes, such as for prevention or treatment of CMDs (47). About a decade ago, Eichenberg and Ott (44) could show that most EMH services were used for treatment (71%), 19.1% for prevention and only 9% for rehabilitation purposes. Meanwhile, digital health applications (medical apps) for mental health such as selfapy (48), velibra (49) or deprexis (50) have been integrated into routine care in Germany in fall 2020 and are now used along the entire patient journey (51). Medical apps are guided or unguided programs which are self-directed mobile phone- or web-based programs that entail information and a fixed number of modules or exercises for (mental) health problems (12, 48, 50). Oftentimes, the basis of guided medical apps is internet-based cognitive behavioral therapy (iCBT) which involves the user following a written electronic treatment program, together with receiving synchronous or asynchronous support from a therapist via e-mail, texts or calls (52). This therapeutic approach has been shown to be effective in reducing anxiety disorders (53), depressive symptoms (23), suicidal ideation (54) or insomnia (55). In Germany, medical apps can be prescribed by physicians for self-help purposes, aftercare or relapse prevention (38, 56). In Switzerland, medical apps are similarly used, expanding their traditional health care system (57). For self-help purposes, unguided programs are most often used as they offer a possibility to monitor and better understand perceived symptoms and help users to take actions on their own to improve their mental health (12). For aftercare and rehabilitation purposes, professionally guided programs have been predominantly implemented, with health experts supporting clients in health promotion by providing some sort of synchronous or asynchronous interaction or feedback in addition to unguided services (12). Nevertheless, reducing EMH to medical apps would fall short as there are several more ways to use EMH. For instance, there is psychotherapy via videoconference or telephone which is most often used as an alternative treatment delivery service, either as an addition to or substitute for face-to-face-therapy (58). It has been shown to be an effective and timely treatment option for depression and anxiety disorders, especially for patients living in rural areas (58). However, the evidence base of the efficacy of psychotherapy via videoconference or telephone is still scarce and researchers have only started to investigate the efficacy of this EMH service with the outbreak of the COVID-19 pandemic (59–61). Virtual reality (VR) is another EMH service that has been used for diagnostic purposes (62), for prevention (63), and the treatment of a range of CMDs in clinical settings (62, 64). For instance, VR therapy has been shown to be a valuable treatment for social anxiety (65), panic disorder (66) or PTSD (67).

TABLE 1 | Means and standard deviations of EMH service acceptance.

	M	*SD*
Acceptance of psychotherapy via telephone	3.36	1.21
Acceptance of psychotherapy via videoconference	3.7	1.15
Acceptance of VR treatment	2.7	1.1
Acceptance of unguided programs	2.55	1.14
Acceptance of guided programs	2.88	1.14
General acceptance of EMH	3.4	1.12

Clearly, EMH services are characterized by great heterogeneity of applied methods, target groups, desired objectives and scientific evidence (68). However, EMH acceptance has yet barely been examined in a differentiated manner with regard to specific areas of application. Thus, general conclusions about EMH acceptance fall short. Instead, it is necessary to assess the intention to use various EMH services for different application purposes to get an extensive picture. Therefore, the research aim of this study was (1) to directly compare the acceptance of psychotherapy via telephone,

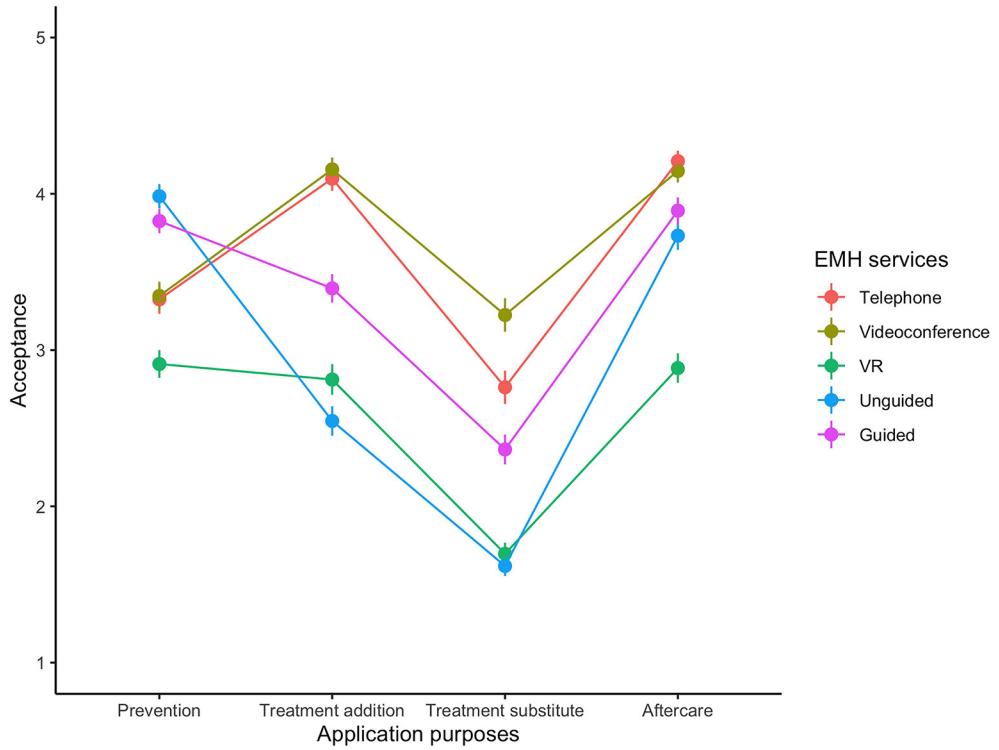

FIGURE 2 | Mean Acceptance Scores for different EMH Services across Application Purposes.

psychotherapy via videoconference, VR, unguided and guided programs among psychotherapists in clinical training (PiT) for different application purposes, including prevention, treatment substitute and treatment addition in acute care as well as aftercare. Additionally, factors that potentially predict EMH acceptance have most often been assessed in general and not for distinct EMH services. Thus, another aim of this study was (2) to apply an extended UTAUT model to exploit which predictors best determine EMH service acceptance. We chose PiT as our study population because they will shape the future healthcare system. In Germany and Switzerland, PiT already hold a university degree in either psychology or medicine and are now in their postgraduate clinical training which is required to obtain the state-approved permission to practice psychotherapy. Even though the advancing digital transformation of healthcare has already started to shape the professional routines and careers of PiT, their perspective has rarely been included in research.

MATERIALS AND METHODS

Study Design

This is an exploratory secondary analysis based on data derived from a cross-sectional survey-study that was carried out by a research team of the University of Zurich in summer 2020. For the primary analysis the acceptance and perceived barriers of EMH were calculated as an average of five different EMH services (psychotherapy via telephone, psychotherapy via videoconference, VR, unguided and guided programs) among PiT. The current acceptance scores of EMH services were compared to pre-COVID-19 acceptance scores, which were assessed retrospectively. Results will be reported elsewhere in full length[1]. Participants were recruited between June and July of 2020 via recognized educational institutions for psychotherapy within Germany and the German-speaking part of Switzerland. Recruitment was administered solely via e-mail, asking the post-gradual educational institutions to forward the link to the survey to PiT. Thereby, PiT were directed to the survey, which was conducted online and completely anonymous. The survey contained 50 questions and mean processing time was 19.1 min (SD = 5.9). As an incentive, participants could take part in a raffle of book vouchers worth 50 euros. Institutions were contacted again if they did not answer the request after 2 weeks. In total, 29 institutions in Switzerland and 232 institutions in Germany were contacted. Since only a few institutions gave feedback on forwarding the questionnaire, no statement can be made about the response rate on an institutional level. In total, the questionnaire was opened 692 times, with 228 PiT completing the survey which results in a dropout rate of 68.7 %. We could not control for multiple clicking, thus the dropout rate might appear higher than it actually is 0.12 participants

[1]Staeck, R., Drüge, M., Albisser, S., and Watzke, B. (submitted). Acceptance of E-mental health interventions and its determinants among psychotherapists-in-training during the first phase of COVID-19.

were excluded from analyses as they had not started the practical part of their postgraduate clinical training yet. After written consultation with the President of the Ethics Committee of the University of Zurich on 3 March 2020 and the checklist to self assess ethical safety, no further approval of the ethics committee was necessary to garantuee the ethical safety of the study.

Measures

Sociodemographic Characteristics

The survey contained items on sociodemographic data covering age categorized in eight subgroups (20–24 to 55–59, each category including 5 years) to preserve anonymity of respondents, sex, education, country of education (Switzerland or Germany) and theoretical orientation (i.e., behavioral therapy, depth psychology or psychoanalysis, systemic therapy, humanistic therapy). Following sociodemographic questions, the survey continued with a definition of EMH (47) and each EMH service (68).

Primary Outcome

Acceptance was operationalized according to UTAUT (28). Consequently, acceptance was assessed using three items: "I could imagine including the following EMH services in my work", "I intend to try out the following EMH service in my work within the next year", and "How high is your intention to use the following EMH service in your work ever?". The first two items were rated on a 5-point Likert scale ranging from (1) *totally disagree* to (5) *totally agree*. The third item was rated on a scale ranging from 0 to 100 and adapted from Elfeddali et al. (69) to measure the intention strength. For statistical analyses, the third item was converted into a 5-point Likert scale and a mean score of all three items was calculated for EMH acceptance.

Secondary Outcomes

Acceptance of different EMH services for various application fields was operationalized as the intention to use psychotherapy via telephone, psychotherapy via videoconference, VR and unguided as well as guided programs for prevention, therapy substitute in acute care, therapy addition in acute care and aftercare (e.g., "Which EMH services would you use for prevention?"). All items were rated on 5-point Likert scales ranging from (1) *totally disagree* to (5) *totally agree*, with higher scores indicating elevated acceptance. The UTAUT predictors performance expectancy (e.g., "The following EMH service would be a useful extension to existing treatment measures"), effort expectancy (e.g., "I would find the following EMH service easy to use and to understand"), social influence (e.g., "My colleagues would approve the use of the following EMH service") and facilitating conditions (e.g., "I have the necessary preconditions for using the following EMH service") were measured each with two items that were partly adapted from previous studies (28, 33). Answers were rated on a 5-point Likert scale ranging from (1) *totally disagree* to (5) *totally agree*. Barriers (i.e., data insecurity, impersonality, irresponsibility, legal concerns, concerns about therapeutic alliance) and advantages (i.e., time flexibility, simplified information provision, geographic flexibility, and simplified contact maintenance) were assessed as other possible predictors of acceptance and also based on previous studies (70–73). Additionally, the survey included three items on the knowledge about EMH services that were adapted from Hennemann et al. and Ebert et al. (e.g., "I know what I can expect when using virtual reality as a therapeutic tool") (28, 33). Answers were rated on a 5-point scale ranging from (1) *totally disagree* to (5) *totally agree*. The item on EMH experience in their role as healthcare provider (e.g., "In percentage, how much do you already use the following EMH services in your therapeutic work?") was adapted from previous studies (33). The item on evidence assessment of EMH services (e.g., "How would you rate the scientific evidence base of the following EMH services?") was self-constructed. All items that we used for our analyses can be found in the **Supplementary Materials**, including the English translation.

TABLE 2 | V-statistics of EMH service acceptance for different application purposes.

	V	*p*
Prevention—psychotherapy via telephone	10,323.000	**<0.001**
Prevention—psychotherapy via videoconference	10,859.000	**<0.001**
Prevention—VR treatment	5,731.500	0.870
Prevention—Unguided EMH programs	13,156.500	**<0.001**
Prevention—Guided EMH programs	11,408.500	**<0.001**
Treatment addition—psychotherapy via telephone	16,788.000	**<0.001**
Treatment addition—psychotherapy via videoconference	18,368.500	**<0.001**
Treatment addition—VR treatment	5,649.500	0.962
Treatment addition—unguided EMH programs	3,791.500	1.000
Treatment addition—guided EMH programs	8,176.500	**<0.001**
Treatment substitute—psychotherapy via telephone	7,089.000	0.991
Treatment substitute—psychotherapy via videoconference	10,608.000	0.084
Treatment substitute—VR treatment	1,059.500	1.000
Treatment substitute—unguided EMH programs	441.000	1.000
Treatment substitute—guided EMH programs	3,050.000	1.000
Aftercare—psychotherapy via telephone	19,372.000	**<0.001**
Aftercare—psychotherapy via videoconference	18,352.000	**<0.001**
Aftercare—VR treatment	5,176.500	0.958
Aftercare—unguided EMH programs	12,061.000	**<0.001**
Aftercare—guided EMH programs	12,968.000	**<0.001**

Wilcoxon signed-rank test.
For all tests, the alternative hypothesis specifies that the median is >3.
Values indicated in bold are significant.

Statistics

Data were analyzed using IBM SPSS Statistics 26 and R (Version 4.0.0). To answer the question whether the acceptance of EMH services varies between application purposes, we used as a statistical model a 2-factor within-subject (repeated measure) ANOVA with the factors EMH services (five steps: psychotherapy via telephone, psychotherapy via videoconference, VR treatment, unguided programs, guided programs) and application purposes (four steps: prevention, treatment substitute, treatment addition, aftercare)

TABLE 3 | Estimates of barriers to the acceptance of EMH services.

	EMH service acceptance	
Predictors	**Estimates**	***p***
Constant	4.93 (0.14)	**<0.001**
EMH service: videoconference	0.17 (0.08)	**0.043**
EMH service: VR treatment	−0.43 (0.08)	**<0.001**
EMH service: unguided	−0.22 (0.09)	**0.010**
EMH service: guided	−0.28 (0.08)	**0.001**
Data Insecurity	−0.03 (0.03)	0.308
Impersonality	−0.24 (0.03)	**<0.001**
Irresponsibility	−0.05 (0.03)	0.150
Legal Concerns	−0.07 (0.03)	**0.027**
Concerns about Therapeutic Alliance	−0.16 (0.04)	**<0.001**

N CASE 209.
Observations 991.
Marginal R2 / Conditional R2 0.298 / 0.557.
Values indicated in bold are significant.

TABLE 4 | Estimates of drivers to the acceptance of EMH services.

	EMH service acceptance	
Predictors	**Estimates**	***p***
Constant	0.96 (0.17)	**<0.001**
EMH service: videoconference	0.26 (0.08)	**0.001**
EMH service: VR treatment	−0.51 (0.10)	**<0.001**
EMH service: unguided	−0.77 (0.09)	**<0.001**
EMH service: guided	−0.69 (0.09)	**<0.001**
Simplified information provision	0.27 (0.03)	**<0.001**
Time flexibility	0.14 (0.03)	**<0.001**
Geographic flexibility	0.09 (0.04)	**0.012**
Simplified contact maintenance	0.18 (0.03)	**<0.001**

N CASE 209.
Observations 991.
Marginal R2 / conditional R2 0.361 / 0.578.
Values indicated in bold are significant.

and EMH acceptance as dependent variable. The model included both main effects (EMH services and application purposes), as well as their interaction (EMH services x application purposes).

To identify how different barriers to the acceptance of EMH services might differentially affect EMH service types, we adopted a two-step approach. First, we identified an appropriate model of the relation of the barriers to the different EMH services in terms of general acceptance. Specifically, we considered three candidate linear mixed-effects models in our model set. All models included a main effect of EMH service type and a random subject intercept. The random subject intercept was included as acceptance was assessed multiple times, that is once per EMH service for each participant (i.e., as a repeated measure). This is a standard procedure to account for within-subject correlation of measures (e.g., see (74), p. 29). The first model (A1) additionally included a main effect of all five barriers each (data insecurity, impersonality, irresponsibility, legal concerns, concerns about therapeutic alliance), as well as pair-wise interaction terms of each barrier and EMH service type. Hence, this model represented a differential relationship of barriers to EMH service acceptance depending on the type of service. The second model (A2) dropped the interaction terms, hence representing a uniform influence of the barriers on EMH acceptance. The third model (A3) dropped the main effect terms of the five barriers, representing no influence of the barriers on EMH acceptance. Our criterion of model comparison was based on Akaike Information criterion (AIC) weights (75), which express the probability that a model is the best in the model set conditional on the data. Second, we inspected the regression coefficients of the best fitting model specifically for the five barriers to gain insights on which barriers had a significant influence on EMH acceptance.

We followed an equivalent procedure to better understand the influence of advantages of EMH services. Again, we firstly identified an appropriate descriptive model, considering three candidate linear mixed-effects models in our model set. All models included a main effect of EMH service type and a random subject intercept. The first model (B1) additionally included a main effect of all four advantages each (simplified information provision, time flexibility, geographic flexibility, simplified contact maintenance), as well as pair-wise interaction terms of each advantage and EMH service type. Hence, this model represented that the relationship of advantages to EMH service acceptance depended on the type of service. The second model (B2) dropped the interaction terms, hence representing a uniform influence of the advantages on EMH acceptance. The third model (B3) dropped the main effect terms of the four advantages, representing no influence of the advantages on EMH acceptance. Again, we inspected the regression coefficients of our best fitting model specifically for the four advantages, to gain insights on which of them had a significant influence on EMH acceptance.

Lastly, we aimed to put the different pieces of our data modelling together within the UTAUT framework. Specifically, we wanted to test if adding possible influences of barriers and advantages (depending on the analyses above) presented a meaningful extension to the classic UTAUT predictors and simple comparison model featuring only demographic predictors (age, gender). All models included a main effect of EMH service type, age, gender, and a random subject intercept. In addition, model C1 included the UTAUT predictors (performance expectancy, effort expectancy, social influence, and facilitating conditions), the barriers and advantages, as well as knowledge about, experience with and subjective assessment of the scientific evidence base of different EMH services as they have been shown to have an influence on EMH acceptance. Model C2 only additionally included the UTAUT predictors, while model C3 did not include additional predictors. Again, our criterion of model comparison was based on Akaike Information criterion (AIC) weights.

TABLE 5 | Estimates of EMH service acceptance determinants (advanced UTAUT model).

	EMH service acceptance	
Predictors	**Estimates**	***p***
Constant	0.29 (0.36)	0.414
Age: 25–29	−0.19 (0.25)	0.449
Age: 30–34	−0.15 (0.25)	0.563
Age: 35–39	−0.11 (0.27)	0.672
Age: 40–44	−0.08 (0.28)	0.770
Age: 45–49	−0.17 (0.32)	0.603
Age: 50-54	−0.47 (0.60)	0.428
Age: 55–59	−0.10 (0.35)	0.785
Gender: male	−0.16 (0.12)	0.189
EMH service: videoconference	−0.02 (0.07)	0.808
EMH service: VR treatment	−0.20 (0.10)	0.059
EMH service: unguided	−0.06 (0.09)	0.521
EMH service: guided	−0.25 (0.09)	**0.004**
Experience with EMH services	0.01 (0.00)	**<0.001**
Knowledge about EMH services	0.04 (0.03)	0.181
Evidence assessment of EMH services	0.01 (0.00)	**<0.001**
Data Insecurity	0.01 (0.02)	0.733
Impersonality	−0.06 (0.03)	**0.038**
Irresponsibility	−0.01 (0.03)	0.655
Legal concerns	−0.00 (0.02)	0.851
Concerns about therapeutic alliance	−0.10 (0.03)	**<0.001**
Simplified information provision	0.09 (0.02)	**<0.001**
Time flexibility	0.07 (0.03)	**0.005**
Geographic flexibility	−0.02 (0.03)	0.432
Simplified contact maintenance	0.07 (0.03)	**0.009**
UTAUT: performance expectancy	0.36 (0.04)	**<0.001**
UTAUT: social influence	0.19 (0.04)	**<0.001**
UTAUT: facilitating conditions	0.01 (0.03)	0.654
UTAUT: effort expectancy	0.08 (0.04)	0.078

N CASE 209.
Observations 991.
Marginal R2 / conditional R2 0.584 / 0.738.
Values indicated in bold are significant.

RESULTS

Sociodemographic Characteristics

Figure 1 provides a summary of key sociodemographic characteristics. The sample size was $n = 216$ participants, with $n = 60$ participants who trained in Switzerland (27.8%) and $n = 156$ in Germany (72.2%). Most of them were female (88.4%) and between 25 and 39 years old (85.2%). $N = 197$ respondents studied psychology (91.2%) and $n = 6$ medicine (2.8%) before starting with their clinical training to become a psychotherapist and $n = 13$ indicated completing other degrees (6%). Regarding the theoretical orientation, 67.1% stated that they are trained in behavioral therapy (cognitive/cognitive-behavioral), 16.2% in depth psychology or psychoanalysis, 12.5% in systemic therapy, and 4.2% in humanistic therapy. $N = 33$ participants named various or different integrative approaches (15.3%).

Acceptance of EMH

Based on prior research (33, 70) the mean score of EMH acceptance was categorized as low (1–2.34), moderate (2.35–3.67), or high (3.68–5). In general, results revealed that acceptance of EMH was moderate ($M = 3.4$, $SD = 1.12$), while acceptance of psychotherapy via videoconference was highest ($M = 3.7$, $SD = 1.15$) and acceptance of unguided programs was lowest ($M = 2.55$, $SD = 1.14$). **Table 1** gives an overview.

Among respondents, general perceived personal knowledge about EMH was moderate ($M = 3.64$, $SD = 0.86$), while psychotherapy via videoconference was most well-known ($M = 4.34$, $SD = 0.72$). Practical experience with EMH was generally low, as participants stated using EMH services in only one out of ten therapeutic cases ($M = 10.37$, $SD = 10$, range 0–100%) between the onset of the COVID-19 pandemic and the time of data collection (June-July 2021). However, there were considerable differences between EMH services and high variance scores within psychotherapy via telephone and videoconference. Psychotherapy via videoconference ($M = 26.55$, $SD = 28.80$) and via telephone ($M = 23.05$, $SD = 25.07$) was used in about one out of four therapeutic cases. Participants indicated serving only $M = 1.34\%$ ($SD = 2.2$) of their patients with VR. Lastly, PiT recommended unguided EMH programs to only $M = 3.38\%$ ($SD = 10.50$) of their patients, while they stated that they have accompanied $M = 4.19\%$ ($SD = 12.95$) of their patients with guided programs.

Acceptance of EMH Services for Different Application Purposes

Figure 2 provides an overview of the key results. Mauchly tests for sphericity revealed relevant violations (all $p < 0.001$) wherefore we report Greenhouse-Geisser corrected statistics. Our results confirmed the expected heterogeneity in the acceptance of different types of EMH services depending on their intended application purpose. Specifically, we found an interaction effect of EMH service and application purpose ($F(6.229, 1283.088) = 111.497$, $p < 0.001$, $\eta^2 = 0.21$). Post-hoc tests showed that, on average, over all application purposes, psychotherapy via videoconference was the most accepted EMH service (all $p\_bonferroni < 0.001$). Further, EMH services were comparatively less accepted as a treatment substitute in acute care than for other application purposes (all $p\_bonferroni < 0.001$). Interestingly, unguided and guided programs were specifically well accepted in preventive care (more so than all other services, all $p\_bonferroni < 0.059$). VR was comparatively less accepted across all application purposes (all $p\_bonferroni < 0.001$).

Beyond comparative statements, we used one-sample, one-sided Wilcoxon signed-rank tests against test value of 3 (neutral) to test which EMH services for which application purposes were seen as a valuable addition to the therapy catalogue on absolute scale. This was the case in 11 of 20 combinations. Specifically, results show that EMH services, except VR, are seen as useful for prevention and aftercare whereas they are not accepted as treatment substitution. **Table 2** summarizes the results.

Determinants of EMH Service Acceptance

Influence of Barriers on the Acceptance of EMH Services

To identify how different barriers to the acceptance of EMH services might differentially affect EMH service types, we considered three candidate linear mixed-effects models in our model set. All models included a main effect of EMH service type and a random subject intercept. The first model (A1) additionally included a main effect of all five barriers each, as well as pair-wise interaction terms of each barrier and EMH service type. The second model (A2) represented a uniform influence of the barriers on EMH acceptance, while the third model (A3) represented no influence of the barriers on general EMH acceptance. Our model comparison unequivocally favored model A2 ($Pr > 0.999$), suggesting that barriers had a uniform influence on general EMH acceptance.

An inspection of the regression coefficients of model A2 revealed that impersonality, therapeutic alliance, and legal concerns were significant predictors of EMH service acceptance (in decreasing order of regression weight – predictors were assessed on a common scale; see **Table 3**).

Influence of Advantages on the Acceptance of EMH Services

An equivalent procedure was followed to better understand the influence of advantages of EMH services. The first model (B1) included a main effect of all four advantages each, as well as pair-wise interaction terms of each advantage and EMH service type. The second model (B2) represented a uniform influence of the advantages on EMH acceptance. The third model (B3) represented no influence of the advantages on EMH acceptance. Similar to our result for the barriers, our model comparison unequivocally favored model B2 ($Pr > 0.999$), suggesting that advantages had a uniform influence on general EMH acceptance.

Inspecting the regression coefficients of Model B2, we found that all four, that is simplified information provision, simplified contact maintenance, time flexibility, and geographic flexibility were significant predictors of EMH service acceptance (in decreasing order of regression weight; see **Table 4**).

Advanced UTAUT Model

Lastly, we wanted to test if adding the uniform influences of barriers and advantages (as suggested by the analyses above) presented a meaningful extension to the classic UTAUT predictors and a simple comparison model. Our results confirmed that the extended UTAUT model (C1) which included the UTAUT predictors, the barriers and advantages, as well as knowledge about, experience with and subjective assessment of the scientific evidence base of different EMH services was the best given the model set and the data ($Pr > 0.999$), explaining 74% of variance. **Table 5** shows the regression coefficients, while **Figure 3** visualizes the predictive performance of model C1.

DISCUSSION

The present study aimed at exploring the acceptance of various EMH services among German-speaking PiT shortly after the global outbreak of the COVID-19 pandemic that has forced changes in the provision of psychological support around the world for the prevention, treatment and aftercare of CMDs.

Accordingly, there was an urgent need for valid and flexible EMH services as alternatives or additions to traditional mental health in-person measures in spring 2020. In our paper, we primarily focused on the intention to use unguided and guided EMH programs, psychotherapy via telephone, psychotherapy via videoconference and VR treatment as EMH services and prevention, therapy addition, therapy substitute and aftercare as application purposes among PiT during the first wave of the COVID-19 pandemic in Germany and the German-speaking part of Switzerland. Based on an adapted UTAUT model (28, 70), we included performance expectancy, effort expectancy, facilitating conditions and social influence as potential predictors of EMH service acceptance as well as barriers (i.e., data insecurity, impersonality, liability, legal concerns, and concerns about therapeutic alliance), advantages (i.e., time flexibility, simplified information provision, geographic flexibility, and simplified contact maintenance), EMH knowledge, experience with EMH and subjective assessment of the scientific evidence base of different EMH services.

Main Findings and Comparisons With Prior Work

Acceptance of EMH Services for Different Application Purposes

First of all, the acceptance of EMH was overall moderate among PiT. In general, acceptance of psychotherapy via videoconference was highest, while acceptance of unguided programs was lowest. This is in line with Gerlinger et al. (38), who could show that healthcare providers are, in principle, receptive to the possibilities of such unguided programs. However, from the healthcare providers' point of view, the preconditions for a successful integration into the healthcare system are not yet fulfilled. Even though a recent survey among the twenty biggest social health insurance companies in Germany shows an upward trend regarding prescription rates of medical apps, numbers are still relatively low with projected 45.000 prescriptions (76). In comparison, according to the Scientific Institute of the National Health Insurance Schemes and the Federal Association of Company Health Insurance Funds (AOK) about 685 million finished medicinal products were prescribed in 2020 (56). Nevertheless, when looking at acceptance rates across different application purposes, our results show that guided and unguided EMH programs were specifically well accepted in preventive care, even more so than all other services including synchronous interactions between the patient and therapist via videoconference or telephone. In fact, prior research has demonstrated that unguided and guided EMH programs such as medical apps are perceived as being helpful for the promotion of patient empowerment by physicians and psychotherapists (38) which has been shown to be related to health status in the general population (77). Concerning prevention and health promotion purposes, there seems to be a greater emphasis on self-help activities (e.g., help for self-help), which could be well supported

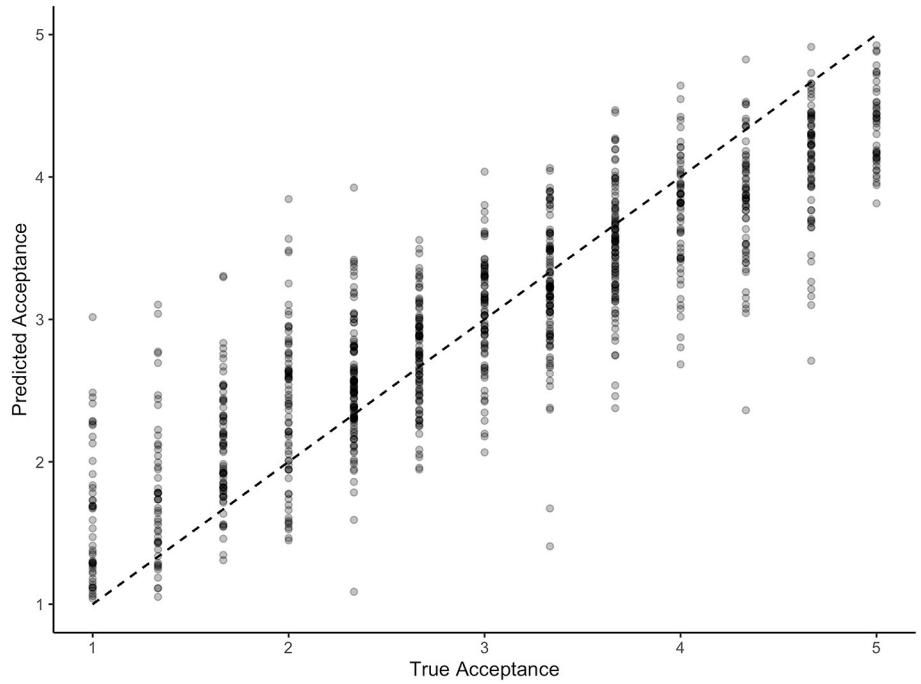

FIGURE 3 | Predictive Performance of the Advanced UTAUT Model.

by structured self-help programs, such as stress management trainings, mental health apps and early interventions. Moreover, primary prevention does not fall into the therapeutic field and does not require a trained psychotherapist to guide these kinds of nontherapeutic interventions. Additionally, our results show that EMH services, except VR, are also well accepted for aftercare purposes. At least for health experts, our results seem to be in line with prior research. For instance, Hennemann et al. (33) could show that acceptance of online aftercare for work-related stress was moderate among health professionals of various professional groups including physicians and psychologists in inpatient rehabilitation facilities. Similar to preventive care, EMH services seem to be promising tools to overcome barriers to the utilization of traditional aftercare, such as limited local accessibility, temporal incongruity with work and private life, concerns about anonymity or stigmatization (78–80). Thus, to support patients in health promotion and self-efficacy in their rehabilitation process, health experts tend to accept EMH services.

Furthermore, we identified the highest acceptance of psychotherapy using videoconference software for complementary treatment purposes, as well as similarly high acceptance ratings for therapeutic interactions via telephone. In contrast, EMH services were comparatively less accepted as a treatment substitute in acute care than for other application purposes. Particularly, as a treatment substitute psychotherapy via videoconference was accepted most, while all other EMH services were rated relatively low. Potentially, PiT prefer having more visible control of the acute treatment process including the therapeutic alliance and feel more comfortable with direct synchronous communication, including the interpretation of verbal and nonverbal signals. Interestingly, the evidence base of the effectiveness of psychotherapy via videoconference or telephone is a still a growing research area (60, 61, 81, 82) and there is considerably more evidence on the treatment effectiveness and acceptance of structured EMH self-help programs such as minimally guided iCBT which also forms the basis of some medical apps for mental health (48). From the perspective of potential clients, individuals seem to generally prefer these therapist-guided internet interventions such as iCBT over videoconferencing and unguided internet interventions when they have to choose between different EMH services (25) as well as blended delivery modes combining online or telephone contact with face-to-face psychotherapeutic sessions (83). At least for acute treatment purposes, we found contrasting results for PiT which could be explained with comparatively low practical experience with EMH services and self-reported little knowledge about EMH services. Additionally, within guided EMH programs we did not differentiate between whether oneself as a PiT is guiding the client through the EMH program or another, additional therapist which could be of interest for future research.

Moreover, our results indicate that VR was comparatively less accepted across all application purposes in the sense that VR treatment did not score highest in any purpose. Again, this result can be explained by respondents indicating having almost no experience with VR, while at the same time, having at least modest experience with psychotherapy via videoconference,

which was applied in about one out of four therapeutic cases on average. Lacking knowledge about possible advantages and disadvantages of VR might have resulted in a low willingness for future use as past research has shown a link between usage experience and acceptance (28–30). Additionally, the acceptance of VR may be reduced due to technical requirements and may further depend on its yet restricted application options especially in the context of PTSD and anxiety disorders, such as specific phobia (e.g., exposure to feared stimuli via systematic desensitization).

In line with other research, our results clearly show that EMH acceptance should be assessed distinctly as it varies between EMH services, target groups and application purposes. For instance, research by Apolinário-Hagen et al. (45) revealed that self-help books, health websites and face-to-face counselling were perceived as more useful than web-based counselling and therapies within the general population. Hennemann et al. (33) found limited acceptance of EMH interventions among health professionals of inpatient treatment, while results revealed moderate acceptance of online aftercare for work-related stress. Among licensed psychotherapists in Austria, Schuster et al. (84) could show a preference for blended (face-to-face plus web-based) interventions over web-based interventions to treat CMDs. Varying results from study to study can be linked to distinct study populations, different framing including varying application purposes and other time periods of data assessment. Additionally, a lack of shared terminology limits comparability between studies (85). Furthermore, despite these evident differences, EMH is often still assessed very broadly which leads to less meaningful results. Hence, future research should put emphasis on these differences when assessing acceptance, elicit possible explanations and agree on used terminology.

Determinants of EMH Service Acceptance

As potential advantages that influence the acceptance of EMH services, we identified simplified information provision, simplified contact maintenance, time flexibility, and geographic flexibility. Concerning perceived barriers, we found that impersonality, legal concerns, and therapeutic alliance were significant predictors of EMH service acceptance. Comparing different predictor models of the intention to use EMH services among PiT, the extended UTAUT model fitted our data best (model C1). Overall, our findings correspond to other research targeting the views and experiences of psychotherapists. Among European psychotherapists having mainly positive experiences with online consultations during the COVID-19 pandemic, De Witte et al. (43) reported several barriers that might hinder implementation, such as data security issues or concerns about relational aspects, for instance impersonality and fostering a therapeutic alliance. In a study by Sander et al. (86), German professionals reported having little experience or knowledge about internet-delivered interventions and the most frequently anticipated barriers were too severe symptoms of patients, the feared neglect of face-to-face contacts and insufficient technical equipment. The most frequently mentioned potential benefits were an optimized treatment structure and patient empowerment. Schuster et al. (84) found similar advantages of EMH services to be of importance, such as time and geographic flexibility, simplified information provision, patient empowerment but also discretion and the suitability for young patients. To further increase acceptance of and trust in EMH services, Gerlinger et al. (38) emphasize the need for verified evidence on the effectiveness, data security and interoperability of EMH services. Furthermore, the additional workload for health care providers should be transparently available before they use or prescribe EMH services, such as mental health apps.

In summary, EMH acceptance of PiT may be explained according to the UTAUT model when coupled with their perceptions of barriers and drivers as well as their practical experience as healthcare providers with EMH, knowledge about EMH and their perception of the scientific evidence base of EMH services. Even though the UTAUT model has recently been successfully validated and adapted to digital health care (9), our results show that it is necessary to extend this model and adapt it to the context of PiT given the complex nature of EMH acceptance and its determinants. In short, we did not assess all factors that could potentially influence EMH acceptance and focused on those that we perceived as being most important for PiT, knowing that there might still be missing factors that could be relevant. Congruently, Ammenwerth (87) pointed out that technology acceptance depends on multiple factors that have yet been overlooked, such as emotional, socio-organizational, cultural or workflow aspects. Thus, future research is needed to examine additional factors and strongest predictors to gain a deeper understanding of the intention to use different EMH services, while differentiating between target groups. This would help to design acceptance-facilitating interventions (AFIs) to educate PiT about different EMH services concerning applying them for prevention, treatment or aftercare purposes.

Limitations

While this study contributes to the understanding of the acceptance of different EMH services for various application purposes and its determinants, it also has some limitations that should be considered. First, we must consider the time point of assessment. Data were gathered during the first months of the outbreak of the COVID-19 pandemic which could explain higher acceptance rates compared to older studies (32, 33, 45). The given circumstances have accelerated the use of remote services and forced psychotherapists to rethink about digital alternatives to treat patients. Additionally, the online survey included a description of structural benefits of psychotherapy via telephone or videoconference, especially in extraordinary conditions such as the COVID-19 crisis, which could have positively influenced acceptance scores for these two EMH services. At the same time, general acceptance rates could also be lower compared to newer studies as experience with EMH was still relatively low among respondents and EMH experience has been shown to be positively related to technology acceptance (28, 35, 88). Even if we consider the early stage of implementation of EMH services in Germany and Switzerland (38, 89, 90), healthcare experts have gained experience with digital medicine during the

COVID-19 pandemic, the intention to use EMH services might increase concurrently.

In addition, the gender ratio was not balanced as more female than male psychotherapists in clinical training participated in our study which might have influenced our results. Moreover, the response rate was rather low, as on average less than one respondent per institution completed the survey. Age and gender were no predictors of acceptance in the advanced UTAUT model, which is likely due to the selection bias with few male participants and little variation in age. Female psychotherapists in some European countries like Germany have been shown to be more likely to endorse and provide digital psychotherapy during the first weeks of the COVID-19 outbreak in Europe, especially by those who were more concerned about an infection with COVID-19 (60). However, in our study we did not control for nontherapeutic reasons for providing digital psychotherapy, such as concerns regarding an infection.

Furthermore, the present study only focused on acceptance and fell short in the question of how behavioral intention and actual use behavior might be linked. Even though UTAUT describes behavioral intention as a direct predictor of the actual uptake (28), potential users do not always follow their intentions ("intention-behavior gap", (91)). Thus, we agree with Philippi et al. (9) that future research should focus on the relationship between the intention to use different EMH services and use behavior (92) and investigate whether identified predictors of EMH acceptance could potentially influence actual uptake rates.

Lastly, the operationalization of technology acceptance was slightly different to other studies focusing on acceptance toward digital interventions, thus comparability is limited. Even though we based our assessment of behavioral intention on the frequently used UTAUT, individual adaptations of the UTAUT questionnaire and the number of items can differ between studies. For instance, acceptance is sometimes operationalized with four items (32, 93) or two items (33) that are rated on a 5-point scale ranging from (1) *does not apply at all* to (5) *applies completely*. Apolinário-Hagen et al. (45) only used one item by assessing intentions to use EMH services with an abbreviated version of the procedure applied by Klein and Cook (94), asking participants how likely they would use 10 different conventional and EMH services in case of emotional problems on a 5-point rating scale ranging from (0) *very unlikely* to (4) *very likely*. In our study, we used three items to assess behavioral intentions, including two items that were also used by Hennemann et al. (33) and one item asking psychotherapists in clinical training for their intention to use different EMH services in their work ever (range 0–100) that was adapted from Elfeddali et al. (69) to measure intention strength.

Practical Implications

To expand the uptake of EMH, there is a need to focus on increasing psychotherapists' acceptance of EMH services as they play a crucial part in patients' attitude formation and thus on the implementation of EMH services (35). Our results provide evidence of the need to focus on informing prospect psychotherapists about advantages of various EMH services when applied in different contexts such as prevention and aftercare, but also on how potential barriers such as data security or legal concerns could be overcome. Confirmatory, a study by Humer et al (61) revealed that several psychotherapists in Austria wished for more information on data protection and security. Even before the COVID-19 pandemic, lack of personal contact, data protection and security were already seen as most important disadvantages of online interventions to prevent common mental health disorders by stakeholders such as psychotherapists, policymakers and potential users in Germany, Switzerland, Austria and Spain (95). Thus, these aspects of EMH services should be addressed in training and further education of psychotherapists. Additionally, a clear regulatory framework is needed to reduce legal concerns of psychotherapists. Countries in an earlier stage of digital health implementation into healthcare, such as Switzerland or Germany, could learn from countries that are more advanced in the implementation of EMH services such as the Netherlands or the United Kingdom (27). As a starting point, van Daele et al. (96) have recently formulated an association with the European Federation of Psychologists' Associations (EFPA) general guidelines for mental health workers, health services, regulatory agencies as well as developers to promote the implementation of evidence-based EMH services. The strong need for training and further education also becomes visible in a recent study by De Witte et al. (43), in which participants were asked whether they received any form of training on online consultations about EMH. Results revealed that only 11% of the sample received a form of training, however, only half of these training programs were specific to EMH and lasted just <4 h in every second case. In accordance, Gerlinger et al. (38) indicate that mental health workers do not feel well informed about possible benefits and risks of EMH services, while only few have already gained practical experience with EMH services (97, 98).

To address misconceptions and knowledge gaps through information provision, AFIs have been found to be an established tool in educating individuals about novel treatment options such as EMH services and in increasing their acceptance (30, 32, 45, 99). For instance, Baumeister et al. (32) could show that an AFI such as receiving a short video of blended therapy can increase performance expectancy, effort expectancy, facilitating conditions and overall acceptance toward blended therapy. In the future, similar AFIs could be integrated into the curricula of postgraduate training programs and continuous professional education to increase knowledge about our identified drivers (i.e., simplified information provision, simplified contact maintenance, time flexibility, and geographic flexibility) as well as barriers (i.e., impersonality, legal concerns, and therapeutic alliance) to the acceptance of EMH services. By making EMH an integral part of the education, PiT could gain valuable experience in integrating EMH services into their therapeutic work with patients.

Furthermore, PiT with varying theoretical backgrounds might need different education. For instance, unguided EMH

programs such as mental health apps are most often based on cognitive behavioral therapy, which could lead to the assumption that psychotherapists with a background in cognitive behavioral therapy might be more open to use such EMH services (40, 100). In line with this assumption, Baumeister et al. (32) pointed out that particularly psychodynamic oriented psychotherapists could profit from AFIs as they initially seem to be rather skeptical about unguided EMH programs. Furthermore, There are already several studies that have identified associations between theoretical orientation (e.g., psychodynamic, cognitive behavioral, and others) and attitudes toward the use of EMH services (40, 100, 101), however findings are comparatively inconsistent, thus to deduce practical implications future research in this area is needed.

Conclusions

This study is one of few to examine the acceptance of different EMH services (i.e., psychotherapy via videoconference, psychotherapy via telephone, VR, unguided and guided programs) across varying application purposes (i.e., prevention, treatment substitute, treatment addition, aftercare) from the perspective of PiT. We could show that acceptance for several EMH services differed for application purposes among PiT. The results showed that acceptance of EMH services was best predicted with an extension of the UTAUT model, including barriers (i.e., data insecurity, impersonality, liability, legal concerns, and concerns about therapeutic alliance), advantages (i.e., time flexibility, simplified information provision, geographic flexibility, and simplified contact maintenance), EMH experience, EMH knowledge, and EMH evidence assessment. As the use of EMH services will most probably increase in the next years because they offer quick and location-independent help for the prevention, treatment and aftercare of CMDs, our results highlight the need to distinctly inform PiT about different EMH services and their possible application areas. At the same time, our results provide support for stakeholders that are planning and designing training for PiT by highlighting factors that should be addressed if the goal is to increase EMH acceptance.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

After written consultation with the President of the Ethics Committee of the University of Zurich on 3 March 2020 and the checklist to self assess ethical safety, no further approval of the ethics committee was necessary to garantuee the ethical safety of the study involving human participants. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PB: conceptualization, project administration, and writing—original draft preparation. MD: conceptualization, supervision, methodology, and writing—reviewing and editing. SH: writing—reviewing and editing. RS: conceptualization, methodology, investigation, software, and data curation. FN: formal analysis, visualization, and writing—reviewing and editing. JA-H: supervision, validation, and writing—reviewing and editing. All authors have read, revised, and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdgth.2022.840869/full#supplementary-material

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Tailoring Guidance in Internet-Based Interventions With Motive-Oriented Therapeutic Relationship

Anik Debrot[1]*, *Laurent Berthoud*[1], *Franz Caspar*[2], *Thomas Berger*[2] *and Valentino Pomini*[1]

[1] *Institute of Psychology, Faculty of Social and Political Sciences, University of Lausanne, Lausanne, Switzerland,*
[2] *Department of Clinical Psychology and Psychotherapy, University of Bern, Bern, Switzerland*

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INTRODUCTION

The feasibility and effectiveness of Internet interventions for mental health problems is well-established (1, 2). Most of the rapidly growing evidence comes from studies investigating guided self-help approaches, in which the presentation of a web-based self-help programme is combined with minimal but regular therapist contact. "Therapeutic guidance" often consists of a therapist's weekly scheduled written feedback per e-mail and the possibility for clients to ask questions (3, 4). Less common forms of guidance are "technical guidance" (5) or "guidance on demand" (6). The current literature suggests that unguided internet interventions are associated with lower adherence (7) and lower effects (8). However, guidance does not always seem necessary. For instance, for social anxiety disorders, good outcomes have emerged for unguided interventions if a proper diagnosis was established [e.g. (6, 9)]. Furthermore, the benefit of guidance in internet interventions for depression is evident only in moderately to severely depressed participants but not in mildly depressed individuals (8). Overall, recent evidence shows that the association of guidance with effectiveness is rather small (8) and that not all individuals need the same form and amount of guidance (3).

Little is known about how guidance should be personalized to improve adherence and outcome, and how to ensure optimal allocation of treatment resources (8). The Supportive Accountability Model (10) provides useful *general* guidelines on how to deliver guidance to *all* participants. It argues that human support enhances adherence in Internet interventions through accountability (i.e., the perception of a therapist being trustworthy, benevolent, and competent). However, to our knowledge, no theoretical framework specifies how to optimize *individualized* support. We argue that the Motive-Oriented Therapeutic Relationship (MOTR) approach, developed and investigated in face-to-face psychotherapy (11, 12), can be a promising avenue to tailor guidance, especially with participants experiencing difficulties with the self-help programs. Indeed, in the first controlled trial investigating MOTR in face-to-face therapy, there were fewer dropouts in the MOTR condition (13). Furthermore, adding an MOTR framework to a face-to-face therapy for borderline personality disorder yielded an additional reduction in general problems and a stronger therapeutic alliance (14). Next, we will introduce the MOTR approach with an illustrative example from a study on an internet-based guided self-help treatment for several anxiety disorders (15).

MOTIVE-ORIENTED THERAPEUTIC RELATIONSHIP

In guided internet-based self-help treatments, participants can struggle completing some tasks and exercises, as illustrated in the example below[1], in this exchange of messages between a therapist and a participant. The female student, who suffered from panic disorder and depression, wrote the message below after using the program for 4 weeks. By then, she had already completed

[1]It is a modified example of real messages from Berger et al. (15), representing a prototype e-mail of rather difficult exchanges with participants.

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Tom Van Daele, Thomas More University of Applied Sciences, Belgium

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André Luiz Monezi Andrade, Pontifical Catholic University of Campinas, Brazil
Margrit Löbner, Leipzig University, Germany

***Correspondence:**
Anik Debrot
anik.debrot@unil.ch

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multiple exercises such as applied relaxation, cognitive restructuring with a thought record, and behavioral experiments [for a description of the programme; see (15)].

> *Hi,*
> *I'm feeling awful right now. I can't do what I wanted to do or what we discussed in the last message. It's just terrible! I didn't do the exercises in the program, I did not go shopping, and did not do anything for my studies. And my boyfriend says that's not so bad. Meanwhile, he complains about my whining. I am just demotivated, and everything is too much. I don't think I can do the exercises next week.*
> *Best, H.*

The therapist's response, which was not articulated according to MOTR, was:

> *Dear H.,*
> *Thank you very much for your message. You don't have to feel bad. It's not so bad that you did not manage to do the exercises. Your motivation problems will certainly pass. Please try the exercises anyway next week. Write me when you have done the activities. This also creates some commitment.*
> *I am looking forward to your email.*
> *Best wishes, D.*

Five minutes later, the participant answered:

> *I feel totally misunderstood. I feel worse than ever, and you write to me that my motivation problems are passing. I don't just whine like that, and EVERYTHING IS TOO MUCH TO ME! YOU ARE LIKE MY BOYFRIEND!*

How can we understand the participant's reaction? The basis of MOTR is the so-called Plan Analysis (11, 12), a concept and method presuming that patients employ their behavior, especially their interpersonal behavior, to achieve certain goals, motives or needs. Plans consist of a purpose/motive and means that are serving them. They are organized hierarchically, whereby the highest level is represented by more universal, basic human psychological needs. Plans may be pursued both implicitly, unconsciously, and explicitly, in full consciousness.

What Plans might the participant pursue with her initial message? What does she want to achieve with her initial statement? When she states, "*I'm feeling awful right now*" and "*It's just terrible,*" she probably wants to show how badly she is doing and make sure that she and her problems are taken seriously. Furthermore, when she explains being "*demotivated*" and that "*everything is too much*" and adds "*I don't think I can do the exercises next week,*" she probably pursues the Plan to not be further overburdened with tasks.

What does the therapist do? Their behavior is not motive-oriented at all. Rather, by stating, "*You don't have to feel bad. It's not so bad that you did not manage to do the exercises. Your motivation problems will certainly pass,*" insinuating she will be able to do them later, they do not take her and her problems seriously. Moreover, with the request "*Please try the exercises anyway. Write to me when you have done the activities. This also creates some commitment*," the therapist further overloads the participant. Consequently, the participant feels totally misunderstood and not taken seriously by the therapist, just as by her boyfriend.

Therapists using MOTR proactively adapt their behavior to the participant's motives. Relying on MOTR and the underlying motives of the participant outlined above, the therapist could have answered the following:

> *Dear H.,*
> [In order to respond to the acceptable motive "*Make sure that me and my problems are taken seriously*"]: *Thank you very much for your email. I have understood that you are very burdened, that everything is too much at the moment and I think it is good that you write to me so openly. While reading your message, I got the picture of a huge mountain of things that need to be done or that you want to do. And with the exercises and tasks, we have also contributed to this mountain.*
> [In order to respond to the motive "avoid being overburdened by all these tasks"]: *What you have written to me is important, and you should continue to write to me in the future if I overwhelm you with the tasks. Can I count on you to keep writing to me immediately if I overwhelm you with an assignment? It is also crucial for next week that you avoid taking steps that are too big. "Small steps" are essential. Could you imagine thinking about what realistic small steps would be?*
> *Best wishes, D.*

As illustrated above, a principle of MOTR is to identify unproblematic motives that guide problematic behavior, and to proactively satisfy them. It aims to render behavior that is not useful for or even hindering therapeutic progress superfluous by providing the participants with what they need. Hence, MOTR aims to satisfy the motivational basis of "problematic" behavior that is not helping patients move forward. In our example, the participant first needed to do more to be taken seriously and avoid being further overburdened ("*EVERYTHING IS TOO MUCH TO ME*") because the therapist did not recognize and satisfy the motives behind her behavior. By satisfying the guiding motives, the motivational basis of the complaining behavior weakens or dissolves, and the participant and therapist can focus on the actual therapeutic tasks at hand. For important additional considerations for MOTR, see Caspar (12).

APPLYING MOTR TO INTERNET INTERVENTIONS

The effects of MOTR on the quality of the therapeutic alliance and treatment outcome were demonstrated in several studies in face-to-face therapy [see (12)], including a randomized controlled trial with patients with borderline personality disorder (14). In guided internet-based interventions, there is only anecdotal evidence that the application of MOTR is feasible and useful (16). However, we can expect the application of MOTR within guidance to improve adherence and outcome of internet interventions (see **Figure 1**).

First, as outlined above, MOTR allows to focus on the tasks that help the participants reduce symptoms and improve their wellbeing. As illustrated above, participants no longer need unproductive behaviors when their motivational basis is satisfied.

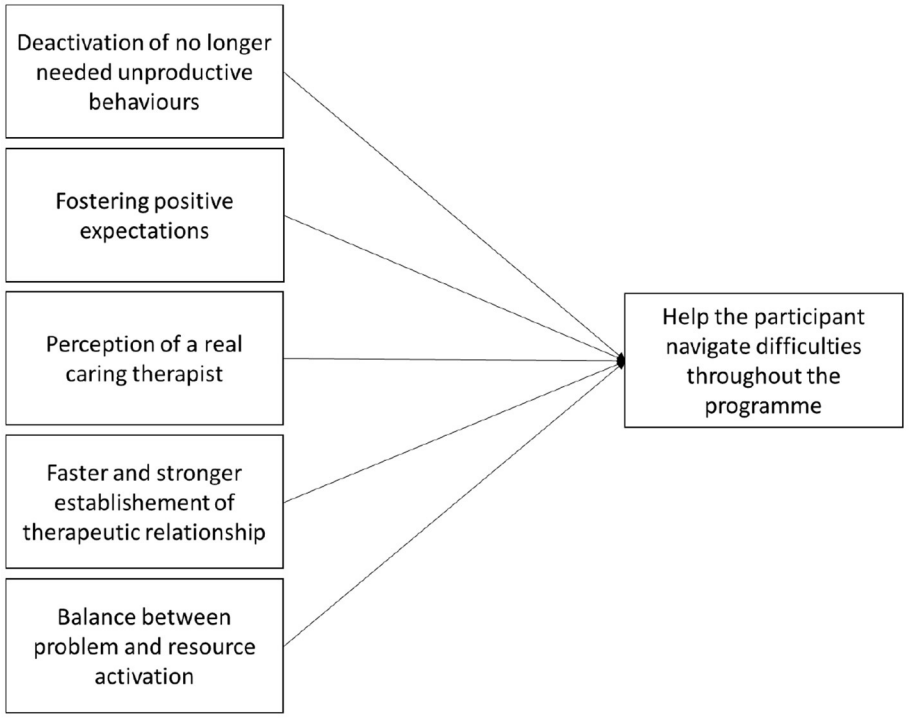

FIGURE 1 | Expected MOTR processes in internet interventions.

Second, MOTR can foster patient's positive expectations toward the intervention. Indeed, with statements that are neither trivial nor trivializing, and that do not serve as an incentive which effect could be deleterious on a motivational level, MOTR can help to overcome moments of discouragement or rupture.

Third, individualized guidance allows participants to perceive a trustworthy and competent therapist on the other side of the screen, a genuinely caring human being able to understand their unique motives empathically. Thus, MOTR could increase the supportive accountability of therapists (10). Indeed, the significance of the therapist's credible communicated empathy for a successful therapeutic outcome was proven long ago (17).

Fourth, MOTR could speed up the establishment of a therapeutic alliance by making the therapist attuned faster to the participants' needs compared to conventional, somewhat standardized guidance. Current research suggests that the therapeutic alliance can also be established in internet interventions and is related to treatment outcomes (3, 18). However, this research often uses self-report measures. Because participants' expectations regarding the alliance in guided internet interventions usually are relatively low, the patients' alliance assessment is often very positive (3). Despite of this, there is room for improvement and deepening of the therapeutic relationship.

Finally, the tasks and exercises introduced in self-help programs, such as cognitive restructuring and exposure exercises, are often challenging for participants. Indeed, they often bring them into direct contact with painful emotions. In face-to-face therapy, evidence shows that productive therapeutic work is more likely if therapists do not mainly focus on problems and painful emotions, but also activate resources and focus on the patient's sound and healthy parts (19). In Internet interventions, resources activation is often realized in the guidance part. MOTR helps addresses a participant's individual motivational resources. Overall, MOTR can help to create a balance between problem and resource activation.

Hence, these five aspects allow to accompany the participant throughout different difficult moments during the intervention. At the beginning, some participants might not yet be in an action phase, ready to take steps to change and to realize the tasks and exercises delivered through the self-help program (20). They might thus benefit from the individualized motivational support provided by MOTR. During the intervention, participants may experience alliance ruptures, difficulties completing the exercises, understanding the psychoeducation, or seeing the meaning of their participation. As illustrated above, MOTR can provide individualized solutions that help participants seeing the benefits of the interventions. Finally, at the end of the intervention, MOTR might help the participants deal with the difficulties of terminating the contact with the therapist by fostering productive work with the self-management tasks at hand.

CONCLUSION AND OUTLOOK

There is little work on how guidance can be optimally implemented in guided self-help approaches. To apply MOTR

to Internet interventions, therapists would ideally perform a Plan Analysis-based case formulation. We would recommend that the professionals be trained psychologists who have received specific MOTR training and some supervision during their first guidance experiences. Some training is particularly important, as a limitation to applying MOTR to Internet interventions is the limited information about the patient (i.e., lack of non-verbal information or medical history). We anticipate MOTR to be particularly useful for more difficult patients [e.g., with higher symptom levels, see (8), or with personality disorders, see (21, 22); or bipolar disorder, (23)]. Moreover, MOTR could be particularly suitable to a guidance on demand format, as the quality rather than the quantity of guidance appears to influence outcome (4). An RCT comparing an already tested or newly developed Internet intervention with classic therapeutic guidance vs. MOTR-based guidance would allow to assess the added benefit of such an approach.

MOTR provides a promising avenue to improve the quality and impact of guidance in Internet interventions. MOTR-based messages can be expected to improve the efficiency of guidance as they respond more closely to the participants' needs and functioning. Future research should investigate whether this approach can indeed help improve the adherence and effectiveness of guided Internet interventions.

AUTHOR CONTRIBUTIONS

AD and LB drafted the paper. FC, TB, and VP revised the work. All authors contributed to generate the ideas for the present paper and provided approval of the version to be submitted.

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OPINION
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Progress in Objective Detection of Depression and Online Monitoring of Patients Based on Physiological Complexity

Milena Čukić [1,2,3*] *and Victoria López* [4]

[1] *Institute for Technology of Knowledge, Complutense University, Madrid, Spain,* [2] *3EGA B.V., Amsterdam, Netherlands,* [3] *General Physiology and Biophysics Department, Belgrade University, Belgrade, Serbia,* [4] *Quantitative Methods Department, Cunef University, Madrid, Spain*

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***Correspondence:**
Milena Čukić
micukic@ucm.es

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The advent of artificial intelligence (AI) and machine learning (ML) in particular, in medicine, holds many promises. Although the acceptance of any innovation in medicine is chronically slow, psychiatry showed to be especially conservative in this regard (1). There are brilliant examples of ML applications in medicine, such as skin-cancer/sarcoma detection (2), early detection of retinopathies (3), and many more (4). But despite a lot of effort invested in computational psychiatry projects (5) we can see zero clinical applications (6). In addition, recent publications coming from review done by AI experts are showing that 'medical information is more complex and less available than the web data that many algorithms were trained on, so results can be misleading' (7, 8).

Our group focused mainly on data-driven computational psychiatry research (9–14). We also became aware of so-called unwarranted optimism (15–17) and reported on it (10, 12). The expression' unwarranted optimism' is coined in ML community to signify for unrealistically inflated high accuracies of models due to unresolved Dimensionality of problem, absent external validation, unproportional ratio between number of variables and number of subjects in high-dimensional medical datasets, and existance of unattended blind spots. It also illustrates the phenomenon that the scientific community, in our opinion, lulles itself into thinking that we are developing models that work much better than they actually do (7).

A recent publication demonstrated that ML's purely reliance on patient's medical history, medication, epidemiological data, and scales/questionaries data (18) are simply not capable of providing practically useful results. We also explored the possibilities of this methodology in forecasting mania in bipolar depression disorder-BDD (13, 14, 19, 20). In this research we collected daily self-reports (via mobile phone applications), clinical assessment (standard clinical interviews and scales/questionaries), medical histories (including medication, and other important variables), several sleep variables, smartwatch variables (173 variables per person in total) in attempt to construct an accurate dynamical model of transition between five clinically defined states and in order to forecast mania phase. We used complex pipeline, several feature extraction methods, several feature selection models, and applied four different ML models and network flow model, in order to mathematically describe clinically compiled data (to represent the bidirectional transition between five distinct phases in BDD). The aim was in essence to extract the most relatable variables that have prognostic value in early warning of mania, that resulted in real personalized medicine application. Among all the variables the best predictors of mania were sleep quality (and duration) and irritability (13), and Random Forest scored the best. The classification

using only selected variables produced better results than using all available information. Hence, dimensionality reduction of a problem was crucial to this research.

Whelan, Garavan, Gillan, and their colleagues, explained in their publications before 2017, why computational psychiatry projects, even when relying on neuroimaging data are flawed (16, 17), arguing that some basic postulates from Information theory and Statistical learning theory are ignored, despite wide accessibility of many ML models. The consequence is overly optimistic (and misleading) results, that are not leading to clinically useful applications [see also (21–23)]. There are many publications that confirmed (among them the 2021 report from Alan Turing Institute on faulty AI application in Health) the notion that majority of AI applications in Health are simply yielding very poor results, like for example famous IBM's Watson for Oncology that failed catastrophically [(24) report (25)]. See for example (7, 26–28), for review of this particularly inflated expectations of machine learning applications in Health. As phenomenon described in Statistical Learning Theory, a "Curse of dimensionality", demonstrated to be the central problem in particular with datasets with the large number of features in vast digital health data, shown to be challenging the development of robust AI models (in particular, their generalizability). Whenever you sample from all the possible values, the average interpoint distance between samples is rising as the dimensionality of that data space changes (1D, 2D, 3D, etc.). The increased sparsity in the relevant feature space exponentially increases the volume of blind spots in data (7). Those are contiguous regions of feature space for which we don't have samples. By this the training set becomes biased in an important way, and so fails to include samples from the region (7). A small high-dimensional training sample (characteristic for majority of health applications) is susceptible to dataset blind spots (26). Also, the volume of blind spots scales exponentially with the number of features. If data from the sample is susceptible to blind spots and the data from those blind spots are encountered *after* deployment, the model can produce incorrect treatment recommendations that are not detected during model development (7).

We argue here that the central thing that *can* lead to the resolution of this frustration, is an addition of electrophysiological signals analysis, and appropriate characterization of it which yields highly accurate results in detection and prediction of any ML model used (11, 12). The overall accuracies per seven ML models used, depending of the number of principal components included, were between 92 and 95%, showing that the *proper non-linear characterization* of a resting EEG was the key for practically useful detection. We showed that in this way (characterizing EEG with non-linear measures capable to accurately detect its intrinsic dynamics), it is possible to discern between episode and remission phase in MDD (9), besides accurate detection of depression. Other groups of researchers demonstrated that it is possible to detect who is the responder to transcranial magnetic stimulation (rTMS), since this therapy has repeatedly been shown to be effective even in treatment resistant depression (TRD) (29, 30). Another non-invasive brain stimulation technique (NIBS), transcranial direct current stimulation (tDCS), has shown to be effective in MDD treatment (31, 32). We demonstrated how this modality of stimulation leaves a detectable impact on the brain lasting longer than half an hour after the stimulus was presented (9). In another publication, we explained why NIBS techniques might work in depression treatment, based on the physiological complexity approach (32). By connecting earlier findings coming from fMRI research (33), observed increased complexity in EEG (34, 35) and already mentioned decreased complexity after the therapy (29, 30), we concluded that the feature of successful therapy for depression, must be connected to its ability to decrease said aberrated complexity, that represents the distinct internal dynamic.

The key concept to understand here is the so-called physiological complexity (or complex variability in physiology), an analytical approach to electrophysiological signal analysis stemming from electrical engineering, statistical physics and complex systems dynamics theory (chaos) (36–40). A more familiar name for this approach is fractal and nonlinear analysis (41). Despite the fact that many medical professionals are labeling this approach "novel" it is not novel by any standard; seminal work by Mandelbrot from 70's, Pincus, Hausdorf, Peng, and Goldeberger from 80's and 90's last century made that possible. They all built on early mathematics work of Cantor (Cantor's set, 1893), Peano (1890), Sierpinski (Triangle,1907), Koch (Snowflake, 1909), Lucia (Lucia's set, 1917) and others who could not generalize their findings before the advent of modern computers.

If a researcher in any medical field wants to explore the effect of a certain factor, the most probable way to do it is to calculate the means, standard deviations, *p*-values, and other measures coming from frequentist statistics that dominates the field. Irregularity statistics, like any entropy-based measure, for example, quantify the changes in physiological systems in a much more accurate and practically meaningful way (42). These two approaches (standard or conventional vs. non-linear) are simply measuring different information contained in the data, but as repeatedly shown physiological signals are far more complicated that we previously thought (43). Knowing that human physiology is not linear (in essence, not additive) and has many fractal dependencies in its control mechanisms, a better approach to analyzing signals from such a complex systems dynamics would be non-linear analysis (38, 39). Wouldn't it be logical to apply analytics that is better suited for non-stationary, non-linear, and noisy signals, than to just focus on how smeared are the data around the means?

From the existing literature, coming mainly from engineering and technical background, it is clear that fractal and non-linear analysis is much better suited for this task (38, 41).

Just to mention some of the facts important in research of depression (and mood disorders in general), to improve the understanding of the above-mentioned research. Cortico-vagal control (CVC) is connected to heart rate variability (HRV), which showed to be a robust marker of depression, anxiety, and several other psychiatric conditions (44–46). Cortico-vagal control (as well as many structural and functional physiological phenomena) is proven to have fractal nature (40, 44). Heart dynamics also has a fractal structure (40). There is much research evidence on the connection between autonomous nervous system (ANS)

and heart dynamics in depression, obtained by use of non-linear analysis approach (47–51). There is also evidence that non-linear measures are much more effective in detecting this relationship with a much larger effect size in publications in the last two decades [(52) in review].

What we know now, from the analytical perspective and possible application in clinical practice, is that by the mere addition of that specific non-linear characterization of signal, possible in real-time, one can: detect depression (10, 11, 34, 53, 54), detect the subtypes of depression—melancholic vs. non-melancholic (49), detect comorbidities (48), discern episode and remission phase (9), detect cardiovascular risks early (55), differentiate between unipolar and bipolar depression (56) and even detect existing but unreported suicidal ideation (57). As we already know that small sample sizes jeopardize the overall accuracy of the ML models, the only solution to generalize and effectively arrive at real-life translation to clinical practice of those promising methods of detection/classification is to *collect more data*. The only way to go, is to organize large collaborative projects with identical protocols of data collection, similar to STAR*D. Like many things in life we should try to keep it simple: base our research on already successful research based on small samples, but increase the size of a sample; add some form of electrophysiological data and non-linear feature extraction; keep dimensionality of a problem as low as possible; always perform external validation and once we deploy the model developed in lab, keep monitoring its performance. In order to make the research reproducible, we might preregister the protocols and methods, and publish our negative results. Collaborative data sharing (anonimizied data are a good practice but time series required here are already GDPR compliant) can also contribute to the solution of this problem.

With todays' technology that made possible Telehealth &IoT (portable monitoring devices, with medical-grade signal quality), as a reliable way of remote monitoring of outpatients, we can support clinicians with objective additional information that might largely improve the effectiveness of therapy for depression. It might be close to previously envisaged personal medicine, increasing the ability of every clinician to better navigate many diagnostic decisions. Revisiting some not-so-well-known mathematical concepts that can thrive with cloud technology, would pay off in improved psychiatric diagnostics and treatment.

Although the citation is coming from the economy, it effectively applies to the adoption of these innovations in psychiatry: *The difficulty lies not in the absence of new ideas, but an escape from the old ones* (58).

AUTHOR CONTRIBUTIONS

MČ envisaged and designed the paper and performed a literature search. MČ and VL wrote the paper, reviewed the paper, and corrected the text. All authors contributed to the article and approved the submitted version.

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Associations of Face-to-Face and Instant Messaging Family Communication and Their Contents With Family Wellbeing and Personal Happiness Amidst the COVID-19 Pandemic

Wei Jie Gong[1†], *Shirley Man Man Sit*[1,2†], *Bonny Yee Man Wong*[1,3], *Socrates Yong Da Wu*[2], *Agnes Yuen Kwan Lai*[2], *Sai Yin Ho*[1], *Man Ping Wang*[2*] and *Tai Hing Lam*[1]

[1] School of Public Health, The University of Hong Kong, Hong Kong, Hong Kong SAR, China, [2] School of Nursing, The University of Hong Kong, Hong Kong, Hong Kong SAR, China, [3] School of Nursing and Health Studies, Hong Kong Metropolitan University, Hong Kong, Hong Kong SAR, China

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***Correspondence:**
Man Ping Wang
mpwang@hku.hk

[†] These authors have contributed equally to this work

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Background: Both face-to-face and instant messaging (IM) communication are important for families, but face-to-face communication has reduced amidst the COVID-19 pandemic. We examined the use and contents of both communication methods amidst the pandemic, their associations with family wellbeing and personal happiness, and the mediation effects of communication quality in Hong Kong Chinese adults.

Methods: This population-based online survey enrolled 4,921 respondents in May 2020, who reported (i) any face-to-face or IM family communication when the pandemic was severe; (ii) communication contents being classified as neutral, positive, supportive, and negative; and (iii) communication quality, family wellbeing and personal happiness (score 0–10). Associations of family wellbeing and personal happiness with communication methods and contents (no communication excluded) were examined using linear regressions (β), adjusting for each other, sex, age, socioeconomic status, and the number of cohabitants. Mediating effects of communication quality on these associations were examined. Prevalence estimates were weighted by sex, age, and education of the general population. Interactions of methods and contents were examined.

Results: Of 4,891 included respondents (female: 52.9%, 45–54 years: 37.7%, ≥65 years: 21.3%), 7.1% reported no communication, 12.7% face-to-face communication only, 26.7% IM only, and 53.4% both methods. More males and those at younger ages, had lower socioeconomic status, or fewer cohabitants showed no family communication or face-to-face only. More respondents reported neutral (83.1–99.3%) than positive (42.1–62.2%), supportive (37.5–54.8%), and negative (10.9–34.5%) contents despite communication methods. Communication quality was higher with both methods than IM only, face-to-face only, and no communication (scores: 6.7 vs. 4.5–6.6, all $P \leq 0.02$). Better family wellbeing and personal happiness were associated with using IM only (adjusted βs: 0.37 and 0.48) and both methods (0.37 and 0.42) than face-to-face

only, and positive (0.62 and 0.74) or supportive (0.45 and 0.46) contents (all $P \leq 0.001$). Communication quality mediated 35.2–93.5% of these associations. Stronger associations between positive contents and family wellbeing showed in both methods and face-to-face only than IM only (P for interaction = 0.006).

Conclusions: We have first shown that, amidst the COVID-19 pandemic, family IM communication and positive and supportive contents may promote family wellbeing and personal happiness. People with no family communication may need assistance.

Keywords: communication contents, family wellbeing, happiness, instant messaging (IM), face-to-face (F2F)

INTRODUCTION

The novel coronavirus (COVID-19) pandemic poses global threats to the wellbeing of families and individuals. Increased family-related mental burdens and personal unhappiness have been reported amidst social disruptions and financial insecurity (1–3). Health, social, and economic challenges and adverse consequences from the pandemic are increasing. Posited by Prime and Wade's framework, individuals and families would be differentially influenced by the pandemic and well-functioning families, consisting of effective communication, organization, and belief systems, would be more resilient to these risks (4).

Family communication is a core process of the concepts of family wellbeing and family system and is foundational in maintaining family relationships and fostering individual wellbeing, as stressed in many Western theories and in Chinese culture (4–7). The pandemic triggers various stressors and intensifies the needs of feeling safe, hopeful, and socially connected (8). It has dramatically changed the habitual way many families interact and communicate, especially among those who were separated across different households amidst lockdowns and other social distancing restrictions (9, 10). With such challenges disrupting usual face-to-face communication, communication via digital tools such as instant messaging (IM) has increased substantially (11). Further understanding of how and what families are communicating amidst the pandemic is needed in preparation of the "new normal" and future pandemics.

Previous studies mostly focused on IM communication in social networks in romantic relationships, friendship, and working relationships, but rarely within the whole family (12). IM users did not have emotionally closer feelings with network members when offline (13), and longer duration of IM interactions did not predict better subjective happiness (14). We searched PubMed and Web of Science using a combination of keywords including "COVID-19", "coronavirus", "family", "communication", "face-to-face", "instant messaging" and "wellbeing" up to 21 August 2021 to identify IM use in closed communication circles such as families. Only four of our previous papers separately reported the use of family IM chat groups associated with higher family functioning and wellbeing (15) and with personal happiness amidst the pandemic (16), sharing of family life information associated with higher family wellbeing (17), and socioeconomic disparities in using different digital communication methods for family communication (18). We found no reports on the contents of family communication or their associations with family and personal wellbeing amidst the pandemic.

Throughout the life course, family communication is crucial for a balanced family system and involves the exchange and sharing of information, knowledge, values, and beliefs (6, 19). The content of family communication and type of information being shared can shape behaviors, emotions, and sense of self (20, 21), and may thus influence family and individual wellbeing. In addition to providing support against social isolation and loneliness during the pandemic, family communication can also be an important source of health information (22, 23). Hong Kong has had no lockdowns during the pandemic, but almost 100% voluntary mask-wearing in the public started within a few weeks of the first COVID-19 outbreak. The government implemented social distancing regulations since 29 March 2020 (24), which deterred family gatherings and face-to-face interaction with family members. With such disruptions to in-person communication, communication via IM platforms such as WhatsApp and WeChat became popular alternatives, allowing for convenient and instant exchange of texts, voice messages, images including pictures and photos, videos, and audio clips. The pandemic has led to more older adults making use of the internet and smartphones to stay connected to family members (25, 26). In Hong Kong, both face-to-face communication and IM were previously found to be common methods of family communication (18).

We hypothesized that, (i) the use of face-to-face and IM family communication and their corresponding contents amidst the COVID-19 pandemic are associated with family and personal wellbeing, (ii) these associations are mediated by family communication quality, and (iii) communication methods moderate the associations between communication contents and outcomes. This study aimed to examine the use and contents of face-to-face and IM family communication amidst the COVID-19 pandemic, their associations with family wellbeing and personal happiness, the mediating effects of communication quality, and whether the moderating effects of communication methods exist.

MATERIALS AND METHODS

Study Design and Participants

The Hong Kong Jockey Club SMART Family-Link project (2018–2022) is a large cross-sectoral collaboration between The University of Hong Kong and 26 local family service providers, aiming to advance information and communication technology (ICT) use in family services and to promote family wellbeing and happiness in local people (27). Under this project, the Family amidst COVID-19 survey (FamCov1) was designed to examine ICT related behaviors, attitudes and concerns toward the COVID-19 pandemic, and personal and family wellbeing in Hong Kong families. It was a population-based, cross-sectional survey conducted during 26–31 May 2020 to recruit a sample as large as possible within 6 days when the second wave of COVID-9 outbreak was under control. The target population was Chinese adults in Hong Kong aged 18 years or above who can read and write in Traditional Chinese. Those who were psychologically or physically unable to complete the whole online questionnaires were excluded. Email invitations to join the online survey were sent to both probability and non-probability-based online panels of the Hong Kong Public Opinion Research Institute, a well-known local survey agency (28). Respondents voluntarily answered the questionnaires with no incentive. Among the 20,103 opened invitation emails, 4,921 (24.5%) respondents completed the whole survey. After excluding 30 respondents that had no family members, 4,891 respondents (99.4%) were included in this study.

Details of the methods have been reported in three of our papers using the same data (3, 16, 29), showing that the perceived benefits and harms of COVID-19 were associated with sociodemographic factors (3), the fear of COVID-19 showed socioeconomic differences and was associated with perceived benefits and harms of COVID-19 (29), and that the use of different IM functions in family e-chat groups amidst the pandemic was associated with family wellbeing and personal happiness (16).

Ethics approval was obtained from the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (Reference Number: UW 20-238). All respondents gave informed consent before starting the survey. This study was carried out in accordance with the Declaration of Helsinki and all its amendments.

Measurements

Independent Variables

The definitions of family ("family members who are related through biological, marital, cohabitation, or/and emotional bonding") and IM e-chat group ("a group of 3 or more people in IM communication applications such as WhatsApp or WeChat, etc.") were given before related questions. Face-to-face communication with family was asked by the question, "When the pandemic was severe, on average per week, how many days did you communicate face-to-face with family members?". Respondents answering 0 days or 1–7 days were regarded as either having none or had face-to-face communication with family, respectively. IM communication was asked by two questions, "When the pandemic was severe, on average per week, how many days did you receive/send instant messages from/to family members in family e-chat groups?". Respondents answering 0 days for both questions or 1–7 days for one/both questions were regarded as having none or had IM communication with family, respectively.

The corresponding contents of face-to-face and IM were asked using multiple-choice questions, "When the pandemic was severe, what contents did you communicate face-to-face with family members?" or "When the pandemic was severe, what contents in the instant messages you receive or send from/to family members in family e-chat groups?". The answers include COVID-19-related information, self/family-related things in daily life, self/family-related and unrelated happy/funny things, and related unhappy things, showing care, encouragement, appreciation, good wishes, other health information, and others (e.g., daily life information, news, and current affairs, etc.,).

Dependent Variables

Family communication quality was measured using a single item, "How do you find the quality of communication between you and your family members?", which has been used in our previous study (30). Family health, harmony, and happiness (3Hs) were measured using the Family Wellbeing Scale, with validity shown in our previous studies (7, 31). Family wellbeing was calculated as the average score of family 3Hs. Personal happiness was examined using a single item, "How happy do you think you are, "with reliability and validity shown in previous surveys (32). All outcomes were measured on an 11-point scale (score 0–10), with higher scores indicating better outcomes, which allows more differentiation of the answers than Likert scales with fewer options (33).

Covariates

Information on sociodemographic characteristics was collected, including sex, age group (18–24 years, 25–34 years, 45–64 years, and 65 years or above), education (primary or below, secondary, post-secondary, and university or above), monthly household income (no income, less than HK$ 4,000, HK$ 4,000–9,999, HK$ 10,000–19,999, HK$ 20,000–29,999, HK$ 30,000–39,999, and HK$ 40,000 or higher) (US$ 1.0 = HK$ 7.8), housing type (rented and owned), and household size (number of cohabitants, including the respondent).

Statistical Analysis

Education was dichotomized as secondary or below and tertiary. Monthly household income per person (income being divided by household size) was dichotomized as lower and higher using the median household income and household size of the 2019 Hong Kong census data (34). Socioeconomic status was calculated as a composite score of education (0 = secondary or below, 1 = tertiary), income (0 = lower, 1 = higher), and housing (0 = rented, 1 = owned) and analyzed as low (0–1), medium (2), and high (3). Communication methods were divided into four groups, including no communication, face-to-face only, IM only, and both methods. Contents in

TABLE 1 | Weighted characteristics and family and personal outcomes by communication methods[a].

Characteristics	No family communication (n = 348, 7.1%)		Face-to-face only (n = 619, 12.7%)		IM only (n = 1,304, 26.7%)		Both methods (n = 2,607, 53.4%)	Total
	n (%)	P (vs. both methods)[c]	n (%)	P (vs. both methods)[c]	n (%)	P (vs. both methods)[c]	n (%)	n (%)
Sex		0.03		<0.001		<0.001		
Male	183 (52.5)		403 (65.1)		505 (38.8)		1,204 (46.2)	2,295 (47.1)
Female	165 (47.5)		216 (34.9)		799 (61.2)		1,403 (53.8)	2,583 (52.9)
Age group (years)		0.03		<0.001		<0.001		
18–24	43 (12.4)		83 (13.3)		21 (1.6)		270 (10.4)	416 (8.5)
25–44	127 (36.6)		244 (39.4)		374 (28.7)		837 (32.1)	1,581 (32.4)
45–64	127 (36.6)		200 (32.3)		545 (41.8)		967 (37.1)	1,839 (37.7)
≥65	50 (14.4)		93 (15.0)		365 (28.0)		533 (20.5)	1,041 (21.3)
Education		0.002		0.07		<0.001		
Secondary or below	248 (72.3)		370 (60.1)		904 (70.2)		1,661 (64.0)	3,183 (65.7)
Tertiary or above	95 (27.7)		246 (39.9)		385 (29.9)		936 (36.0)	1,662 (34.3)
Monthly household income per person		0.01		0.33		<0.001		
Lower	180 (58.3)		274 (52.1)		650 (56.8)		1,098 (49.7)	2,201 (52.6)
Higher	129 (41.7)		252 (47.9)		495 (43.2)		1,111 (50.3)	1,986 (34.3)
Housing type		<0.001		<0.001		0.06		
Rented	167 (49.3)		273 (45.8)		463 (36.0)		842 (33.0)	1,744 (36.6)
Owned	172 (50.8)		322 (54.2)		822 (64.0)		1,709 (67.0)	3,025 (63.4)
Socioeconomic status[b]		<0.001		<0.001		<0.001		
Low	187 (61.6)		267 (52.8)		644 (56.6)		1,063 (48.7)	2,160 (52.3)
Medium	80 (26.5)		164 (32.5)		363 (31.9)		768 (35.2)	1,376 (33.3)
High	36 (11.9)		75 (14.8)		131 (11.5)		353 (16.2)	595 (14.4)
Number of cohabitants		<0.001		<0.001		<0.001		
Mean ± SD	1.9 ± 1.4		2.3 ± 1.1		1.8 ± 1.1		2.5 ± 1.1	2.3 ± 1.3
Family and personal outcomes, mean ± SD[d]								
Family communication quality	4.5 ± 2.8	<0.001	6.0 ± 2.2	<0.001	6.6 ± 1.9	0.02	6.7 ± 1.8	6.6 ± 2.4
Family wellbeing	5.6 ± 2.3	<0.001	6.6 ± 1.9	<0.001	7.1 ± 1.6	0.003	7.3 ± 1.5	7.1 ± 1.6
Personal happiness	5.0 ± 2.4	<0.001	5.3 ± 2.2	<0.001	6.1 ± 2.1	0.43	6.2 ± 2.0	6.0 ± 2.1

IM, Instant messaging; SD, Standard deviation.

[a] *Weighted by sex, age, and education of the 2019 Hong Kong census data. Respondents with missing data were excluded. Total percentages may not be 100.0% after rounding. Frequencies may not add up tp the total numbers after weighting.*

[b] *Socioeconomic status: a composite score of education (0 = secondary or below, 1 = tertiary), income (0 = lower, 1 = higher), and housing (0 = rented, 1 = owned), analyzed as low (0–1), medium (2) and high (3).*

[c] *Pairwise comparisons using Chi-square test for categorical variables and t-test for continuous variables with Bonferroni adjusted level of significance: 0.05/3 = 0.017.*

[d] *Score 0–10, higher scores indicate better outcomes.*

family communication were divided into four groups by their affective interpretation, including neutral (self/family-related things in daily life, COVID-19-related information, other health information, and others, e.g., daily life information, news, and current affairs, etc.,), positive (self/family-related and unrelated happy/funny things), supportive (showing care, encouragements, appreciations, and good wishes) and negative (self/family-related unhappy things) contents. Among them, neutral, positive, and negative contents have been used before (35, 36). We especially distinguished supportive from positive contents, because Chinese people tend to have implicit and indirect expressions instead of direct verbal expressions of supportive contents (37–39).

The raw data and prevalence estimates were weighted by sex, age, and educational attainment of the 2019 Hong Kong census data (40, 41). Pairwise comparisons using Chi-square tests for categorical variables and *t*-tests for continuous variables were used to compare the characteristics and outcomes of respondents having no family communication, face-to-face only, and IM only with those using both methods, and to compare the contents in the following 3 pairs of communication methods: face-to-face only vs. IM only, both methods vs. face-to-face only, and

TABLE 2 | Weighted percentages of contents by communication methods[a].

Contents	Total			One method only			Both methods (n = 2,607)		
	F2F, n (%) (n = 3,225)	IM, n (%) (n = 3,911)	P[b]	F2F only, n (%) (n = 619)	IM only, n (%) (n = 1,304)	P[c]	n (%)	P[c] (vs. F2F only	P[c] (vs. IM only)
Self/family-related things in daily life	2,564 (79.5)	2,330 (59.6)	<0.001	454 (73.3)	675 (51.7)	<0.001	2,233 (85.7)	<0.001	<0.001
Information of COVID-19	2,522 (78.2)	3,150 (80.6)	0.02	461 (74.4)	1,065 (81.7)	<0.001	2,271 (87.2)	<0.001	<0.001
Self/family-related happy/funny things	1,520 (47.1)	1,481 (37.9)	<0.001	219 (35.4)	439 (33.7)	0.46	1,495 (57.4)	<0.001	<0.001
Others (e.g., daily life information, news, and current affairs, etc.)	1,483 (46.0)	1,572 (40.2)	<0.001	241 (39.0)	465 (35.7)	0.16	1,468 (56.3)	<0.001	<0.001
Showing care	1,380 (42.8)	1,611 (41.2)	0.17	226 (36.5)	613 (47.0)	<0.001	1,347 (51.7)	<0.001	0.01
Other health information	994 (30.8)	1,384 (35.4)	<0.001	181 (29.3)	495 (38.0)	<0.001	1,093 (41.9)	<0.001	0.02
Self/family-related unhappy things	945 (29.3)	627 (16.0)	<0.001	120 (19.4)	142 (10.9)	<0.001	899 (34.5)	<0.001	<0.001
Self/family-unrelated happy/funny things	866 (26.9)	756 (19.3)	<0.001	123 (19.8)	219 (16.8)	0.10	881 (33.8)	<0.001	<0.001
Encouragements	479 (14.9)	661 (16.9)	0.02	44 (7.2)	239 (18.3)	<0.001	581 (22.3)	<0.001	0.004
Appreciations	390 (12.1)	341 (8.7)	<0.001	46 (7.4)	122 (9.4)	0.16	414 (15.9)	<0.001	<0.001
Good wishes	382 (11.9)	636 (16.3)	<0.001	37 (5.9)	262 (20.1)	<0.001	492 (18.9)	<0.001	0.36
Different kinds of contents[d]									
Neutral contents	3,174 (98.4)	3,444 (88.1)	<0.001	602 (97.3)	1,083 (83.1)	<0.001	2,589 (99.3)	<0.001	<0.001
Positive contents	1,694 (60.8)	1,717 (43.9)	<0.001	262 (42.3)	550 (42.1)	0.95	1,621 (62.2)	<0.001	<0.001
Supportive contents	1,465 (45.4)	1,796 (45.9)	0.68	232 (37.5)	701 (53.7)	<0.001	1,428 (54.8)	<0.001	0.54
Negative contents	945 (29.3)	627 (16.0)	<0.001	120 (19.4)	142 (10.9)	<0.001	899 (34.5)	<0.001	<0.001

F2F, Face-to-face; IM, Instant messaging.

[a] *Weighted by sex, age, and education of the 2019 Hong Kong census data. Respondents with no family communication and those with missing data were excluded. Contents were ranked by their weighted percentages in total face-to-face.*

[b] *Chi-square test.*

[c] *Pairwise comparisons using Chi-square test and Bonferroni adjusted level of significance: 0.05/3 = 0.017.*

[d] *Neutral contents: self/family-related things in daily life, information of COVID-19, other health information, and others (e.g., daily life information, news, and current affairs, etc.,). Positive contents: self/family-related and unrelated happy/funny things. Supportive contents: showing care, encouragements, appreciations, and good wishes. Negative contents: self/family-related unhappy things.*

both methods vs. IM only, with Bonferroni adjusted level of significance (0.05/3 = 0.017).

Adjusted regression coefficients (βs) and their 95% confidence intervals (CIs) were estimated using multivariable linear regressions to estimate the associations of outcomes, including family wellbeing and personal happiness, with the four communication methods in Model I, with the four kinds of contents in Model II, and with both methods and contents in Model III, adjusted for sex, age groups, socioeconomic status, and the number of cohabitants. People having no family communication were excluded in Model II and Model III. Based on model III, we additionally examined the mediating effects of family communication quality on these associations using the Baron and Kenny approach (42), and whether the mediating (indirect) effects were significant were examined using the Sobel tests. The bias-corrected bootstrap CIs of the total, indirect and direct effects were calculated with 1,000 replications, adjusted for sex, age group, socioeconomic status, and the number of cohabitants. The moderating effects of communication methods on the associations of contents with outcomes were examined by additionally including the interaction terms of methods and contents in corresponding regression models. A 2-sided $P < 0.05$ was considered statistically significant. All statistical analyses were performed using STATA version 15.0 (StataCorp LP, College Station, TX, USA).

RESULTS

Of the 4,891 respondents included in this study, after weighting, 52.9% of them were female, with the mean age of 43.5 years (37.7% aged 45–64 years and 21.3% aged ≥65 years). Details of their sociodemographic characteristics have been previously reported (3, 29). **Table 1** shows that after weighting, over half of respondents (53.4%) communicated with family members using both methods (face-to-face and IM messages), followed by IM only (26.7%), face-to-face only (12.7%), and no family communication (7.1%). Compared with those using both

TABLE 3 | Associations of communication methods with outcomes, adjusted β (95% CIs) (n = 4,891).

Family communication	Family communication quality[a]	Family wellbeing[a]	Personal happiness[a]
Model I[b] (n = 4,891)			
Methods			
Face-to-face only	0	0	0
No communication	−1.67 (−1.94, −1.39)***	−1.08 (−1.31, −0.85)***	−0.33 (−0.62, −0.04)*
IM only	0.35 (0.15, 0.55)**	0.40 (0.23, 0.57)***	0.53 (0.32, 0.74)***
Both methods	0.58 (0.40, 0.75)***	0.57 (0.43, 0.72)***	0.63 (0.45, 0.82)***
Model II[c] (n = 4,571, no communication excluded)			
Kinds of contents			
Neutral			
Yes (vs. No)	0.39 (0.11, 0.67)**	0.20 (−0.03, 0.44)	0.25 (−0.05, 0.55)
Positive			
Yes (vs. No)	1.00 (0.89, 1.11)***	0.48 (0.68, 0.87)***	0.81 (0.69, 0.94)***
Supportive			
Yes (vs. No)	0.90 (0.79, 1.02)***	0.67 (0.57, 0.76)***	0.66 (0.53, 0.78)***
Negative			
Yes (vs. No)	0.82 (0.69, 0.95)***	0.51 (0.40, 0.62)***	0.37 (0.23, 0.51)***
Model III [c] (n = 4,571, no communication excluded)			
Methods			
Face-to-face only	0	0	0
IM only	0.35 (0.16, 0.53)***	0.37 (0.21, 0.53)***	0.48 (0.28, 0.69)***
Both methods	0.30 (0.14, 0.46)***	0.37 (0.23, 0.51)***	0.42 (0.24, 0.60)***
Kinds of contents			
Neutral			
Yes (vs. No)	0.21 (−0.06, 0.49)	0.08 (−0.16, 0.32)	0.20 (−0.11, 0.50)
Positive			
Yes (vs. No)	0.70 (0.58, 0.83)***	0.62 (0.51, 0.73)***	0.74 (0.59, 0.88)***
Supportive			
Yes (vs. No)	0.62 (0.51, 0.74)***	0.45 (0.35, 0.56)***	0.46 (0.33, 0.59)***
Negative			
Yes (vs. No)	0.27 (0.13, 0.41)***	0.05 (−0.07, 0.17)	0.15 (−0.30, 0.01)

CI, Confidence interval; IM, Instant messaging.
$^{*}P < 0.05$.
$^{**}P < 0.01$.
$^{***}P < 0.001$.
[a]Score 0–10, higher scores indicate better outcomes, β is the score versus that for face-to-face only as reference.
[b]Model I and II: adjusted for sex, age group, socioeconomic status, and number of cohabitants.
[c]Model III: including communication methods and contents in one model, adjusted for sex, age group, socioeconomic status, number of cohabitants, and mutually adjusted for each other.

methods, more respondents having no family communication or having face-to-face communication only were male (52.5 and 65.1%, respectively, vs. 46.2%), at younger ages, and had lower socioeconomic status (low: 61.6 and 52.8%, respectively, vs. 48.7%) and fewer cohabitants (all $P \leq 0.03$); while more of those using IM only were female (61.2 vs. 53.8%), at older ages, and had lower socioeconomic status (low: 56.6 vs. 48.7%) and fewer cohabitants (all $P \leq 0.001$). The unweighted characteristics are shown in **Supplementary Table 1**.

Table 2 shows that after weighting, in face-to-face communication, self/family-related things in daily life (79.5%) were the most frequent contents, followed by information of COVID-19 (78.2%), self/family-related happy/funny things (47.1%), others (e.g., daily life information, news, and current affairs, etc.,) (46.0%), showing care (42.8%), other health information (30.8%), self/family-related unhappy things (29.3%), self/family-unrelated happy/funny things (26.9%), encouragements (14.9%), appreciations (12.1%), and good wishes (11.9%). In IM messages, information of COVID-19 (80.6%) was the most common contents, followed by self/family-related things in daily life (59.6%), showing care (41.2%), and others (40.2%), whereas encouragements (16.9%), good wishes (16.3%), self/family-related unhappy things (16.0%), and appreciations (8.7%) were the least 4 common ones. When contents were grouped into 4 kinds, fewer respondents reported neutral (88.1 vs. 98.4%), positive (43.9 vs. 60.8%), and negative contents (16.0 vs. 29.3%) in IM communication than in face-to-face communication (all $P <$

TABLE 4 | Adjusted total, indirect, and direct effects of communication methods and positive and supportive contents on outcomes mediated by family communication quality, adjusted β (95% CIs) (n = 4,571)[a].

Mediation	Family wellbeing[b]	Personal happiness[b]
IM only vs. Face-to-face only		
Relative total effect	0.37 (0.21, 0.53)***	0.48 (0.27, 0.68)***
Relative indirect effect	0.23 (0.09, 0.38)***	0.19 (0.07, 0.30)***
Relative direct effect	0.14 (0.04, 0.23)**	0.29 (0.11, 0.47)**
Proportion of relative total effect mediated	63.0%	39.4%
Both vs. Face-to-face only		
Relative total effect	0.38 (0.25, 0.52)***	0.44 (0.26, 0.62)***
Relative indirect effect	0.19 (0.07, 0.32)***	0.16 (0.06, 0.25)***
Relative direct effect	0.19 (0.11, 0.28)***	0.29 (0.13, 0.44)***
Proportion of relative total effect mediated	50.1%	35.2%
Positive contents (Yes vs. No)		
Total effect	0.62 (0.51, 0.73)***	0.74 (0.59, 0.88)***
Indirect effect	0.47 (0.38, 0.56)***	0.38 (0.30, 0.45)***
Direct effect	0.15 (0.08, 0.21)***	0.36 (0.23, 0.48)***
Proportion of total effect mediated	76.1%	51.4%
Supportive contents (Yes vs. No)		
Total effect	0.46 (0.35, 0.55)***	0.46 (0.33, 0.59)***
Indirect effect	0.43 (0.35, 0.51)***	0.34 (0.27, 0.40)***
Direct effect	0.03 (−0.03, 0.09)	0.12 (0.01, 0.24)*
Proportion of total effect mediated	93.5%	73.9%

CI, Confidence interval; IM, Instant messaging.
$^{*}P < 0.05$.
$^{***}P < 0.01$.
$^{***}P < 0.001$.
[a]Respondents having no family communication were excluded. Results were adjusted for sex, age group, socioeconomic status, and number of cohabitants, neutral contents, negative contents, and mutually adjusted for each other.
[b]Score 0–10, higher scores indicate better outcomes.

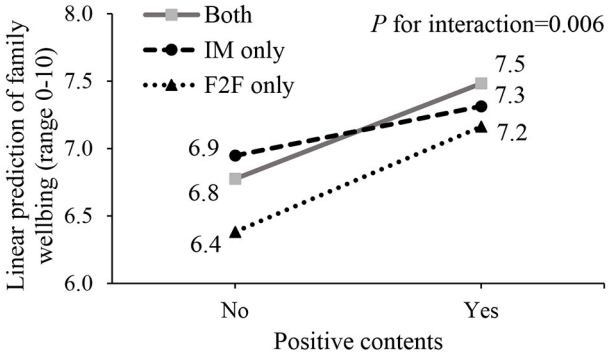

FIGURE 1 | The linear prediction of family wellbeing by communication methods and positive contents[a]. [a]IM, Instant messaging; F2F, Face-to-face.

0.001). The unweighted percentages of contents are shown in **Supplementary Table 2**.

Compared with face-to-face communication only, IM only included less self/family-related things in daily life (51.7 vs. 73.3%) and self/family-related unhappy things (10.9 vs. 19.4%), but more information of COVID-19 (81.7 vs. 74.4%), showing care (47.0 vs. 36.5%), other health information (38.0 vs. 29.3%), encouragements (18.3 vs. 7.2%), and good wishes (20.1 vs. 5.9%) (all $P < 0.001$). For the 4 kinds of contents, it included less neutral (83.1 vs. 97.3%) and negative contents (10.9 vs. 19.4%) but more supportive contents (53.7 vs. 37.5%) (all $P < 0.001$). Using both methods included higher percentages of almost all contents than using one method only (all $P \leq 0.02$) except good wishes compared with IM only (18.9 vs. 20.1%, $P = 0.36$). In general, using both methods contained more neutral, positive, and negative contents than using one method only ($P < 0.001$), except supportive contents (both 54.8% vs. IM only 53.7%) ($P = 0.54$).

Table 3 shows that after excluding those with no communication, when communication methods and contents were included in the same models, compared with using face-to-face communication only, using IM only and using both methods were associated with higher levels of family communication quality, family wellbeing, and personal happiness (Model III, adjusted βs: 0.30–0.48, all $P < 0.001$). Only positive, supportive and negative contents were associated with higher levels of family communication quality (adjusted βs: 0.27–0.70, all $P < 0.001$), and only positive and supportive contents were associated with higher levels of family wellbeing and personal happiness (adjusted βs: 0.45–0.74, all $P < 0.001$).

Family communication quality partially mediated the associations of communication methods and positive contents with family wellbeing (proportion mediated: 50.1–76.1%) and personal happiness (proportion mediated: 35.2–51.4%), and the associations of supportive contents with personal happiness (73.9%), and almost fully mediated the association of supportive contents with family wellbeing (93.5%, P for direct effect = 0.35) (**Table 4**).

Communication methods moderated the associations of positive contents with family wellbeing (P for interaction=0.006) (**Figure 1**). Positive contents had stronger associations with better family wellbeing in using both methods (estimated score changes: 0.71, 95% CI: 0.57–0.85) and face-to-face only (0.78, 95% CI: 0.53–1.03) than in IM only (0.37, 95% CI: 0.18–0.56) (P = 0.004 and 0.009, respectively).

DISCUSSION

This is the first study to report family communication methods and contents were independently associated with family communication quality, family wellbeing, and personal happiness, showing that better family wellbeing and personal happiness were associated with using IM only and both methods than face-to-face communication only, and were associated with having positive and supportive contents in family communication. About half to almost all these associations were mediated by communication quality. Communication methods moderated the association between positive contents and family wellbeing, showing stronger associations of family wellbeing with both methods and face-to-face only than IM only. These results are consistent with our three hypotheses.

Our results highlight the importance of using IM messages to communicate with family members amidst the COVID-19 pandemic, which showed better outcomes than face-to-face communication only. Due to physical isolation and social distancing, traditional face-to-face family communication and usual family gatherings have been disrupted, while digital communication via IM tools is increasingly used and often the only option in maintaining familial interactions in separated households (43). Those who could only use IM communication may value the interaction more and thus feel connected and supported. More men and younger people used face-to-face communication only probably because some might choose not to or seldom use IM messages for family communication even under social distancing restrictions. Consistent with previous studies, women and older people cared more about family affairs and participated in more IM family communication (17, 44). Their behaviors may be encouraged by perceived usefulness and enjoyment, attachment motivation, and relationship commitment, which were predictors of the intention of continuously using IM to sustain interpersonal relationships (45).

We found that when using both IM and face-to-face communication within the family context, almost all contents increased to a greater or lesser degree (15.9–87.2%) than using one method only (face-to-face only: 5.9–74.4%, IM only: 9.4–81.7%), except good wishes which were similar to IM only. Using both methods means more communication. IM messages may act as a supplement of face-to-face communication as an additional way of conversing even when face-to-face is possible, as IM is more convenient. For example, more COVID-19 and health-related information can be promptly shared in their original formats via IM messages, such as long texts, web links, photos, and short videos. Also, as Chinese people tend to indirectly express their encouragements, appreciations, and good wishes to family members (37–39), IM has become a brand-new platform to deliver and convey supportive contents beyond merely text, with emojis and many readily available e-messages for more vivid and intimate expressions (46). Face-to-face communication contains more self/family-related things in daily life and unhappy things and can provide better communication satisfaction through verbal, facial, and body language but is restricted by physical location (47).

All kinds of contents were associated with better family communication quality when sociodemographic characteristics were controlled (Model II), but only positive and supportive contents remained associated with family wellbeing and personal happiness when communication methods were also controlled (Model III). In a well-functioning family, members should be willing to share all kinds of contents, including negative ones. An effective coping mechanism in combating stress of negative life events is to seek comfort and help within social support networks such as family (48), through the sharing of affection and empathy, and giving encouragement, advice, and practical help such as health information (49). COVID-19 and health-related information have been widely spread amidst the pandemic, and the related sharing and forwarding behaviors could mean both showing care to family members and a cause of the ongoing infodemic, pandemic fear, and mental health burdens (50, 51). Previous studies have linked positive and supportive contents with confidence and competence among family members, while negative contents such as criticism were associated with lower self-esteem and defiance (20, 52). While open and direct expression of affection, both verbal and non-verbal, are encouraged in Western families (53), such as saying "I love you", this is not common in Chinese households, where strong emotions are typically held back, stemming from a historical emphasis on the regulation of social behaviors and expression of emotions (54, 55). Such differences can also be observed in the discussion of funny and humorous topics within families (56). Considering the relatively low weighted percentages of positive and supportive contents (positive: 42.1–62.2%; supportive: 37.5–54.8% vs. neutral: 83.1–99.3%), increasing these contents through IM first may lead to increased use in face-to-face communication, which may promote family wellbeing and personal happiness. Intervention studies on IM use to deliver such contents to promote family and individual wellbeing are warranted.

The moderating effect of communication methods showed that positive contents in face-to-face communication only and both methods were more strongly associated with better family wellbeing than in IM messages, suggesting that sharing self/family-related and unrelated happy/funny things by IM only may be less effective for maintaining and nourishing family relationships. In face-to-face communication, non-verbal language, such as laughter and smiles, can give real-time positive feedbacks and immediately create a happy and enjoyable atmosphere (57). According to the attachment theory, pleasant and frequent interactions with others contribute to individual mental and emotional wellbeing (45), which may evoke better family wellbeing in family communication.

The mediation effects of family communication quality can provide new evidence to Prime and Wade's framework (4). Amidst the COVID-19 pandemic, family communication provides clear information, emotional sharing, collaborative problem-solving, and dyadic and family coping to connect family members and share beliefs. Quality communication, such as using both face-to-face and IM communication and including positive or supportive contents, can thus provide security and hope for vulnerable members during periods of stress (4), shown as higher perceived family wellbeing and personal happiness in the present study.

In Hong Kong, the most westernized city in China, the high penetration rate of smartphones (91.5% in 2019) and the Internet (87.0% in 2019) means most people can conveniently use social media and IM messages (58, 59). With 93.6% of the population being Chinese, Hong Kong people highly value family relationships, which are influenced by collectivism and Confucius ideals in traditional Chinese culture (31). However, we found that 7.1% of people had no family communication and they reported the lowest family communication quality, family wellbeing, and personal happiness. They tended to be in low socioeconomic status and could be vulnerable and more adversely impacted by the pandemic than others. This is an example of digital inequality, shown as the inequality in terms of access, usage, skills, and

self-perceptions to digital engagement in individual and macro-level domains (60). Urgent attention and assistance should be given to these vulnerable people from policymakers and social welfare organizations.

Our study had some limitations. First, recall bias and social desirability bias could not be avoided in self-administered questionnaires. However, the use of communication methods and contents in family communication when the pandemic was severe was asked during the easing period of the pandemic, and recall errors would be little within such recent time periods. We used an online survey via emails without interviewers, which could help reduce social desirability bias (61). Second, although we tried to provide a clearer temporal sequence by asking the perceived outcomes during the easing period and the communication methods and contents during an earlier period when the pandemic was severe, due to the cross-sectional observational study design, we could not rule out reverse causality. Future prospective studies are needed to verify the associations and mediation effects we observed. Also, systematic bias due to residual confounding might exist. For example, people having face-to-face communication only could be lack of health literacy to share digital information with family, while sharing family life information through ICT tools were found to be associated with family wellbeing (17). Also, those having IM only might live separately with their family so face-to-face communication was unavailable. Such separation from family, especially amidst the pandemic, could lead to low family wellbeing or personal happiness. Third, as the COVID-19 pandemic changes rapidly and unpredictably, we tried to collect the largest possible sample within a short period, non-response bias could be present as younger and better-educated respondents were included. Generalization could be limited. Finally, details of the contents were not asked, and more in-depth information should be collected in future studies.

CONCLUSIONS

We have first shown that, amidst the COVID-19 pandemic, better family wellbeing and personal happiness were associated with family communication using IM only and both methods than face-to-face only, and with positive and supportive contents. These associations were partially or almost fully mediated by communication quality. Family IM communication and positive and supportive contents may promote family wellbeing and personal happiness. People with no family communication may need urgent attention and assistance. Prospective studies are needed to verify the associations and mediations.

DATA AVAILABILITY STATEMENT

The dataset presented in this article is not readily available because the sharing of data to third parties was not mentioned in subjects' consent. Requests to access the dataset can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (Reference Number: UW 20-238). Informed consent was obtained from all participants included in this study.

AUTHOR CONTRIBUTIONS

WG and SS: formal analysis and writing—original draft. BW: data curation, project administration, and writing—review and editing. SW: methodology and writing—review and editing. AL: conceptualization and writing—review and editing. SH: conceptualization, methodology, and writing—review and editing. MW and TL: supervision, conceptualization, and writing—review and editing. All authors participated in the critical review of this study and provided final approval for publication submission.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2022.780714/full#supplementary-material

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Digital Resilience Among Individuals in School Education Settings: A Concept Analysis Based on a Scoping Review

Haiyan Sun[1], Changrong Yuan[2], Qian Qian[1], Shuzhi He[1] and Qiong Luo[1]*

[1] School of Nursing, Jiangsu Vocational College of Medicine, Yancheng, China, [2] School of Nursing, Fudan University, Shanghai, China

Background: Nowadays, in an informational society, digital technologies are present in most areas of life, including school education fields. Students encounter risks or threats during online experiences. Digital resilience helps individuals recognize and manage the risks and threats they come across when they socialize, explore, or work online and plays an important role in the digital technology challenges. However, so far, the concept of digital resilience among individuals in the educational field has not been analyzed in detail.

Objectives: The purpose of this study is to clarify the concept of digital resilience among students in a school education context, describe antecedents and consequences, and suggest a conceptual model for health educators.

Methods: Walker and Avants' concept analysis method and standards of the scoping review were used to clarify the attributes, antecedents, and consequences from the included articles. A thematic analysis approach of literature was utilized to describe the study findings. No date limitations were applied.

Results: A total of 22 included articles provided data for digital resilience conceptualization. Five defining attributes for the concept were identified as follows: (1) understanding online threats; (2) knowing solutions; (3) learning knowledge and skills; (4) recovering from stress; and (5) moving forward through self-efficacy. Antecedents included digital technology-related threats influenced by individual external and internal factors. Consequences were divided into two categories: behavioral performance and psychosocial functioning.

Conclusion: Based on the results of the concept analysis, a preliminary conceptual model of digital resilience was described as a circular process toward greater performance and function in the form of understanding, knowing, learning, recovering, and moving forward, when facing stressors, challenges, or adversity. The conceptual model of digital resilience can be further tested and may inform the enhancement of digital-specific resilience measures and interventions for students.

Keywords: digital resilience, school education, psychosocial behavior, digital technology, concept analysis, scoping review

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***Correspondence:**
Changrong Yuan
yuancr@fudan.edu.cn

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INTRODUCTION

The concept of resilience has been receiving increasing interest from various disciplines of study such as psychology, ecology, sociology, education, epidemiology as well as social work trauma studies. Due to the increasing interest in resilience research, resilience has been contextualized at an individual level, family level, community level, national level, and cultural level (1). This study is interested in resilience as an individual's trait. On an individual level, resilience is generally understood as the ability to cope with the challenges, stresses, and adversities in life (2).

Since the era of big data, researchers have been studying the impact of digital technologies on health outcomes. Undeniably, digital technologies could promote human health development in many ways (3). However, people may encounter risks when using digital technologies and it is neither possible nor desirable to shield them entirely from these risks. Consequently, the increased use of digital technology has led to a spike in the rates of webinar fatigue, technology-use anxiety, and digital burnout, due to the difficulty of maintaining clear work–life boundaries (4). Interestingly, the majority of people adopt a positive attitude and behavior to cope and hope to reduce the occurrence of negative outcomes. Obviously, individuals witnessed the digital revolution and showed new forms of resilience in the digital context.

This new form of resilience in the digital space is known as "digital resilience." The concept of digital resilience was originally applied within information technology fields. Early studies on digital resilience focused on organizations' technologies and enhancing their ability to adapt and safeguard their system's normal operation when there are informational technology challenges (5, 6). Casalino et al. (7) depicted digital resilience as a constellation of strategies, practices, policies, and programs that safeguard a society's ability to maintain, change, and recover digital capabilities and withstand digital crises and shocks in the organizational level. In technical orientation, digital resilience is described as the technical capabilities of systems and infrastructure to show that they are running continuously after being attacked (8). For communities or societies, data and tools should be freely accessible, interchangeable, operational, of high quality, and up to date (8). Digital resilience in academia is mostly talked about in terms of cybersecurity. Some definitions take a behavioral orientation as they refer to digital resilience as technology adoption process against attacks (9, 10). Consequently, most of the proposed conceptual frameworks address the technologies used in achieving digital resilience instead of the human factor. As of now, the phenomenon of individuals' digital resilience is missing a clear conceptualization. In this study, the core element is human individuals in the psychological and behavioral aspects.

There are different conceptual constructions exploring or proposing frameworks to evaluate, improve, or measure digital resilience among individuals. Initially, the concept of resilience was developed in a socio-technical aspect of digital resilience during disruptive life events at an individual level. For instance, Hua et al. (11) proposed an economic resilient behavior model to study individual psychological resilience in the context of cyberterrorist attacks on financial systems. Equivalently, Budak et al. (12) conducted a study that customers responded to online privacy violations and the behavioral implications of the stressful occurrence. Later, this concept was widely expanded into the human psychobehavioral aspect. Eri et al. (13) extended the theory of social–ecological resilience in the digital technology context and defined digital resilience as the ability of learners to overcome technological difficulties and persist with online learning as they adapt to the changing trends in higher education. However, digital resilience firstly occurred in school education settings due to the massive open online courses and open-access publishing. The authors proposed a framework of digital resilience describing an institution's ability to adapt to digital challenges (14). Since the beginning of 2020, the coronavirus disease 2019 (COVID-19) worldwide pandemic has accelerated the innovation of technology in every field, and the levels of digital use have significantly increased through the pandemic. Consequently, employees were expected to work online, students were expected to study remotely, patients at one point were expected to attend online consultations, and the public was expected to conduct daily errands online due to sudden lockdowns (15). The lockdown and social distancing measures led to a significant change in the modes of work and learning. While the benefits of using technology to maintain day-to-day norms are clear, spending more time online can also increase the risk of encountering issues. This issue thus leads to a concept of how aware the students are of their digital resilience.

The risks of problematic digital behavior like digital burnout, mental health distress caused by digital failures, or unhealthy interactions on social media such as cyberbullying and cybercrime are a huge pressure for individuals. There is a need to enable individuals to build digital resilience and understand mediating psychological concerns to enhance digital resilience (16). In the last few years and above all in the last 3 years, there have been multiple attempts by scholars to define digital resilience. Some definitions agree that digital resilience is the technical capabilities of systems and infrastructure to show resilience (5, 6, 8, 17). Other definitions take a behavioral change as they refer to digital resilience as technology adoption (4, 12, 16, 18), yet the definition of digital resilience is either indistinct or inconsistent in different studies. In addition, in many cases, there is a general conflation between "digital literacy" and "digital resilience" (19). Tran et al. (20) proved a positive relationship between digital resilience and digital literacy. Digital literacy as a necessary skill of future digital citizens was correlated with greater resilience levels. Budak et al. (12) found that the digital literacy set needed to achieve digital resilience was not generic and depends on the context of the stressful event, but it had been found as a factor influencing individual resilience online. Therefore, digital literacy is generally concerned with the effective and ethical understanding and use of digital technologies, whereas digital resilience is related to the capacities of accessing, using, understanding, and spreading effective digital sources and common manipulative techniques, in particular, behavioral and attitudinal change aspects.

From the abovementioned studies, the definition of digital resilience remains to be heterogeneous across different studies. Furthermore, in the social psychological behavior of digital resilience among different populations, some studies even gave controversial results (13, 21). In addition, some concepts or

phrases exist that have similar meanings to that of digital resilience (e.g., information literacy or digital literacy), which are likely to cause confusion. To address these knowledge gaps, we analyze the concept of digital resilience to gain an in-depth comprehension of its components and support the development of theories. Therefore, our aim is to identify the concept of digital resilience, including the underlying processes, and more specifically for online learning students in school education.

METHODS

Concept analysis is used to examine the basic elements of a concept to investigate its structure and function (22). This study draws on a recognized concept analysis method to conceptualize the digital resilience of students in the context of school education (22). There is an eight-step process for concept analysis, which is shown in **Table 1**.

Concept Selection

As a concept, digital resilience is mostly talked about in terms of cybersecurity but it is still unclear at an individual social psychological behavior level. A concept analysis is used based on Walker and Avant (22) because this method is applicable that is prevalent in practice and has been used across disciplines.

Purpose of Analysis

Concepts describe the phenomena of interest, and a better understanding and application of the concept is able to promote health and wellbeing in research. The strength of a concept depends on it being clearly defined (22). However, as a concept, digital resilience is much talked about but ill-defined, so the key step is to agree on an unambiguous definition of what it actually means in a special context. Therefore, the purpose of this concept analysis is to validate the meaning of digital resilience, developing an operational definition of the concept within the context of higher education.

Literature Search Strategy

As we aimed to map the literature about digital resilience involving individuals, we decided on a scoping review methodology. Such a review is systematic and focuses on central concepts and an overview of the current state of research (23). A systematic search was conducted in electronic databases including Web of Science, PubMed, CINAHL, EBSCO, PsycINFO, Wiley, Scopus, and ProQuest on November 20, 2021. We used the keywords "digital resilience" OR "digitally resilient" OR "digitally resilient" OR "digital Resiliency" OR "online resilience" to retrieve relevant literature and bibliography. The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist was utilized to ensure completeness in the scoping review (24). This process therefore systematically, transparently, and comprehensively identifies, selects, analyzes, and synthesizes the body of literature where the conceptual expression of digital resilience is found to identify the attributes, antecedents, consequences, references, surrogate, and similar concepts and contextual variations. No date limitations were applied to the search strategy. All the studies published in English focused on digital resilience in individuals. We included peer-reviewed original publications, reviews, guidelines, and gray literature.

TABLE 1 | Eight steps for concept analysis as interpreted from Walker and Avant.

Order	Specific content
Step 1	Identify and select concept
Step 2	Clarify the purpose of analysis
Step 3	Identify the uses of concept
Step 4	Determine the defining attributes
Step 5	Construct a model case
Step 6	Construct additional cases
Step 7	Identify antecedents and consequences
Step 8	Define empirical referents

Article Selection

The selection process was carried out by two independent assessors (HS and QQ). This selection was validated by a third researcher (SH). The inclusion criteria consisted of the concept of at least one of the following items: definitions, attributes, antecedents, consequences, and/or methods for digital resilience measurement. Conference abstracts and studies that examined digital resilience beyond or below the level of individuals (organization, institution, community, and system) were excluded from the analysis. The study selection process was presented in **Figure 1**. A total of 277 results were found, and 151 studies were excluded after removing duplicates. Based on title and abstract assessments, 48 studies were excluded because of irrelevant researches, book reviews, letters to the editor, and studies published in other languages. Afterward, 56 studies were excluded in terms of the inclusion and exclusion criteria by screening the full text. Finally, 22 articles and records were included as they were particularly relevant to this concept analysis.

Data Analysis

To analyze data, we followed a two-phase approach. In the first phase, we systematically extracted basic information from each article, including authors, the year, countries, study method, population, and definition as shown in **Table 2**. In the second phase, the thematic analysis approach was used to identify attributes, antecedents, and consequences. Data were explored for contexts for meaning based on identifying the relevant characteristics of digital resilience. We categorized common themes through multiple iterations of the included studies of the articles in **Table 3**. Ultimately, the thematic network of the digital resilience concept's attributes, antecedents, and consequents was built in **Figure 2**.

RESULTS

Studies Included

Based on the above inclusion and exclusion criteria, 22 studies were retained for the final analysis, including 10 qualitative studies, 5 quantitative studies, 2 mixed-method studies, 5 various

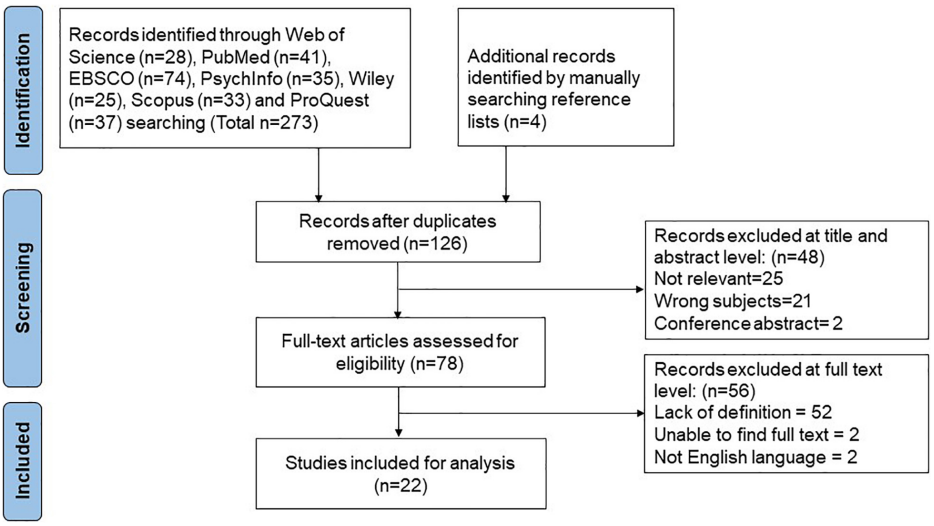

FIGURE 1 | Flow chart of study selection process.

reviews, and 1 field study. The dates of publication ranged from 2014 to 2021. The studies were conducted in 11 countries, which were mainly distributed in Europe, Asia, and North America. The studies including the details are presented in **Table 2**.

Uses of the Concept

The third step is to identify the various utilizations of the concept by consulting different resources such as dictionaries, encyclopedias, and research databases (22). The aim of this step is to scope the possible uses and definitions of digital resilience.

The Oxford English Dictionary (2018) defines "digital" as "using a system of receiving and sending information as a series of the numbers one and zero, showing that an electronic signal is there or is not there" or "connected with the use of computer technology, especially the internet" or "showing information in numerical digits." Indeed, we live in the Age of Big Data because digital technologies have become an inevitable part of our daily lives by changing how humans interact. There are some risks or threats to digital technologies, so it is neither possible nor desirable to be entirely away from risks.

Resilience is a very commonly used term within multiple disciplines. *Merriam-Webster Dictionary* defines resilience as "the ability to recover from or adjust easily to change or misfortune" (37). The *Oxford English Dictionary* defines "resilience" as (1) "the capacity to recover quickly from difficulties; toughness" or (2) "the ability of a substance or object to return to its original shape; elasticity" (38). *Mosby's Dictionary of Medicine, Psychology and Health Professions* defines resilience as "the ability of a body to return to its original form after being stretched or compressed" [(39), p. 1,606].

Different disciplines had divergent understandings of the concept of resilience. In physics and engineering sciences, resilience is conceptualized as material strength and the ability of the material to return to its original shape after physical strain (40). From an ecological perspective, resilience is the ability of an ecosystem to absorb disturbances and reorganize while undergoing change so as to continue to retain essentially the same function, structure, feedback, and therefore identity (41). In the biology field, resilience is conceptualized as the ability of an organism to regenerate in a dynamic process (42). Resilience is also applied in business with corporate trends, money, production, and the stock market with their ability to manage crises and recover from economic or market downturns (43). In the social sciences, such as psychology, social work, and nursing, the meaning of resilience shifted to a process of growth and adaptation, not only a state of bouncing back after experiencing adversity or challenges (44). Recently, research has expanded to the cybersecurity field. In these studies, resilience is linked to the ability of organizations to continue to carry out their mission by anticipating and adapting to cyber threats and other relevant attacks (5).

The above-mentioned studies focused on contextualization in different settings and disciplines, and lately, it also has been introduced into the digital field. Although the context of the concept may change, a common theme is that resilience is the ability to recover and return from threats or adversities. Some state that resilience can be understood as a stable personality trait, while some define resilience as a dynamic process that changes over time (1). Considering the popularity of the concept within various disciplines, a wide range of definitions is available.

Given the digital revolution witnessed in this epoch, individuals showed new forms of resilience through technical innovations. To narrow the search for this concept analysis, the focus is on individual resilience and more specifically on digital resilience. Previous researches about digital resilience not only concerned the community, organization, or national level but also perceived resilience at the individual social psychological behavior level (45). Digital technological innovation cannot be defined as adversity, but it can certainly be described as a major life challenge. In the first study on digital resilience in

TABLE 2 | Articles included for the final analysis.

No.	Authors/Year	Study population	Country	Research design	Definition in digital resilience
1	(18)	Children	India	Literature review	A way of coping with the digital challenges (e.g., MOOCs, open-access publishing, risk), or resilience as the final aim of a project by implementing digital methods (e.g., digital storytelling, social networks)
2	(25)	Adolescents living in out-of-home	United Kingdom	Longitudinal qualitative study	An orientation that recognizes digital vulnerabilities and seeks to empower the susceptible individuals to navigate toxic elements in the context of supportive relationships
3	(26)	The youth	South Africa	Qualitative study	The ability to acquire new digital skills that can help an individual to navigate increasingly digitally oriented, dynamic societies
4	(27)	12–17-year-old middle and high school students	United States	Quantitative study	The capacity to spring back, rebound, successfully adapt in the face of adversity, and develop social and academic competence despite exposure to severe stress or simply the stress of today's world
5	(19)	Vocational college students	Netherlands	Mixed-method research	The responsible, safe, and active participation in online communities having the capacities of critical thinking, media literacy, social behaviors online, peer safeguarding, and the law online
6	(4)	Tertiary-level students	Australian	Qualitative study	An individual student's psychological capacity to remain functional by absorbing, recovering from, adapting to and learning from adversities stemming from the use of digital technology in the tertiary educational context
7	(28)	Children and young people	United Kingdom	Scoping review	A dynamic personality asset that grows from digital activation through engaging with appropriate opportunities and challenges online, rather than through avoidance and safety behaviors
8	(29)	Children and young people	United Kingdom	Qualitative study	The responsible, safe, and active participation in online communities
9	(30)	Citizens	Thailand	Field study	Thai citizens are able to utilize digital technologies to help themselves withstand the COVID-19 pandemic
10	(20)	Secondary students	Vietnam	Cross-sectional study	Students could protect themselves and others from online risks and recover and learn from risky situations
11	(10)	Learners, instructors, policymakers	United States	Scoping review	The ability to adopt new digital technology solutions quickly and seamlessly in order to recover, rebound, and move forward if things go wrong
12	(31)	University students	United Kingdom	Literature review	Students develop an awareness to cope with adversity and challenges from technology and develop positive strategies for their technology use
13	(32)	First-year student teachers	United Kingdom	Cross-sectional study	Student teachers' ability to avoid disturbances caused by or the distractions of digital technology during their studies
14	(33)	Children	Thailand	Literature review	Digital resilience is a necessary skill for digital citizens that they can learn to deal with online violence using their coping capacities
15	(34)	Syrian refugees	Netherlands	Qualitative study	Engaging in digital media to cope, escape, feel stronger, fight back, find, and foster community in a new environment after the systemic violence and historic trauma
16	(13)	Tertiary students	Australia	Mixed-method approach	Students' tech-savviness and preparedness to adapt to different digital environments as they pursue higher education
17	(16)	All individuals	India	Literature review	A new concept that refers to the learning, recovery, and bouncing-back process after having negative or adverse experiences online
18	(35)	Remote working employees	United Kingdom	Cross-sectional study	People have e-skills, trust building, self-care, remote social, and remote emotional self-efficacy
19	(9)	Residents aged 18 years or older	Qatar	Quantitative research	Refers to an individual being cognitively well placed to adopt new technologies and accept digital transformation as a way to bounce back from disruptive events
20	(21)	Children and adolescents	United Kingdom	Qualitative study	The ability to be confident online or having a reasonable refusal in a situation or to de-escalate negative online communication
21	(36)	Translation students	Poland	Qualitative study	Be understood as a way of coping with digital challenges grounded in the concept of learner autonomy
22	(12)	Consumers	Croatia	Literature review	Consumers can change their attitudes and behaviors to withstand, recover from, and reorganize after an online privacy breach

UKCIS, UK Council for Internet Safety.

TABLE 3 | Attributes, antecedents, and consequences of digital resilience in the included studies.

No.	Authors/Year	Descriptions in attributes	Descriptions in antecedents	Descriptions in consequences
1	(18)	Learning digital methods	Environment: Challenges in medical curricular changes	Achievement: Lifelong learning
2	(25)	Understanding digital media Knowing risk management Moving forward with self-empowerment	Environment: Digital media usage Policy: Top–down cyber-safeguarding risk-management policies	Safety: Keeping safe online
3	(26)	Learning digital skills Recovering in reaction and behavior	Service: Digital infrastructure, access to local digital Support: Family Digital literacy: Skills and knowledge	1. Achievement: Improving academic achievement, and increasing self-efficacy, leadership, and empathy skills 2. Lifestyle adjustment: Long-term behavioral change
4	(27)	Understanding stress Recovering formal life Moving forward by social and academic competence	N/A	Safety: Preventing bullying and cyberbullying victimization
5	(19)	Knowing with critical thinking Learning media literacy and social behaviors online, peer safeguarding, and the law online	Digital technology-related threats and service: Extremist grooming and exploitation online Environment: The Internet and social media Digital literacy: Knowledge and skills Psychological trait: Attitudes and behaviors	Safety: Using social media effectively, safely, and constructively as effective digital citizens
6	(4)	Self-learning reactively and proactively Recovering through reactive self-efficacy and proactive self-efficacy	Psychological trait: Self-motivation toward study Support: Peer influence, university support	Achievement: Helping students achieve positive learning outcomes
7	(28)	Understanding when you are at risk Knowing what to do to seek help Learning from experiences Having appropriate support to recover	Psychological trait: Mental and cognitive health issues, vulnerabilities External factors: Environment, content, service, policy	N/A
8	(29)	Knowing using critical thinking Learning in digital literacy	Environment and content: Innovative social media simulations	Safety: Using online technology safely and appropriately
9	(30)	Learning how to optimize the use of technology Recovering life in overstepping space constraints	Environment: Information and communication technologies, the rise of information society	Mental health: Helping citizens' mental health during lockdown or mobility restriction
10	(20)	Learning a necessary skill can use digital tools Recovery in handling online risks	Digital literacy: Skills and knowledge Support: Society, family Psychological trait: Girls are more likely to obtain digital resilience than boys	Achievement: Helping students to achieve a better outcome from online learning methods
11	(10)	Recovery from the crisis Moving forward into a new reality	Policy: COVID-19 pandemic lockdown	Lifestyle adjustment: Delivering education Achievement: Promoting lifelong learning
12	(31)	Knowing balanced technology use Moving forward the transition to university life	Digital technology-related challenges and environment: Technology use transferring to a virtual context	Mental health and safety: Have the skills and confidence to conduct themselves safely in an online world
13	(32)	Understanding the importance of engaging responsibly with the digital world Recovery from dissolving the boundaries between online and off	Digital literacy Service: Online activity Content: Free information resources	Lifestyle adjustment: More time spent on individual studies Achievement: Benefit learning and working
14	(33)	Understanding digital environment Learning coping skills, problem-solving skills, and emotional literacy	Digital literacy Psychological traits: Self-esteem, psychological difficulties Support: Parental support, peer norms, school educational support Service: Kind of sites, apps, etc	Mental health: Cognitive responsibilities
15	(34)	Knowing methods in coping adversity Recovery in feeling stronger and fighting back Moving forward in finding and fostering new integration	Environment and service: Information and communication technology Social support	Health promotion and wellbeing safety: Identity management
16	(13)	Understanding technological difficulties Learning digital competence and skills Recovering with psychological resilience Moving forward with confidence	Digital technology-related challenges: Digital learning stress Environment: Digital technology innovation Service and policy: Learning environments changing Digital literacy: Prior knowledge and experience with digital technology	Lifestyle adjustment: Digital transformation and the new normal of higher education Mental health: Students' wellbeing, mitigating social isolation Achievement: Pursuing higher education
17	(16)	Understanding the awareness of online etiquette and digital deviance Knowing behavioral inhibition Learning digital hygiene skills Recovery in emotional regulation	Digital technology-related threats: Digital burnout, webinar fatigue, cyberbullying, cybercrime, doom surfing doom scrolling, digital failures Service: Awareness and impairing education about healthy and deviant digital use Support: Family Digital literacy: Digital hygiene skills, behavioral inhibition Psychological traits: Emotional regulation, confidence, self-esteem, flexibility, coping strategies, etc	Mental health: Cyber wellbeing Lifestyle adjustment: Reducing the adverse effects of excessive online usage

(Continued)

TABLE 3 | (Continued)

No.	Authors/Year	Descriptions in attributes	Descriptions in antecedents	Descriptions in consequences
18	(35)	Learning knowledge and skills Recovery in attitudes and behaviors	Environment: Rapid advancements in the technology of remote working practices	Achievement: Promoting sustainable, productive, engaging, and healthy remote working and delivering the best personal and work outcomes
19	(9)	Recovering after hardship Moving forward when faced with challenges	Psychological trait: Self-efficacy Digital literacy: Skills and knowledge Support: family, community capital	Lifestyle adjustment: Raising the level of digital readiness to the workforce
20	(21)	Recovering with a kind of psychosocial skill	Risks and threats in digital technologies	Lifestyle adjustment: Controlling online behaviors Safety: Protecting internet addiction and risk behaviors
21	(36)	Learning knowledge and skills	Environments: Distance learning—new spaces for learning in the new training environments outside the classroom	Lifestyle adjustment: Improving overall learner autonomy Mental health: Gaining more confidence in learning
22	(12)	Moving forward the adaptive capacity in behavior and attitudes	Digital technology-related threats: Online privacy violation Digital literacy: Attitudes toward Internet usage Support: Social support, family relationships, peers	N/A

N/A means that the included articles did not provide the content.

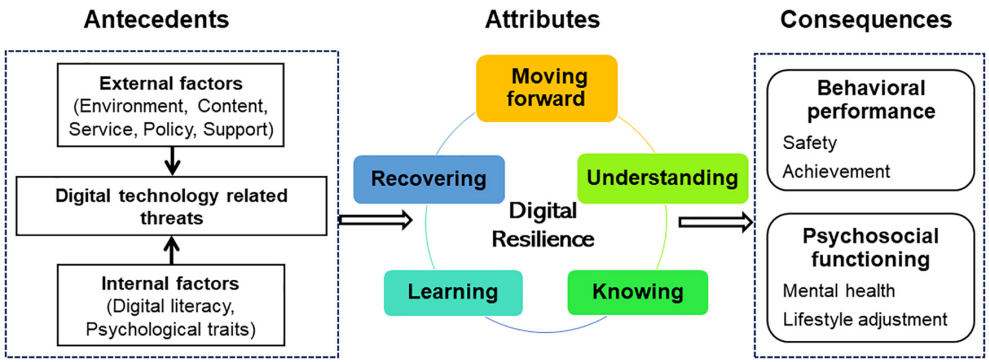

FIGURE 2 | Preliminary conceptual model of digital resilience.

higher education, the concept was defined as the "utilization of technology to change practices in order to adapt to new circumstances while retaining the underlying function of the practices" (14). Then, the construct of digital resilience is rising in the last decade, especially during the coronavirus disease 2019 (COVID-19) worldwide pandemic. There is a two-fold link between resilience and digital tools: digital tools promote resilience in education and health education; resilience is a means to face digital challenges (18). It is necessary to make a clear definition of digital resilience and its possible antecedents and consequences in the field of education for students' development. Furthermore, its uses also help to extend implications in other populations.

Defining Attributes

Determining the defining attributes of a concept offers an assembly of characteristics most often associated with the concept and improved discernment of the concept. The following attributes were compiled after doing an extensive screening about digital resilience in the included studies (n = 22). In a consultation with the research team, there are five connected elements that were developed as digital resilience attributes in **Table 3**. These five attributes are the process of dynamic circulation. Therefore, digital resilience is understanding when you may be at risk online, knowing what to do to seek help, learning knowledge and skills from experiences, being able to recover from appropriate support, and moving forward through self-efficacy in challenges.

Understanding Online Threats

Understanding online threats is the first term to be used throughout digital resilience literature (16, 25, 33). Individuals recognize the risks or threats online and can make informed decisions about the digital space that they are in. Diverse students perceive different risks or threats in digital learning environments like problematic online behaviors, cyberbullying, and webinar failures. For example, webinar fatigue makes students feel pressured to attend online meetings and sessions excessively, due to peer pressure, the perceived stress to upskill, and anxiety in the "fear of missing out" (16). Moreover, students may have unhealthy interactions on social media that can lead to deviant behaviors such as cyberbullying and cybercrime (16). In addition, the excessive time spent on digital platforms is a big risk that can cause significant mental health distress to students, which can impact an individual's lifestyle such as their sleep schedule or appetite (28). Several studies also showed that understanding unhealthy online threats is an important start in building digital resilience (4, 16, 26). Users were encouraged to report harm when using online technologies, which was a style of proactive self-efficacy to reflect their capability to discern risks during

online experiences. Therefore, having an awareness of online challenges is necessary for digital resilience.

Knowing Solutions

Knowing solutions is a way of critical thinking so as to consider the pros and cons even during challenging situations (19, 25, 28, 29, 33). In other words, individuals know what to do to seek help from a range of approaches and their sources. Knowing the resources about how to manage and act on their behaviors and attitudes by using critical thinking is an imperative attribute for enhancing digital resilience in the school education context. Reynolds and Parker (19) thought that digital resilience is an educational intervention designed to increase the resilience of young people to hate and extremism online. Students were taught to know what opportunities, resources, and skills may be useful to cope in a stressful, disadvantaged, or traumatic situation. In addition, knowing what to do to seek help from family and social support is also conductive to promote critical thinking abilities in their real lives (28). Hammond and Cooper (25) considered digital resilience as an orientation that recognizes digital vulnerabilities and seeks to empower the susceptible individuals to navigate toxic elements in the context of supportive relationships. A healthy support system means making sure that the individual knows when to reach out for support and is made aware of the possible educators or organizations that can help with negative digital experiences (25).

Learning Knowledge and Skills

The third digital resilience attribute is learning knowledge and skills including learning how to recognize and manage risk and learn from difficult experiences (19, 20, 25, 28, 29, 35). If individuals have digital skills and knowledge, they can deal with unfamiliar technological circumstances. Learning knowledge and skills does not mean that people should have an expertise in informational technology. A higher level of expertise not only allows better utilization of technology during disruptive life events; it also results in familiarization, which should lead to a reduction in technology anxiety and widen the usage of the technology (9). Individuals learn knowledge and skills from their experience and are able to adapt their future choices where possible (19). In the United Kingdom, some colleges or universities equipped students with colorful knowledge, skills, and strategies and also instructed them to recognize when to access help and support and where to find it (25). Further, resilient students in the digital world are more likely to initiate learning novelties or proactively interact with the environment, not just passively waiting for assistance. Thus, students could protect themselves from online risks and learn from risky situations depending on their level of digital literacy (20).

Recovering From Stress

Recovery was selected as one attribute to show the process of adaptation. Individuals can recover when things go wrong online by receiving the appropriate level of support. It is seen as a natural and instinctive characteristic built in all humans through adaptation and evolution. Both Sharma et al. (16) and Al-Abdulghani et al. (46) describe that digital resilience is returning to a pre-event level of functioning (recovery process) after having negative or adverse experiences online. They believed that an individual is cognitively well placed to adopt new technologies and accept digital transformation as a way to rebound from disruptive events. Meanwhile, Eri et al. (13) declared digital resilience as an individual's psychological capacity to remain functional by recovering from, adapting to, and learning from adversities stemming from the use of digital technology in the tertiary educational context. Obviously, recovery is a vital part of individual development in adopting new digital technology. It is an adaptive capacity for the individuals who adjust based on the immediate situation, knowing past conditions, or predicting future ones. People are also encouraged to seek methods to recover from the events when they suffered severe harm (28). Therefore, recovery represents that an individual bounces back to his/her normal activity as it was before a stressful event happened.

Moving Forward Through Self-Efficacy

An important yet often-overlooked consideration when conceptualizing digital resilience is moving forward in the face of new digital technology challenges. Moving forward through self-efficacy is defined as moving on with the belief in the capability to overcome difficulties in the context of supportive relationships (25), and these individuals have the confidence or assertiveness to deal with online challenges successfully in the future (18, 31). By building the aforementioned four attributes of digital resilience, they can help to empower the particularly vulnerable group to keep themselves safer online. Bhagat and Kim (10) described that the trajectories of digital resilience did not stay at the same functional level. It involved bouncing forward into a new reality. Self-efficacy is described as a robust stress-resistance resource after coping to challenges or having the confidence to conduct themselves safely in a digital world. In a study conducted by Rabbanee et al. (4), self-efficacy was found as a significant support to the positive aspects of the use of digital technology in the tertiary educational context. In this digital age, digitally resilient students are also those who have the abilities to avoid disturbances caused by or the distractions of the digital learning environments during their studies, which helps students achieve learning effectiveness (32). Moving forward through self-efficacy was selected as an attribute to reflect the broad characteristics of being well-adjusted in the population (35). It means that an individual is not in the same state as before, and they are thriving at the bounce-back-better level.

Cases of Digital Resilience

Based on Walker and Avant (22), cases can help illuminate and clarify concepts. Therefore, the fifth and sixth steps involved the development of four types of cases, which were generated from the qualitative data of included studies and the authors' experience.

Model Case

A model case contains all the necessary attributes of a concept (22). Jack is a 20-year-old young university student who participates in a large number of online courses and plays online games every day during COVID-19. He had

some negative emotions such as anxiety, worry, irritability, and aggression because of his excessive reliance on online technology. He understands that it adversely affects interpersonal relationships with family members and friends and produces issues of academic stress in the feeling of "fear of missing out" (understanding online threats). He knows that engaging in excessive digital interactions causes work–life imbalance, so he struggles with online fatigue and screen exhaustion. With encouragement from the teachers, Jack attends a series of curricula of student psychoeducation from a healthy school support network (knowing solutions). This helps Jack to learn many problem-solving skills and digital hygiene knowledge including identifying cyberbullying, making plans to attend webinars, and protecting information security (learning knowledge and skills). After that, he gives up attending a lot of online lectures and meaningless online interactions. Jack becomes more self-disciplined to manage study–life transformation in a virtual world (recovery from online stress). Now, to keep this healthy lifestyle, he believes that he is tech-savvy and prepared to adapt to different digital environments as he pursues higher education (moving forward through self-efficacy).

Borderline Case

A borderline case is an instance of the concept containing some but not all of the attributes of the concept (22). Selina is an 18-year-old freshman, and she can surf the Internet at any time and any place. She is recommended to use a lot of social software online from classmates and advertisements. These online platforms often send unhealthy messages and pictures to users. Selina is horrified when catching sight of these contents and feels the impact this may have on her health at first. She refuses to join these cyberspace interactions and attempts to seek alternative options to escape them. However, she does not report these cybercrimes to others and does not seek consultation regarding how the practices and behaviors in the digital world are. This leads to the reduction of productivity and satisfaction in her daily learning, although she is mentally able to adapt to the digital environment.

Related Case

A related case is an example that is related to digital resilience but does not encompass any defining attributes (22). Allen is a 19-year-old student who is pressured to attend meetings, webinars, and online sessions excessively. She finds that her entertainment, hobbies, work, and even academic study are all from digital sources online. She does not recognize that it is a kind of information overload by the media and news, along with increased stress every day. She conducts some behavioral inhibition to control her excessive use of digital technology.

Contrary Case

A contrary case is an example of a concept in which none of the attributes are present (22). Mike is a 21-year-old student in a vocational college. He joins some online courses according to the study requirements during the COVID-19 lockdown, and he spends the rest of the time on various online platforms. When he returns to an offline class 1 day, he feels that he is not the same person as before, when he can attend a face-to-face interaction or classroom discussion, but rather "a man in the cyberworld." Due to the negative impact of excessive online use and dependence, he always shows lower self-esteem and irritability in learning activities. His classmates also find him abnormality in the behavior and psychology and talk less to him or directly ignore him as they do not know what to say. He is frustrated as his previous image of self-confidence is completely shattered by living in a virtual world. He feels that digital technology controls him, and he has no control of his study and life anymore. As a result, he becomes more addicted to online use and has difficulty maintaining clear work-life boundaries.

Antecedents and Consequences

According to Walker and Avant (22), identifying antecedents and consequences helps us to have a deeper understanding of a concept within a social context. Antecedents are the events that take place prior to the occurrence of digital resilience, and consequences are those that occur as an outcome of the appearance of the concept (22). **Table 3** gives an illustration of the antecedents, attributes, and consequences of digital resilience among individuals.

Antecedents

Three antecedents of digital resilience were identified in this analysis: Digital technology-related threat and individual external factors and internal factors.

Firstly, adversity or threat events are common terms used to describe the antecedents of resilience. In the context of digital technology, the adversities are related to the use of digital technology such as cyberbullying (21), webinar fatigue (16), deviant use of technology (16, 19), excessive use of online technology (16, 32), digital burnout or failure (16, 46), and the challenges of technology innovation in a virtual context (18, 36). These threats may be triggered by different external and internal factors and may place an individual at risk of maladaptation.

Secondly, external factors have already existed during the use of digital technologies. The examples of external factors include environment, content, service, policy, and support (4, 28, 34). Environment includes any access point to the internet from private to public spaces, which makes people exposed to stressors such as distance learning and training environments (13). Content includes entertainment and educational content, the terms of service, and any messaging about the use of digital technologies that provide or deliver to the users and may be unhelpful or useless, or even harmful (32). Service contains devices, platforms, apps, games, and websites that may bring many possibilities of changes, challenges, and stressors (16). Policy includes local, national, and institutional policies such as top–down cyber-safeguarding risk-management policies (25). Support includes family, school, and society support networks, and people with support are more resilient and are able to better cope with stress and adversity in their life (33). Students supported by their family, friends, peers, and teachers are more likely to deal with adversities and develop a psychological capacity of resilience.

Thirdly, it is important that the individual internal factors also play a role in facing challenges to activate the resiliency attributes. The internal factors encompassing digital literacy mainly include basic technical knowledge and skills and the psychological traits of coping, which can help individuals build resilience and remedy the impact of adversity or disruptive events. Digital literacy can be used to evaluate information reflecting their capabilities to manage their life and work/learning tasks using digital technologies (19). In addition, individuals need psychological resources to develop resilience under the threat of the online and offline world, including self-control (32), self-reflection (33, 46), self-confidence (13), self-efficacy (12, 46), and self-esteem (33) as positive factors of psychological traits. From the individual viewpoint, digital resilience is understood as a proactively interactive concept dealing with the aggregation of individuals' severe risk experiences with different relatively favorable psychological resources.

Consequences

Behavioral Performance

Under the influence of digital resilience, the behavioral patterns of students will develop into a positive performance, which explains the impact of digital resilience on good long-term learning behavior. First, digital resilience brings safety, which is an important healthy behavior, and students think that they consider it necessary to surf the web or use online platforms. That is because students have the skills and confidence to conduct themselves safely in an online world (31). Students with responsible, safe, and active participation in an online environment allow them to use social media effectively, safely, and constructively (19, 29). Second, digital resilience encourages students to get a better achievement and explore new online challenges into the learning process. Digitally resilient students sustain motivation, achievement, and performance in their studies while being able to overcome and deal with stressful events (13). Those students with a habit to control online behaviors could be protected against internet addiction and more time spent on individual studies' development, which benefits learning and working and improves academic achievement (21). Hence, in the presence of digital resilience, students will gradually increase the long-term behavioral change, especially in the field of lifelong learning.

Psychosocial Functioning

Students with access to digital resiliency attributes at the time of stress or threat during the use of technology period have more chances to deal with these stressors in a positive way (26, 34). Multiple studies showed that digital resilience had various positive impacts on psychological and social functioning. For psychological functioning, digital resilience may assist students to maintain or promote positive emotions, which better enable them to adjust in the midst of negative emotions or even improve individuals' cyber wellbeing after such as recognizing what is right in their behavior (16). Especially, digital resilience could help promote individuals' mental health during the COVID-19 lockdown or mobility restriction (13, 30, 35). With respect to social functioning, research shows that digital resilience is positively correlated with a lifestyle adjustment. People with high levels of digital resilience may manage to adapt to challenging situations and strive to go back to or maintain their previous social life (19). In other words, individuals owing digital resilience show anti-interference ability when they encounter various technical risks or opportunities. Taking COVID-19 as an example, the nature of digital resilience is conducive to mitigate mental fatigue from facing social and academic isolation (13). Those with lower resilience and less adaptation may keep an unhealthy lifestyle paradigm, resulting in decreased anti-interference when encountering various technical risks or opportunities (32).

Empirical Referents

The final step of the concept analysis is empirical referents for the operational definitions of concept variables (22). To date, no specific instruments of digital resilience have been identified to measure the existence or attributes of the concept. Currently, there are several empirical instruments available to recognize or measure the occurrence of resilience for children, youth, young adults, or older adults. Windle et al. (47) found there are 19 resilience scales commonly used and recommended that the Connor–Davidson Resilience Scale, Resilience Scale for Adults, and Brief Resilience Scale have the best psychometric ratings. However, digital resilience has specific features that differ from resilience in general. To our knowledge, not one widely used tool is fit for scaling digital resilience. Although some authors used self-designed subjective instruments (9, 19, 20, 26, 28) to measure digital resilience in either behavior or attitudes, they did not assess the validity and reliability. In the future, it might be appropriate to measure the defining attributes as separate and additional constructs and be useful to measure not only behavior but attitudes as well.

Conceptualization of Digital Resilience

Based on the analysis of the defining attributes, antecedents, and consequences of digital resilience, we propose a final, clarified, and refined definition in school education settings. Digital resilience is the capacity and dynamic cycle process of an individual to change their behavioral performance and psychological functioning through understanding the risk, knowing approaches, learning knowledge and skills, recovering from stress, and moving forward when facing various digital technology-related threats within the school education settings. A preliminary conceptual model covering the relationship between attributes, antecedents, and consequences of digital resilience was established based on this conceptualization (**Figure 2**).

DISCUSSION

This concept analysis of individual digital resilience in school education applies the Walker and Avant concept analysis method. The aim of this study was to generate a clarified definition of digital resilience for school education and to facilitate

further interventions for students with unhealthy digitally mental behavior.

Through a concept analysis, the five defining attributes of digital resilience were characterized: understanding online threats, knowing solutions, learning knowledge and skills, recovering from stress, and moving forward through self-efficacy. They are influenced by personal internal and external factors when facing the risks of digital technologies. Individuals who have digital resilience by the above-mentioned attributes could be conducive to their psychosocial and behavioral performance and functioning.

Earlier digital resilience research focused mainly on cybersafety or technological support and mostly within the context of a technical perspective, organizational perspective, and national/societal perspective (9, 14, 17). Our work contributed to this gap in the literature by focusing on an individual perspective. The emergence of significant risk factors in the digital world means that people experience distress during their use of digital technologies and perceive them as a challenging threat. The current study made a clear elaboration that threats related to digital technologies are a basic antecedent of resilience. Considering the constantly changing digital landscape and the unpredictable and evolving nature of digital risks, it is difficult to avoid online risks or to prepare a person for all possible online risks. However, digital resilience can be observed in individuals' ability to overcome exposure to many adversities or threats such as excessive use of online technology (16, 32) and digital burnout or failure (16, 46). Further, digital resilience can play a major role in promoting sustainable, productive, engaging, and healthy learning for students (10, 21, 35) and has a positive influence on self-efficacy (13, 34). When digital resiliency attributes are absent, some negative outcomes may occur such as intense anxiety, fear, or feelings of distress (16, 27).

Developing effective intervention strategies that target digital resilience is essential. However, the way to develop digital resilience in students has been overlooked. Although some studies have contributed practical implications regarding how school educational institutions facilitated resilience in face of the COVID-19 pandemic lockdown, there are no studies that have specifically focused on the interventions for enhancing digital resilience. In this paper, we would offer some key recommendations for the application of the concept in future research. First, we should promote awareness that digital resilience grows through online use and learned experience and cannot be developed through the avoidance of the digital world. Hence, it is especially important to harness the digital resilience of individuals (48). Second, it is necessary to examine the conceptualization of digital resilience in school education settings to further construct an operational definition by mixed research. It is worth noting that cultural context should be recognized as an important factor influencing individual digital resilience (30, 34) and should therefore be considered in the process of concept examination. Third, strategies should be taken to reconstruct cognitive responsibilities like cognitive training that focuses on creating attitudinal change in an effort to influence online behavior. In this process, educators should help subjects feel responsible for their actions and be able to control their behaviors in the face of online threats (19). Additionally, the preliminary conceptual model of digital resilience needs to be further finalized through qualitative studies, which may be later used as a guide for exploring resilience-based interventions for vulnerable students.

Our findings are in accordance with the current trend that resilience is a dynamic, modifiable process (1, 2). We believe that digital resilience is the product of a dynamic process between an individual (e.g., personality) and their environment (e.g., social support). As Cliff Manning mentioned, digital resilience is a dynamic personality asset that grows from digital activation, i.e., through engaging with appropriate opportunities and challenges online, rather than through avoidance and safety behaviors (49). This shows that the extent to which someone can be resilient will fluctuate over time and is intensively influenced by the context. Longitudinal study designs may be taken into consideration to determine the timing and frequency of assessment on digital resilience.

Several limitations of this study need to be acknowledged. First, in the selection process of included studies, the study is not a systematic review or meta-analysis. Consequently, no quality assessment of included studies or statistical analyses were performed. Thus, there might be a risk of bias in results using a text description. Because of this, we need to be careful regarding utilizing the results. Second, since we only analyzed digital resilience in an English context, there might be a risk of bias in language as only English-written articles were included in the analysis. Critical articles may have been missed that were not available in English. Third, within our search strategy, we only included articles that specifically mentioned the concept of digital resilience. This might be the failure to cover all possible components of digital resilience. Some redundant attributes may overlap the antecedents or consequences. Considering this limitation, only five defining attributes were identified in this study because they provided a broad insight into the concept of digital resilience in school education as a response to online technology-related threats. In addition, most of the included studies came from Europe, Asia, and North America, as we did not find enough digital resilience studies from most developing countries. Therefore, studying digital in different social contexts is also necessary because socioeconomic conditions can greatly influence the psychosocial behaviors of people.

This study is the first step in a broader research protocol to enhance individual digital resilience in school education settings. Digital resilience as a fresh and alien concept in school education is best used *via* a qualitative analysis first. Because there are no standard or matching measurements, we will develop a battery of instruments in the next phase, which is beneficial to evaluate and identify vulnerable individuals in low digital resilience. To enhance digital resilience in school education, future interprofessional curricula will be formulated to provide for students with the struggle of their own digital technology-related threats. It is time to conduct proper training on students who may be exposed to different types of risks within different contexts of online activities. These findings can, in turn, inform schools and families about the applicability of resilience-based interventions and the opportunities to guide individuals to

positive adaptation. Overall, it is not possible to fully guard against or eliminate all digital threats but with digital resilience, individuals are competent to resist digital challenges or threats.

CONCLUSION

This analysis proposes a new conceptualization of individual digital resilience in higher education for the first time based on the identified defining attributes, antecedents, and consequences. We described digital resilience as a circular process toward greater wellbeing in the form of behavioral performance and psychosocial functions when faced with threats, challenges, or adversity during the use of technologies. The presence of resiliency attributes such as understanding online threats, knowing solutions, learning knowledge and skills, recovering from stress, and moving forward through self-efficacy enhances the capacity to be digitally resilient and maintain health promotion. The concept clarification is important for educational work. This concept analysis provides valuable insights that can be used for developing digital resilience intervention measures that may facilitate an early recognition of students' need for psychosocial support within the context of school education.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

HS and CY: conceptualization. HS, QQ, and SH: data acquisition and analysis. HS, CY, SH, and QL: manuscript preparation and modification. All authors contributed to the article and approved the published version of the manuscript.

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OPINION
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What Can Mobile Sensing and Assessment Strategies Capture About Human Subjectivity?

Bruno Biagianti [1,2*]

[1] Department of Pathophysiology and Transplantation, University of Milan, Milan, Italy, [2] Department of Neurosciences and Mental Health, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy

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INTRODUCTION

The pervasiveness of mobile technology on the way we learn, create, work, share, communicate, move, love, and live today exceeds our individual ability to choose whether to be affected or not by it[1]. The unique degree to which each of us is exposed has profound implications on the behavioral responses we are able to generate, with adaptation being increasingly considered the most welcome[2].

Medical knowledge and clinical care are being revolutionized by mobile technology, even more so after the onset of the COVID-19 pandemic, which has functioned as an accelerator of changes that have permanently reshaped the way providers and patients today think of, talk about, and manage physical and mental health (1).

The relationship between mental health and mobile technology is growing more complex and unpredictable every day, with providers and researchers animated both by the drive to keep up with the promising tools developed by technological innovation, and the need to better characterize and understand this relationship prior to taking actions that may prove all but therapeutic in the long term (2, 3). A controversial area of debate that has emerged from the relationship between mental health and technology is whether the unprecedented wealth of data captured by a mobile device can produce information that ultimately has clinical relevance for the provider and/or for the patient, and whether the acquisition, understanding, and attribution of meaning to said information comes with a toll (4, 5). Addressing the latter point likely offers tools to approach the former with greater awareness.

SENSING AND MEASURING THE ECOLOGICAL SELF

Reviewing the physical and psychological implications of being tethered on human perception, consciousness, and behavior exceedingly falls outside the scope of this letter (6). Suffice to say that psychological constructs such as boundaries, once considered indispensable for shaping subjective identity and demarcating it from external reality—or at least a shared definition of it—are being interrogated if not questioned by mobile technology (7). Mobile sensing—i.e., technology that passively collects data from sensors embedded in mobile devices—arguably represents the epitome of this transformation. Modern day smartphones come with a number of embedded sensors such as a high-resolution complementary metal-oxide semiconductor, image sensor,

[1] https://www.pewresearch.org/internet/2018/04/17/the-future-of-well-being-in-a-tech-saturated-world/
[2] https://sloanreview.mit.edu/article/pushing-back-on-pervasive-technology/

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Edited by:
Heleen Riper,
VU Amsterdam, Netherlands

Reviewed by:
Manuel Ottaviano,
Polytechnic University of Madrid, Spain

***Correspondence:**
Bruno Biagianti
bruno.biagianti@unimi.it

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global positioning system (GPS) sensor, accelerometer, gyroscope, magnetometer, ambient light sensor, and microphone (8). These sensors can be used to measure several health parameters such as heart rate (HR), HR variability, respiratory rate, sleep quality, and health conditions such as ear and eye diseases, thus turning the smartphone into a continuous and long-term health monitoring system (9). Moreover, using a combination of data from motion sensors and cellular network providers, today it is rather trivial to capture movement patterns—including step count, time spent inside and outside, distance traveled. These variables all serve as proxies of physical daily activity levels, and are known to predict and impact mental wellbeing (10). Similarly, frequency and length of SMS and calls stored on the device that have been shown to function as proxies of social activity levels (11). Even more so than with Ecological Momentary Assessments (i.e., repeated sampling of subjects' current behaviors and experiences in real time, in subjects' natural environments)—which naturally pose issues of engagement, reliability, and durability—mobile sensing demonstrates that as contemporary subjects we are effortlessly traceable, measurable, and most importantly, knowable in ways to which we have been historically oblivious (12–14). Yet, enthused by the opportunities that mobile technology is presenting, we have perhaps paid less attention to the relevance of what exactly is being known of us (15, 16).

DISCUSSION

The matter of signifying incoming data transmitted in real time by mobile devices must not cease to interpellate researchers, clinicians and end-users likewise (17). If artificial intelligence and machine learning algorithms today allow quite strikingly to chart and predict the fluctuations of measured behaviors, should there exist an interdisciplinary dialogue on the epistemological responsibilities of this process? Certainly, the medical field has long resorted to the measurement of quantitative variables in order to provide patients with clinical information, yet the infrequent collection of such measurements, along with the interpretation and delivery of their findings, has been a prerogative of trained health professionals. The ease with which enormous amounts of data can be captured and transmitted by mobile devices today, in addition to the fact that mobile sensing and real-time assessments minimize recall bias, maximize ecological validity, and allow study of micro-processes that can influence real-world behavior, are truly dismantling the existing and collectively-shared definitions of health and illness (18), while shedding new, slightly darker, light of scientific positivism (19). If "the more we measure, the more we know" has induced unimaginable progress and innovation in the medical field thus far, now that we realize how much technology can measure, can we feel equally confident about "the more we measure, the more we understand," especially in the delicate matter of subjectivity (20)?

The definition of subjectivity and its implications on the self-perceived relationship between health and illness has entertained different psychological theorists. Just to list a few, psychoanalysis, Gestalt and post-structuralist approaches have all attempted a specific proposition that reflects distinct cultural-historical traditions (21). In its simplest and most generous connotation, subjectivity is the first-person perspective, no more and no less. The closet concept that cognitive sciences have coined is self-reference, which describes the way a particular individual perceives itself in relation to its immediate environment and its total life situation (22). Certainly, a current viewpoint exists and takes form when a relationship is formed between a subject and its object, between observer and observed. Nonetheless, while acknowledging that a viewpoint could never be described as belonging to a person in any enduring sense, systematic investigations of personality show recurrent traits, observation styles that tell more about the ways in which the subject typically processes the object, whether that is a circumstance, an event, or some other kind of enquiry (23–25). It emerges that subjectivity includes emotionally loaded conceptions and symbolical processes that are generated throughout human experience, and determine, to a large degree, choices, actions and interactions, which all directly impact the degree of functioning and malfunctioning of any individual in its ecological system (26). As a result, the heuristic value of subjectivity encompasses processes that can neither be exhausted by language, nor by discourse, nor, at least not entirely, by awareness (27).

In this context, the matter of new orders of data about the psychological self mobilizes in both providers and patients hierarchically ordered conceptual categories and metacategories, which all express the subjective signification process (28). These categories should not be neglected, and form instead the basis for intersectional conversations between patients, clinicians, scientists and technological innovators on the personal and clinical values that such data should have (29). If historically objective science has been conducted prioritizing the third-person perspective over the first-person accounts, we must recognize that the third-person perspective no longer belongs to a person, but it is now being produced by technological advances[3]. The so-called data driven discoveries, at least in the field of mental health, are often eluding the critical processes of conceptualization, signification, and interpretation—processes that allow humans to grow and know themselves. More importantly, the unbridled proliferation of subject-specific behavioral mobile data is creating the illusion that the foundation for a science of subjectivity is being laid, whereas what is arguably occurring is that subjectivity, with its eschatological and existential functions (30)—functions that cannot and should not be measured, "scientified," technologized—is being declassified.

After a decade of mobile mental health research, we hope that these considerations can enrich the current dialogue between key stakeholders (clinicians, researchers, patients, policy makers, funding agencies, and development

[3]https://techcrunch.com/2016/11/18/big-data-cant-bring-objectivity-to-a-subjective-world/

firms) about the directions that the field of mobile sensing and assessments could explore moving forward. What kind of a research roadmap can be then proposed for the field? Possibly, one where critical aspects of human knowledge and experience that would largely lose their complexity and value if measured—aspects that cannot be absorbed into the mobile technology revolution—will continue to be studied, divulged, epistemologically dignified, and placed in a position of dialectical interplay with technology-based knowledge.

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

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Usability, Feasibility, and Effect of a Biocueing Intervention in Addition to a Moderated Digital Social Therapy-Platform in Young People With Emerging Mental Health Problems: A Mixed-Method Approach

Marilon van Doorn[1], Laurens A. Nijhuis[1], Anne Monsanto[1], Thérèse van Amelsvoort[2], Arne Popma[1], Monique W. M. Jaspers[3], Matthijs L. Noordzij[4], Ferko G. Öry[5], Mario Alvarez-Jimenez[6,7] and Dorien H. Nieman[1]*

[1] Amsterdam University Medical Centers, Amsterdam, Netherlands, [2] Department of Psychiatry and Neuropsychology, Maastricht University, Maastricht, Netherlands, [3] Department of Medical Informatics, Amsterdam Public Health Research Institute, Amsterdam UMC-Location AMC, University of Amsterdam, Amsterdam, Netherlands, [4] Department of Psychology, Health and Technology, University of Twente, Enschede, Netherlands, [5] Buurtzorg Jong, Almelo, Netherlands, [6] Centre for Youth Mental Health, The University of Melbourne, Parkville, VIC, Australia, [7] Orygen, Parkville, VIC, Australia

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Edited by:
Heleen Riper,
VU Amsterdam, Netherlands

Reviewed by:
Warren Mansell,
The University of Manchester, United Kingdom
Abednego M. Musau,
Population Services International, United States

***Correspondence:**
Marilon van Doorn
M.vanDoorn@amsterdamumc.nl

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Introduction: To optimize treatment, it is of utmost importance to take into account the myriad of biological, social, and psychological changes that young people go through during adolescence which make them more vulnerable for developing mental health problems. Biocueing, a non-invasive method to transform physiological parameters into an observable signal, could strengthen stress- and emotion regulation by cueing physiologically unusual values in daily life. The aim of this study is to investigate the usability, feasibility, and exploratory effect of biocueing in addition to ENgage YOung people earlY (ENYOY), a moderated digital social therapy-platform, in young people with emerging mental health complaints.

Methods: A user-centered mixed-method design was used. A focus group was conducted to optimize the ENYOY-platform and biocueing intervention. Biocueing was operationalized by a smartwatch and the Sense-IT app. A within-subjects design was used; 10 days for all participants 'biofeedback off' (control), followed by 10 days 'biofeedback on' (experimental). Emotional awareness and perceived stress were measured using ecological momentary assessment. Eight individuals participated. User-friendliness, usability, and acceptance were assessed using a qualitative design.

Results: Findings from the focus group resulted in several adaptations of the biocueing intervention to the ENYOY-platform and vice versa. The average measurement compliance rate was 78.8%. Level-one findings showed different individual effects on perceived stress and emotional awareness. Level-two analyses showed no overall effects on perceived stress ($B = -0.020$, $p = 0.562$) and overall positive effects on emotional awareness ($B = 0.030$, $p = 0.048$) with small effect sizes (Improvement Rate Difference = 0.05–0.35). The intervention was found to be acceptable and showed moderate

usability. Participants indicated they experienced improvements in reflection on feelings and changes in behavior, such as pausing and evaluating the situation.

Conclusion: These preliminary results show that biocueing could be a promising addition to digital treatment platforms and help young people become more emotionally aware. Improvements should be made regarding the usability and acceptability of the smartwatch, as well as more extensive integration of the biocueing intervention with a digital treatment platform. It would be relevant to gain a better understanding of which individuals would benefit most from an additional biocueing intervention.

Keywords: biocueing, indicative prevention, stress- and emotion regulation, youth mental health, e-health, early detection and intervention

INTRODUCTION

Approximately three-quarters of all mental health problems start before the age of 25 (1–3), and half of all episodes of mental health disorders start at the age of 14 (4, 5). Mental disorders make up for the number one burden of disease in young people (6). Untreated mental health disorders could lead to chronicity, comorbidity, lost potential, a lower social and occupational health, increased risk of suicide, and a lower quality of life for the individuals concerned (7, 8). On a broader scale, mental health disorders are associated with considerable economic consequences (9). Mental health costs are the single highest source of global economic burden in the world (10) and the Netherlands is estimated to spend around 5.7 billion euro annually on curative mental healthcare (11). Therefore, it is very important that early prevention and appropriate interventions are designed for young people (12) at the time when they are developing strategies to cope with stress and negative emotions (13). A very successful Australian initiative has implemented a comprehensive, evidence based youth focused indicative prevention program, which combines care in a stepped-care manner and blends peer-to-peer support with online counseling and therapy (Moderated Online Social Therapy (MOST+); (14–17).

Despite the success of MOST+ it is unknown whether this initiative can be translated to different countries and cultures. Currently, a study to implement the MOST+ platform in the Netherlands is being carried out under the name ENgage YOung people earlY (ENYOY) (18). In addition, most activities in the MOST+ platform require participants to have the ability to note fluctuating levels of stress and physiological arousal. Unfortunately, the ability to sense and feel stress and physiological changes (i.e., interoceptive sensitivity), might be especially impaired in the vulnerable adolescent target group (19–21). Therefore, additional tools that help young people note when physiological arousal is high and help them to apply methods to deal with this (such as behavioral experiments, mindfulness or muscle relaxation) would offer a potential further benefit to a wider group of adolescents. For this purpose biocueing might be an interesting addition. Biocueing is a non-invasive method to transform physiological parameters with a small electronic device into a visible, audible, or tactile signal, cued to the wearer (22). It automatically engages the user by prompts in daily stressful situations (23). The aim of the present study is to exploratory investigate the effects of biocueing as an addition to the moderated online social therapy-platform ENYOY for young people with emerging mental health problems.

During adolescence, the transitional period between child- and adulthood, young people go through a myriad of physical, social, and psychological changes (24–26). Brain areas involved in arousal and risk-reward perception rapidly develop, resulting in heightened stress responsivity and emotional reactivity (27). Fortunately, strategies to cope with stress and negative emotions also begin to form (28), with emotional awareness, (the ability to identify and label internal emotional experiences (29, 30), being an important building block in guiding individuals toward adaptive emotion regulation (19–21). Nonetheless, the functional change in arousal and risk-reward perception seems to precede the development of functional coping strategies, which creates a situation where, as well put by Steinberg (27), 'an engine is started without yet having a skilled driver behind the wheel'. This discrepancy renders adolescents more vulnerable for negative emotions and psychological stress, and consequently heightens the risk of developing mental health problems (13). Indeed, research shows that there is a relation between stress and mental disorders (31). Less stress reactivity has been shown to predict symptom improvement in, for example, children with anxiety disorders (32) and adolescents with depressive symptoms (33). Moreover, different patterns in parasympathetic and sympathetic nervous system activation have been found to respond to different kinds of treatments (34).

It is of importance to take into account the multiple biological processes that make young people more vulnerable for psychological stress and further optimize treatment accordingly. In an attempt to reduce mental health problems among young people and reach them for indicative prevention mental health treatment, an Australian initiative has been successfully implemented (12). In more than 100 Headspace centers young people can find help for general health and education problems, drug use and (emerging) mental health complaints. Evidence-based interventions are provided in a stepped- care manner (17).

In addition to face-to-face interventions, Moderated Online Social Therapy (MOST+) has been developed to provide

young people with comprehensive, adaptive, and integrated digital support. MOST+ merges peer-to-peer social networking; theory-driven and evidence-informed therapeutic interventions; expert clinician and vocational support; and peer support and moderation (14, 17, 35, 36). Findings from several pilot studies with young people diagnosed with (ultra-high risk for) psychosis, depression, social anxiety, and suicidal ideation have consistently shown high levels of feasibility, acceptability, engagement, and safety; and indicated effectiveness in a wide range of clinical and social outcomes [for a comprehensive overview, see: (14, 16, 17, 35)]. Additionally, MOST+ was found to be effective in improving vocational recovery and reducing utilization of emergency services in young people with a first episode of psychosis (16). Currently, a study to implement the MOST+ platform in the Netherlands is being carried out under the name ENgage YOung people earlY (ENYOY) (18). The MOST+ platform has been translated and adapted in cooperation with Dutch experts to fit the needs of young Dutch people, and will be continuously adapted to the wants and needs of participants over the course of the study.

With the goal of all young people benefitting fully from the platform, it would be of interest to look for adaptations or additions to the platform in the Netherlands. Although high levels of feasibility and acceptability were found for the use of the platform in Australia, not all users concluded that MOST+ was relevant to their needs (17), and engagement rates with the platform in young people with psychosis were found to be good, but not for all (80% engaged for the first 3 months, and 47% at 9 months) (16).

A factor that could play a role is the largely verbal content on the platform - though the platform also provides visual and audible exercises such as audio tracks and comics - , exercises are explained and information is given in text and metaphors, and the community is largely made up of verbal posts. However, not all individuals are equally verbally strong (e.g., (37, 38), and thus might not be able to understand its contents. Moreover, some of the exercises of the evidence-based therapies offered on the platform rely on interoception. For example, noting one's own thoughts and emotions (39) is required in the "reflective actions" on the platform. Possibly, some young people may not benefit because they have problems with interoception or, for some, interoceptive sensitivity might not have been fully developed yet (40). Another possible explanation for lower engagement rates could be that the intervention requires a certain amount of self-reliance of the individual, although monitored by a clinical moderator, namely to actively go online themselves. This might be challenging for some, for example for individuals with attention-deficit/hyperactivity disorder who have problems with, for instance planning [e.g., (41)], or individuals with relatively mild mental health complaints (42). Lastly, adherence rates for online interventions are found to be highly varying [e.g., 27.9 and 98% in (43)], for which a medium that could send reminders might contribute (44).

For individuals who are verbally less strong, have problems with interoception, and/or have problems with adherence, an intervention that addresses these individual factors may be helpful. Biocueing could be a suitable extra tool to support the development of coping strategies, as well as interoception, thereby strengthening an individual in stress- and emotion regulation (23).

Biocueing is a non-invasive method to transform physiological parameters, e.g., heartbeat or skin conductance, with a small electronic device - such as a smartwatch - into a visible, audible, or tactile signal, cued to the wearer (22). It automatically engages the user by prompts in everyday life stressful situations. These wearable devices can be helpful in supporting antecedent emotional regulation strategies in response to emotion evoking events and have been found to decrease self-reported stress-levels (23). De Looff and colleagues (45) found that in the 20 minutes leading up to an incident of aggression in individuals with borderline personality disorder, skin conductance level and the number of nonspecific skin conductance responses per minute rose significantly. This means that it is possible to detect certain interoceptive signals, thereby heightening emotional awareness and supporting reappraisal of emotions (20, 46), a process which is essential to mental health (46).

The aim of this study is to exploratory investigate the effects of biocueing as an addition to the moderated online social therapy-platform ENYOY for young people with emerging mental health problems. The objectives are three-fold: (1) to qualitatively explore whether biocueing could be of additional value to ENYOY; (2) to assess the effect of biocueing in combination with ENYOY on perceived stress and emotional awareness; (3) to evaluate the attitude of users concerning the usability, acceptance, and user-friendliness of the biocueing application and smartwatch in combination with the ENYOY-platform as an intervention.

METHODS

Study Context

The present study took place within the context of the ENYOY-project [ENgage YOung people earlY; for a comprehensive summary, see (18)], where young people between the ages of 16 and 25 with emerging mental health complaints use the Dutch Moderated Online Social Therapy (MOST+) platform for 6 months. The goal of ENYOY is to offer young people a self-efficacious way of reducing their mental health complaints with digital interactive psychological interventions focused on using and developing personal strengths in combination with online counseling meetings with a psychologist and/or peer worker (a young person with lived experience with mental health complaints).

The ENYOY-project has received ethical approval from the Medical Ethics Review Committee (MERC) at Amsterdam University Medical Centers (AMC), the Netherlands (reference: NL66345.018.18), and was registered in the Netherlands Trial Register (ID NL8966). Written informed consent was obtained from all participants before inclusion to the study.

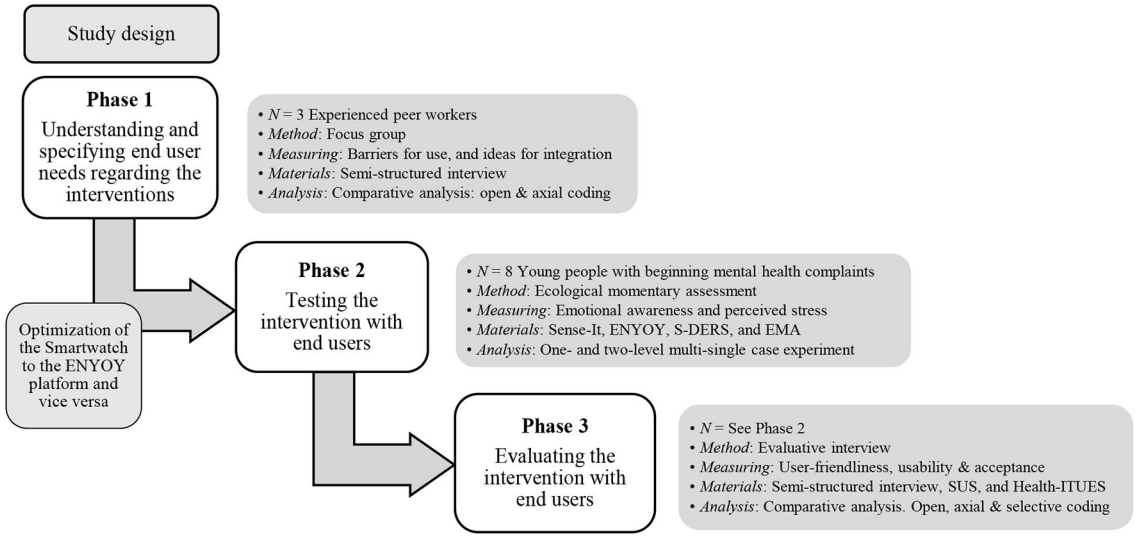

FIGURE 1 | Study design. N, amount and type of participants; ENYOY, ENgage YOung people earlY project; S-DERS, State Difficulties in Emotion Regulation Scale; EMA, ecological momentary assessment; SUS, System Usability Scale; Health-ITUES, Health Information Technology Usability Evaluation Scale.

Study Design

A user-centered (47) mixed method design was used consisting of three phases, see **Figure 1**. In the first phase (Phase 1–*Understanding and specifying end user needs regarding the interventions*), a qualitative design using a focus group, consisting of peer workers of the ENYOY-platform, was administered in which the requirements of end users in relation to the interventions were mapped and used to optimize the usage of the ENYOY-platform with the device and app used for biocueing (see materials > Sense-IT). In the experimental period (Phase 2–*Testing the intervention with end users),* emotional awareness and perceived stress-levels were measured in real time using ecological momentary assessment (EMA). By sampling stress and emotional awareness in real time, EMA aims to minimize recall bias and maximize ecological validity (48). After the experimental period (Phase 3–*Evaluating the intervention with end users),* user friendliness, usability, and acceptance of the interventions using a qualitative design. The Statement on Reporting of Evaluation Studies in health informatics framework will be followed in reporting this study to create a better understanding of the study flow with the different phases (49).

Phase 1–Understanding and Specifying End User Needs Regarding the Interventions

Participants

Three peer workers of the ENYOY-platform with lived experience with similar mental health complaints as the end users participated. Being involved with the ENYOY-platform for over 4 years, the peer workers are experts in using the platform. They have been moderating the community of ENYOY and are in contact with participants since launch. The members of the focus group were aged between 22 and 29 years (M = 25.6, SD = 3.3), two were female and one male, and were all native Dutch speaking.

Materials

A semi-structured interview was conducted with questions regarding barriers for use, ideas for exercises on the platform, and ideas for integration of the biocueing intervention (see materials > Sense-IT) with the ENYOY-platform.

Procedure

Three out of four peer workers of the ENYOY-platform were able to participate in the focus group. In a focus group the informative source is a group of individuals and the heuristic value of this technique lies in the kind of interaction that emerges during the debate they have (50). End user needs were analyzed following the user-centered design framework (47), aiming to increase user acceptance and satisfaction, and decrease user errors and drop-out. The central question of the focus group was: What is the optimal way to combine the usage of biocueing via the Sense-IT/smartwatch with the ENYOY-platform? A researcher with experience and knowledge of the ENYOY-platform and the biocueing intervention led the focus group using open-ended questions such as: 'How do you think the ENYOY-platform should be changed or adjusted to work well with a smartwatch?", which was followed by a discussion in the focus group. Participants were invited to build on each other's answers. Afterwards, participants were sent a summary of their answers and were given the opportunity to make changes. The intervention used in Phase 2 was adjusted based on the feedback received from the peer workers (see Results, *Phase 1*).

Data Analysis

The qualitative data was analyzed using deductive thematic analysis (51). Predetermined themes, as assessed in the semi-structured interview, were formed into categories. Data that did not fit these predetermined categories were further coded openly using inductive coding (51).

Phase 2–Testing the Intervention With End Users

Participants

A total of eight young people from the population of ENYOY users participated. The sample size was chosen with care, as using the biocueing intervention could be burdensome for some individuals when used for extended periods of time, and since the intervention has not yet been tested in combination with a treatment platform. Therefore, a relatively small sample size was used for this feasibility study to not unnecessarily burden participants. EMA was used with multiple measures per day per individual in order to maintain sufficient power, based on previous biocueing research (52). No additional inclusion criteria were administered (18). The exclusion criterion was the inability to wear the smartwatch during daytime (e.g., because of a job in healthcare or the catering industry). All participants were female, with a mean age of 22.38 years ($SD = 2.13$), and all had a formal education, split evenly between higher vocational education and university. Mental health problems were categorized by the clinical staging model (see (53) for the clinical staging model, and (18) for the operationalization in the ENYOY-study). Participants were included if the mental health complaints were found to be stage 1a (help-seeking individuals with mild symptoms and mild functional impairment) or 1b (people with attenuated syndromes with partial specificity, often with mixed or ambiguous symptoms and moderate functional impairment), and their occurrence was evenly divided over both categories. The time that a participant was on the platform ranged from 35 to 175 days [M(*SD*) = 112.38(52.03)].

Materials

Intervention

Sense-IT. The Sense-IT application (54) is designed to help an individual become aware of physiological parameters, such as heartbeat, as measured by the smartwatch. It notifies the user of changes in heartbeat by giving notifications and vibrations through a smartwatch (TicWatch Pro 3 GPS) and smartphone (Moto G30). The app was tailored to the needs of the user by changing the frequency and the message of the notification. The smartwatch ran on Android OS 11 and was connected to the smartphone by Bluetooth. The data on the smartphone was saved offline for privacy concerns. Through the smartphone, the EMA items were administered (see *questionnaires*).

ENYOY. Participants continued to have access to the ENYOY-platform. Young adults could use the plethora of options the platform has to offer: (1) therapeutic exercises based on positive psychology, acceptance and commitment therapy, and cognitive behavioral therapy; (2) biweekly online contact with a clinical moderator and/or peer worker that coaches the young adult to work on their mental health problems; (3) a community newsfeed with peers and peer workers.

Questionnaires

Emotional Awareness. To measure emotional awareness, the Dutch version of the State Difficulties in Emotion Regulation Scale [S-DERS, (55)] was used. This 21-item questionnaire, scored on a 5-point Likert scale (1 = "Not at all" to 5 = "Completely"), was adjusted to EMA for this study, meaning the questions were adapted for answering on a smartphone. The Awareness and Clarity subscales were used: These scales relate to emotional awareness and the other constructs of the questionnaire are beyond the scope of this study. Examples of these subscales, respectively, are: "I am paying attention to how I feel" ($\alpha = 0.79$) and "I am confused about how I feel" ($\alpha = 0.65$). Subscale scores were calculated by summing the scores and averaging: A high score on the aggregated subscale indicates high awareness of emotion.

Perceived Stress. To measure perceived stress, the Dutch EMA survey item "I feel stressed" was used, scored on a 0 to 5-point scale ("Not at all" to "Very much"). This item measures negative affect with high arousal and was extracted from the EMA repository of Kirtley and colleagues (56). A higher score on this scale indicates higher perceived stress-levels.

Procedure

All participants of the ENYOY-study that were online at the time of this study were asked if they were interested in wearing a smartwatch to cope with their stress-levels in addition to their participation on the ENYOY-platform. Out of 40 participants, eight had the time and interest to participate. A total of four appointments with the research assistant took place (a set-up meeting, two calls to check whether the Sense-IT was working properly, and a meeting to evaluate the usability of the intervention). Participants were sent a package by mail containing the hard- and preinstalled software.

During the set-up meeting, participants were asked to choose two moments every day, one in the morning and one in the evening, to prompt the EMA questions. The baseline heart rate of the participant was determined using the protocol used by ter Harmsel and colleagues (57) and participants were asked what they would do when experiencing an above average heartbeat. The ENYOY-platform was mentioned by the researcher to cope with a high heart rate. Specific interventions of the platform that could help reduce stress according to the participant were added to the "toolkit," so that exercises could be accessed easily. The condition alternated over the course of 20 days, in the first 10 days for all participants "biofeedback off" (control), and in the last 10 days "biofeedback on" (experimental). Participants were prompted twice daily to answer the EMA items regarding perceived stress-levels and emotional awareness during both conditions.

Data Analysis

Data from the subscales Emotional Awareness and Emotional Clarity were aggregated per participant, after which a multi-single case experimental design (multiSCED) was used for

measuring perceived stress-levels and emotional awareness per participant (one-level) and overall (two-level). This statistical test is produced using the MultiSCED-tool by Declercq et al. (58). For each participant, condition and time were used to predict stress and emotional awareness by means of the following regression formula:

$$Y_i = \beta 0\,(Intercept_i) + \beta 1\,Time_i + \beta 2\,Condition_i + \beta 3\,(Time \times Condition_i) + e_i \quad (1)$$

The subscript i denotes the measurement nested within a case. To determine the overall effect of bio cueing, condition and time were used to predict stress and emotional awareness by means of the following regression formula,

$$Y_{ij} = \beta 0\,(Intercept_i) + \beta 1\,Time_{ij} + \beta 2\,Condition_{ij} + \beta 3\,(Time \times Condition_{ij}) + e_{ij}\backslash n \quad (2)$$

The Improvement Rate Difference (IRD; (59) was used to calculate the effect sizes. The IRD is defined as the improvement rate of the treatment phase minus the improvement rate of the control phase.

Phase 3–Evaluating the Intervention With End Users

Participants

See Phase 2.

Materials

Evaluative Interview

User-Friendliness. To measure user-friendliness, semi-structured interviews took place in which questions were asked regarding the participants' experience with the hard- and software. These questions were based on earlier research by Derks and colleagues (52).

Usability and Acceptance. To measure the usability and acceptance of the Sense-IT, two questionnaires were administered. The Dutch version of the System Usability Scale [SUS; (60)] is a 10-item questionnaire scored on a 5-point Likert scale (1 = "Strongly disagree" to 5 = "Strongly agree"), measuring the general usability and acceptance of an intervention. An example of an item is "I think that I would need the support of a technical person to be able to use this system." The composite measure ranges between 0 and 100, with higher scores indicating higher usability. Scores below 50 indicate non-acceptance, while scores above 50 indicate acceptance (61).

The Health Information Technology Usability Evaluation Scale [Health-ITUES; (62)] is a 20-item questionnaire, scored on a 5-point Likert scale (1 = "Strongly disagree" to 5 = "Strongly disagree"), which focuses on usability of mobile health technology, and has four subscales: Impact, Perceived Usefulness, Perceived Ease of Use, and User Control. An example item of Impact is: "I think ENYOY combined with the Sense-IT would be a positive addition for persons living with beginning mental health problems" ($\alpha = 0.85$). A high score on User Control and Perceived Ease of Use captures the user-system interaction, whereas Perceived Usefulness evaluates task accomplishments through system use. Impact refers to the system's impact on daily life. A high overall score indicates a higher perceived usability of the technology.

Procedure

After the 20 day experimental period, a meeting took place between the research assistant and the participants of phase 2 to evaluate the intervention by means of the semi-structured interview, the SUS, and Health-ITUES. The interviews were conducted through video call in a secured Microsoft Teams environment by a research assistant with experience and knowledge of the ENYOY-platform and the biocueing intervention.

Data Analysis

The qualitative data was analyzed using deductive thematic analysis (51). Predetermined themes, as assessed in the semi-structured interviews, were formed into categories. Data that did not fit these predetermined categories were further coded openly using inductive coding (51). Finally, selective coding was used to exploratory determine possible relations and connections between the data and categories (63). Considering the SUS and Health-ITUES averages and ranges were calculated and interpreted.

RESULTS

Phase 1–Understanding and Specifying End User Needs Regarding the Interventions

The following adaptations were implemented as a result of the focus group for the optimization of the smartwatch to the ENYOY-platform and vice versa. For a full overview of the results of the thematic analyses, see **Supplementary Appendix A**.

Firstly, in the manual of the Sense-IT the benefits of the intervention were specified, as well as steps to personalize the smartwatch to the issues the young person struggles with. Secondly, access to the ENYOY-platform was made easier by (a) making exercises available offline, (b) helping young people fill their ENYOY toolkit with useful exercises beforehand, and (c) a link was added from the Sense-IT to the ENYOY toolkit. Third, ENYOY was adjusted to the smartwatch and vice versa to help young people slow down and reflect by (i) creating an exercise that helps differentiate between emotions, (ii) questions were prompted about young people's needs and experienced emotions on the smartwatch, and (iii) it was individually addressed whether or not the participant also wanted to be signaled when their heartbeat is low. Finally, in order to deal with obstacles for use, the following steps were taken: (1) young people were helped with deciding whether a smartwatch fits their lifestyle and were helped creating a new habit by linking the intervention to old habits during the introductory meeting; (2) it was addressed in the introductory meeting that hypervigilance could increase stress and that there is no correct or false way of experiencing stress,

TABLE 1 | Summary of study results for dependent variables per participant and per condition.

		Outcome			
		Perceived stress levels		Emotional awareness	
Participant		Control condition	Experimental condition	Control condition	Experimental condition
1	N (measuring points)	19	20	19	20
	Intercept B (SD)	2.426 (0.47)	2.440 (0.63)	2.831 (0.22)	2.901 (0.30)
	Slope B (SD)	−0.001 (0.04)	0.007 (0.06)	0.027 (0.02)	0.044 (0.03)
	IRD	–	0.18	–	0.18
2	N (measuring points)	18	18	18	18
	Intercept B (SD)	1.507 (0.34)	2.976** (0.57)	3.799 (0.21)	**3.212* (0.28)**
	Slope B (SD)	0.005 (0.03)	−0.068 (0.04)	0.009 (0.02)	−0.034 (0.03)
	IRD	–	0.56	–	0.17
3	N (measuring points)	21	20	21	20
	Intercept B (SD)	2.212 (0.35)	2.581 (0.48)	3.099 (0.28)	2.902 (0.39)
	Slope B (SD)	0.038 (0.03)	−0.018 (0.04)	0.016 (0.02)	0.002 (0.03)
	IRD	–	0.46	–	0.27
4	N (measuring points)	20	22	20	22
	Intercept B (SD)	1.721 (0.38)	1.783 (0.51)	3.380 (0.17)	3.378 (0.23)
	Slope B (SD)	**−0.065* (0.03)**	**0.094* (0.04)**	−0.002 (0.01)	0.013 (0.02)
	IRD	–	0.05	–	0.28
5	N (measuring points)	20	17	20	17
	Intercept B (SD)	2.323 (0.35)	2.540 (0.49)	3.090 (0.12)	3.413 (0.17)
	Slope B (SD)	0.021 (0.03)	0.008 (0.05)	**−0.027* (0.01)**	0.008 (0.02)
	IRD	–	0.67	–	0.35
6	N (measuring points)	17	19	17	19
	Intercept B (SD)	1.713 (0.30)	1.645 (0.40)	3.135 (0.17)	3.818** (0.42)
	Slope B (SD)	0.007 (0.03)	0.025 (0.04)	**−0.071*** (0.02)**	**0.061** (0.02)**
	IRD	–	0.22	–	0.16
7	N (measuring points)	23	16	23	16
	Intercept B (SD)	4.127 (0.39)	3.975 (0.58)	2.537 (0.22)	2.776 (0.32)
	Slope B (SD)	**0.079** (0.03)**	**−0.154* (0.06)**	**−0.049* (0.02)**	**0.039** (0.03)**
	IRD	–	0.31	–	0.31
8	N (measuring points)	20	12	20	12
	Intercept B (SD)	2.839 (0.53)	1.810 (0.82)	3.033 (0.29)	2.917 (0.44)
	Slope B (SD)	0.034 (0.04)	0.017 (0.11)	0.018 (0.02)	0.020 (0.06)
	IRD	–	0.33	–	0.53

N, amount of; M, mean; SD, standard deviation. Both intercept and slope refer to respectively the unstandardized B−coefficient and the change in the unstandardized B−coefficient per time unit. $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$. IRD, Improvement Rate Difference. Numbers in bold highlight the significant findings.*

and (3) participants were contacted 2 days into the experiment to ask about the functioning of the smartwatch and Sense-IT application.

Phase 2–Testing the Intervention With End Users

Compliance, as defined by the ratio of the number of measurement occasions that participants completed in relation to the maximum number (64), was on average 78.8%, ranging from 59.4% to 100%. An exact McNemar's chi square test determined that there was a significant difference in compliance between the control condition (86.1%) and the experimental condition (70.8%), $p < 0.001$. In order to improve the quality and reliability, missing data ($N = 64$) was imputed using the Expectation-Maximization (EM) method, following Chen, Feng, Wu, and Peng (65).

The assumption of normality was tested by depicting a histogram of standardized residuals, which indicated that the data contained approximately normally distributed errors, as did the normal probability plot (P-P plot of) standardized residuals, which showed data points followed a straight line.

Table 1 displays an overview of the results from the level-one ordinary least squares regression analysis. Regarding perceived stress-levels, in the control condition (biocueing off) no significant effect was found for six out of eight participants (see **Figure 2**; participant (P) 1: $B = -0.001$, $SD = 0.04$, $p = 0.980$; P 2: $B = 0.005$, $SD = 0.03$, $p = 0.872$; P 3: $B = 0.038$, $SD =$

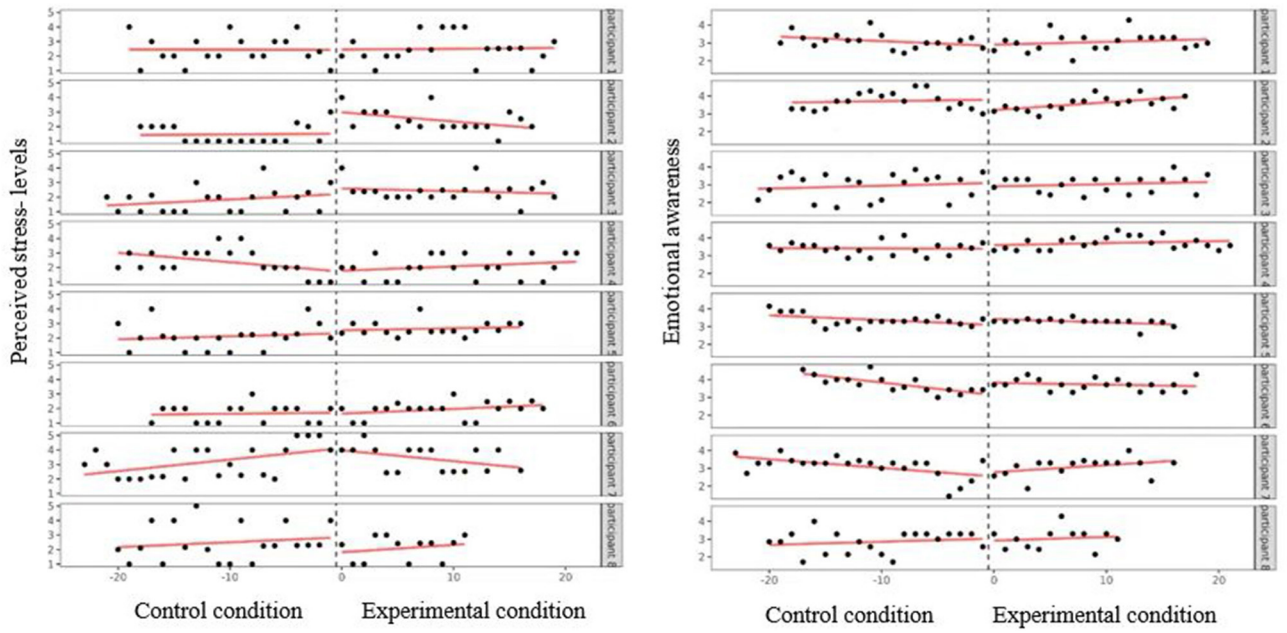

FIGURE 2 | Perceived stress-levels (left) and emotional awareness (right) as a function of condition and measuring time per participant.

0.03, $p = 0.178$; P 5: $B = 0.021$, $SD = 0.03$, $p = 0.480$; P 6: $B = 0.007$, $SD = 0.03$, $p = 0.802$; P 8: $B = 0.034$, $SD = 0.04$, $p = 0.450$). One participant showed an increase (P 7: $B = 0.079$, $SD = 0.03$, $p = 0.009$) and one a decrease (P 4: $B = -0.065$, $SD = 0.03$, $p = 0.047$). In the experimental condition (biocueing on), no significant effect of the intervention on stress-levels was found for six out of eight participants (P 1: $B = 0.007$, $SD = 0.06$, p = 0.903; P 2: $B = -0.068$, $SD = 0.04$, $p = 0.129$; P 3: $B = -0.018$, $SD = 0.04$, $p = 0.177$; P 5: $B = 0.008$, $SD = 0.05$, $p = 0.868$; P 6: $B = 0.025$, $SD = 0.04$, $p = 0.511$; P 8: $B = 0.017$, $SD = 0.11$, $p = 0.870$). One participant showed an increase (P 4: $B = 0.094$, $SD = 0.04$, $p = 0.03$) and one participant showed a decrease (P 7: $B = -0.154$, $SD = 0.06$, $p = 0.01$). Improvement rate difference (IRD) effect sizes ranged from 0.16 to 0.35, which is indicative of a small effect size of the combination of biocueing and ENYOY on perceived stress-levels. Results from the level-two ordinary least squares regression analysis show that, across cases, there was no significant effect of the intervention on perceived stress-levels, ($B = -0.020$, $SD = 0.03$, $t(6.39) = -0.61$, $p = 0.562$). These findings indicate that biocueing in combination with ENYOY does not decrease perceived stress-levels among participants.

No significant effect for emotional awareness in the control condition was found for five out of eight participants, see **Table 1** and **Figure 2** (P 1: $B = -0.027$, $SD = 0.02$, $p = 0.17$; P 2: $B = 0.009$, $SD = 0.02$, $p = 0.644$; P 3: $B = 0.016$, $SD = 0.02$, $p = 0.487$; P 4: $B = -0.002$, $SD = 0.01$, $p = 0.891$; P 8: $B = 0.018$, $SD = 0.02$, $p = 0.456$). Three participants showed a decrease in levels of emotional awareness (P 5: $B = -0.027$, $SD = 0.01$, $p = 0.012$; P 6: $B = -0.071$, $SD = 0.02$, $p < 0.001$; P 7, $B = -0.049$, $SD = 0.02$, $p = 0.004$). In the experimental condition, no significant effect was found for six out of eight participants (P 1: $B = 0.044$, $SD = 0.03$, $p = 0.111$; P 2: $B = 0.034$, $SD = 0.03$, $p = 0.211$; P 3: $B = 0.002$, $SD = 0.03$, $p = 0.941$; P 4: $B = 0.013$, $SD = 0.02$, $p = 0.484$; P 5: $B = 0.008$, $SD = 0.02$, $p = 0.612$; P 8: $B = 0.002$, $SD = 0.06$, $p = 0.966$). Two participants showed an increase in levels of emotional awareness (P 6: $B = 0.061$, $SD = 0.02$, $p = 0.008$; P 7: $B = 0.039$, $SD = 0.03$, $p = 0.007$). The IRD for significant results ranged from 0.05 to 0.31, which is indicative of a small effect size. Results from the level-two ordinary least squares regression analysis showed that, across cases, there was a significant fixed interaction effect of time and condition on emotional awareness ($B = 0.030$, $SD = 0.01$, $t(6.71) = 2.42$, $p = 0.048$), indicating that in the experimental condition, emotional awareness increased significantly over time. These findings indicate that the combination of ENYOY and biocueing could increase emotional awareness.

Phase 3–Evaluating the Intervention With End Users

Thematic analysis from the evaluative interviews yielded the following themes: usability of the Sense-IT, integration of the Sense-IT and the ENYOY-platform, and ideas for improvement of the Sense-IT and the ENYOY-platform.

The overall usability of the Sense-IT could be rated as moderate with reported usability issues. On the one hand, positive experiences were reported. All participants mentioned that they reflected more on how they were feeling and three noted that this helped them understand their emotions better. All participants mentioned making an effort to change

TABLE 2 | Descriptive statistics for subscales of the Health ITUES subscales.

Scale	M (SD)	Median (range)
Overall Health-ITUES score	3.69 (0.30)	3.75 (3.25–4.20)
HI score impact	3.93 (0.43)	3.66 (3.33–4.67)
HI score perceived usefulness	3.71 (0.42)	3.56 (3.11–4.33)
HI score ease of use	3.63 (0.46)	3.80 (2.80–4.20)
HI score user control	3.29 (0.74)	3.00 (2.00–4.33)

HI, Health-ITUES; M, mean; SD, standard deviation.

something in their behavior because of the biofeedback, such as pausing and evaluating the situation or doing a breathing exercise. Scores on the Health-ITUES indicated that participants judged the impact and usefulness of the intervention to be moderate ($M = 3.93$, $SD = 0.43$; $M = 3.71$, SD = 0.42, see **Table 2**). These scores indicate that the intervention impacted the participant's daily life moderately and participants were moderately able to accomplish tasks through system use.

> P5: *"I liked using it. For me personally, the watch was quite big, as I have small wrists. I liked the notifications, like: "Hey, watch out, your heartbeat is quite high, is something the matter?" [...] having the device tell me that something might be happening [within me] helped me to be mindful of that. I liked that very much."* [1]

On the other hand, participants mentioned several technical problems. Most participants [5] noted difficulties with the interface, resulting from problems with making notes in the app [2], not receiving text notifications [1], the watch display changing to default settings [1], and difficulties in figuring out how to know when the biocueing intervention was turned on [1]. Furthermore, most participants [5] expressed doubts about the accuracy of the heartbeat measurements, with participants receiving too much [4] or too little biofeedback [1], and three participants mentioned that their baseline measurement failed multiple times.

> P6: *"Sometimes I got a notification while I was sitting still, it said that my heartbeat was too high and I thought 'That's weird', because I wasn't doing anything stressful. There was also a situation in which I was stressed but I didn't see that on the watch"*

Lastly, half of the participants mentioned that the usage of the intervention was disrupted due to limited battery life of the smartwatch. Half found the appearance of the smartwatch acceptable, others noted that the smartwatch was too big [2], did not fit their style [1], or found the strap uncomfortable [1]. The average system usability score (SUS) of the group was above the cut-off score ($M = 63.78$, $SD = 10.96$), meaning the intervention was permissible in terms of acceptance, though indicating that there are usability issues that are cause for concern. Results from the Health-ITUES yielded a moderate usability score ($M = 3.69$, $SD = 0.30$, ranging from 2 to 4.33; also see **Table 2** for average scores per subscale).

Regarding the integration of the Sense-IT and the ENYOY-platform, the breathing exercises from the ENYOY-platform seemed the most suitable choice when stressed and were done by most participants [7]. Half of the participants did not use the ENYOY-platform during the study, reasons being not having thought about it or not having time [2], finding it difficult to use ENYOY due to double verification which is used for logging in [1], or already having used the ENYOY-platform extensively in the past [1]. Scores on the Health-ITUES were reflective of this fact, as user control and ease of use was judged to be moderate ($M = 3.63$, $SD = 0.46$, see **Table 2**), indicating that the user-system interaction was not optimal.

> P47: *"Well, I haven't thought about it [using the ENYOY-platform], and often when it [the watch] vibrated, I wasn't near my laptop. I use it on my laptop rather than on my phone. I didn't open my laptop the past week, so that must've played a role."*

Of the participants that had used the platform, most noted that they used the platform on their laptop [3] and that they planned time in their agenda to go on the platform [2]. The most used online tools were the toolkit [2] and the explore function [2]. Participants expressed their need for exercises that are short [2], are adapted to their needs [1], are practical [1], or include psycho-education [1]. Half of the participants mentioned that they did not always carry the research smartphone with them, which hindered them from using the intervention fully. They mentioned that they would use the Sense-IT more often if the research smartphone was directly connected to the ENYOY-platform or if they could use their own smartphone [both of which were not possible in this study because the research smartphone was an 'offline' device for privacy concerns (see methods)].

> P83: *"I used it [the ENYOY-platform] once or twice, because this phone wasn't connected to the internet, which made it more of an effort, because then I had to see when I receive a notification and ask myself "why, when?" and then I have to use the platform here [in the bedroom] on my laptop. So for me, it's a bit of an obstacle, because there are more actions involved."*

Some participants thought they would be more inclined to use ENYOY if there were an app [3], if logging in was made easier [1], and if reminders for using the platform were given [1].

Participants gave many suggestions for improvement of the Sense-IT and the ENYOY-platform to further integrate the two interventions and to increase user experience (see **Table 3**). Important suggestions referred to the accessibility of the ENYOY-platform, the integration between the platform and the Sense-IT, and bugs in the Sense-IT.

[1] All quotes were translated from Dutch to English.

TABLE 3 | Overview of bugs, problems and proposed solutions from the semi-structured evaluative interviews.

Intervention type	Problem	Proposed solution
ENYOY	Not all participants used the platform during the study, because they found it difficult to log in	Make an app
		Make the web-app version of ENYOY more accessible (e.g., by incorporating an explanation of how to set the webpage on the home screen of a smartphone)
		Explain how to save double verification log in credentials/personalize double verification log in
	Not all participants used the platform during the study, because they had no time or forgot about it	Set reminders of suggested exercises
		Engage participants more by adding gamification elements to the platform to create positive feedback from the platform (e.g., Balance or Duo Lingo apps)
		Integrate the therapy path and explore function more (suggested exercises)
		Add quizzes to make the content more interactive and test whether or not young people understood the content
		Make sure translations on the platform are well executed
Sense-IT and smartwatch	The last heartbeat measurement was not intuitively visualized	It is less important to be able to click on the last measurement, as this often was not the most important measurement – it may be a better idea to show the last high or last low heartbeat measurement
	The baseline measurement was not adequately measured in many instances	-
	The movement sensor of the Sense-IT did not work properly	This problem is fixed once the intervention is used on a personal smartphone, as the app then is able to pinpoint the exact location through wireless internet connection
	The smartwatch had to be charged often (once daily)	-
	The Sense-IT at times switched off automatically	-
	The Sense IT watch display sometimes switched back to the default watch display	-
	Making notes further back than a few days was bugged	-
Combination ENYOY, Sense-IT, and smartwatch	Not all participants used the platform during the study because there were many actions involved to get to the platform	Provide a link from the Sense-IT to the ENYOY-platform on the smartphone
		Use the Sense-IT application on one's own smartphone
		Integrate a heartbeat measurements overview in the ENYOY dashboard

"-" means that participants did not come up with a solution for this problem.

DISCUSSION

The focus of this study was to investigate the usability, feasibility, and effects of biocueing in addition to the moderated online social therapy-platform ENYOY in young people with emerging mental health problems, following a user-centered (47) mixed-method design framework. The current study had three objectives: 1) to qualitatively explore whether biocueing could be of additional value to ENYOY; 2) to assess the exploratory effect of biocueing in combination with ENYOY on perceived stress and emotional awareness; 3) to evaluate the attitude of users concerning the usability, acceptance, and user-friendliness of biocueing in combination with ENYOY as an intervention.

The findings from the phase 1 (*Understanding and specifying end user needs regarding the interventions*) focus group indicated an additional value of a biocueing intervention to ENYOY and resulted in several suggestions regarding briefing, access, and integration for adaptation of the smartwatch to the ENYOY-platform and vice versa, which were implemented for phase 2 (*Testing the intervention with end users*). The compliance rate of phase 2 was on average 78.8%, which is similar to compliance rates in patient populations (66), and slightly higher then compliance rates for digital therapy platforms for youths [63,81% on average, (43)]. Exploratory findings of phase 2 showed different individual effects of biocueing on perceived stress and emotional awareness. Overall, no effects were found on perceived stress-levels, suggesting that the current combination

of ENYOY and biocueing does not decrease perceived stress in young people. Positive exploratory effects were found on emotional awareness, suggesting that the combination of ENYOY and biocueing could increase emotional awareness and thereby possibly poses a relevant addition to a digital treatment platform. Nonetheless, some caution is advised because of the small sample size of this explorative feasibility study, and since Improvement Rate Difference [IRD; (59)] showed small effect sizes of the intervention.

Results from phase 3 (*Evaluating the intervention with end users*) showed improvements on reflection on feelings and positive changes in behavior - such as pausing and evaluating the situation, doing an exercise on ENYOY, and having a rest - following the biocueing intervention combined with the use of ENYOY. Participants preferred exercises on the ENYOY-platform that were short, adapted to their needs, practical, or included psycho-education. The most common tools used were breathing exercises, the toolkit (a library where the young person can save his/hers favorite exercises), and the explore function (a quick search function to show exercises per category, e.g., "rumination" or "stress"). Not all participants used the platform during the experimental phase, a reason being that the integration of the two interventions was very rudimentary due to the early implementation. These kinds of new intervention products are also known as Minimum Viable Products (MVP), which are first versions of a product or service which are being delivered to a target group as early as possible. The most common issues for MVPs are the non-optimal technical support and lack of resources (67), as was the case in this study. The intervention was found to be permissible in terms of acceptance and showed a moderate usability, with reported usability issues. The most common issues that were reported concerned the use of the smartwatch (e.g., technical issues, difficulties with the interface, doubts about the accuracy of the heart rate measurements, and limited battery life), and design of the smartwatch (appearance not fitting their style and lacking wearing comfort), as well as the non-optimal integration of the smartwatch and the ENYOY-platform (not being available on the same device). Main suggestions for improvement were related to the accessibility (e.g., the option to use both interventions on one device, within one app, and add reminders), engagement of users (e.g., adding gamification elements, create positive feedback for the platform, and make use of fun elements such as a quiz), and the integration (e.g., show heartbeat measurements of the smartwatch on the ENYOY dashboard).

As indicated by the results, the intervention significantly increased emotional awareness, and did not significantly decrease perceived stress. This means that the biocueing intervention in addition to ENYOY seems to make participants more aware of their (negative) emotional states and does not seem to play a part in decreasing perceived stress. The last is contrary to previous research where decreases in self-reported stress-levels were found (23). There are several factors that could play a role in this finding. First, stress was measured using one survey item, asking participants to indicate their stress-levels on Likert scale. It is questionable whether a single survey item, prompted twice a day, can accurately encapsulate a multifaceted concept like stress (68). Even though subjective measures have their obvious limitations, their merit lies in the ability to measure beliefs, thoughts, emotions, and attitudes about stress (69). Stress is not just the simple product of a perceived threat; according to the Transaction Model, stress is a product of the antecedent personal resources and external stressors, mediated by coping, followed by both short- and long-term effects (70). Studying the person-environment interaction and coping may provide additional valuable insight on the way these factors play a role in stress-reduction through biocueing. Furthermore, participants participating in the intervention had relatively low levels of stress, as indicated by the low levels of stress in the control condition. Therefore, stress had a low mean score and had little room for change. This little room for change was emphasized by the short period of time of the experiment: two weeks may not be enough to observably change stress in participants. Additionally, there were no fixed time frames for the measurements. This means that participants were free to answer the stress-related survey item any time after the question was prompted. Presumably, participants who experience heightened stress may not be able to direct their time toward answering the survey question and therefore answer the question later when heightened stress has subsided.

Even though emotional awareness plays a role in stress reduction, being more emotionally aware alone may not automatically cause someone to experience less stress without active attempts to reduce it (71). A biocueing wearable functions as an indicative system that provides the user with feedback on symptoms associated with stress, such as heightened heart rate through skin conductance. Participants that experience stress, but do not make an effort to reduce it through meaningful effort, may therefore become more aware of aversive feelings, but not experience relief from it. To emphasize, only half of all participants used ENYOY during the experimental phase, which raises the question how many participants made an effort to actively reduce stress if any at all. Participants felt that the integration of Sense-IT and ENYOY was lacking. Participants could not use their own phone and carried a research phone that was not connected to the internet or offering direct access to the ENYOY-platform for privacy concerns (an 'online' device is more prone to data leaks and this was found too big a risk for the target population and the nature of their complaints), which was seen as a limiting factor in terms of usability. Participants mentioned they were more likely to use ENYOY if these issues were addressed and participants did not have to switch devices to access ENYOY. Furthermore, increased awareness of bodily sensations may adversely increase anxiety if they are interpreted catastrophically (72). Some young people might stop wearing their smart watches because the watches disturb their life by making them too 'aware' of their stress and situation. Finally, in the field of clinical psychology experiencing negative emotions is seen more and more as being a normal part of life. A stance more toward accepting these and learning how to deal with them might provide individuals with a more fulfilling life than striving to get rid of them [e.g., (73)]. Moreover, one of the keystones of ENYOY is normalizing difficult emotions (18). In this way, one could wonder whether the goal of biocueing and ENYOY should be to reduce stress, or to provide ways in how to deal with the

stress that a person has in his or her life. For future research it would be of interest to not only measure stress-levels, but, more importantly, coping with stress.

The individual differences in effects of the intervention could have multiple reasons. First of all, in individual cases it is uncertain whether results are due to progress rather than time [(74); also see Limitations]. Moreover, individual differences in baseline stress-levels and emotional awareness [e.g., (75, 76)] could mean that for some there was less room for improvement (77) and for others that 10 days of biocueing was insufficient. Interestingly, three out of eight participants showed a decrease in emotional awareness in the control condition, of which two subsequently showed an increase in the experimental condition. This reinforces the idea that the intervention itself changed outcomes rather than time. Moreover, biocueing might not be a suitable intervention for all. If an individual already has a hypersensitivity toward one's internal state and/or experiences panic because of bodily sensation [e.g., for individuals who suffer from illness anxiety disorder, see (78); or individuals who are diagnosed with bipolar disorder, see (79)], biocueing could exacerbate this focus and panic even more. Another example regards individuals with problems with interoceptive sensibility (the capacity to focus on internal sensations and take them into consideration), such as individuals with autism and/or alexithymia, where difficulties are found in discriminating among interoceptive signals, which might result in difficulties understanding one's bodily states (80). For these individuals, a biocueing intervention could be especially challenging since it focuses mainly on interoceptive accuracy (a higher heartbeat is identified) and not on interoceptive sensibility (what does this mean to me?). Extra treatment regarding *how* to interpret, distinguish, and deal with these sensations and emotions would be required (80). Although ENYOY offers some exercises along these lines, this might be insufficient for some. All in all, the individual differences in effects indicate that the biocueing intervention might not be suitable for every individual, which should be addressed before providing individuals with a smartwatch.

A main point that might have countered the true added effects of biocueing to ENYOY is the usability of the biocueing intervention. The overall usability of the intervention was found to be moderate, with reported usability issues. Even though participants reported that the intervention helped them reflect more on how they were feeling or helped them in understanding their emotions, several issues were reported that impacted the usability of the smartwatch. Half of all participants found the smartwatch either too large, not fitting their style, or too uncomfortable. These factors, "aesthetics," play an important part in deciding to either "use or lose" the smartwatch (44, 81, 82), even more so in adolescents who highly value the aesthetics of wearables (83). Therefore, it is important that the smartwatch fits a participant's sense of style to increase usability, which can either be achieved through customizable options or a choice of different styles. The Sense-IT application which was used in the study works on any Android OS watch, however for the purpose of this study all participants received the same smartwatch. One could imagine that a flashy self-chosen smartwatch linked seamlessly to a digital platform would significantly improve the link between signaling and outcomes.

Limitations and Strengths

Several strengths and limitations of this study should be highlighted. A limitation of this study is that not all suggestions opted by the phase 1 focus group could be implemented for the intervention due to missing technical support and resources. This could have contributed to the lower usability and acceptance rates and lower use of ENYOY, and is a missing requirement that is necessary for a user-centered design (47). However, we hope that our findings could provide useful information for future research and implementation. Another limitation of this study are the compliance rates. Over 20% of measurements were missing and significantly more data was missing in the experimental condition. This was dealt with using Expectation-Maximization; a method that is found to keep the power sensitivity stable in case of missing data, even up to 40% (65). Additionally, an AB (A control phase, B experimental phase) approach was opted, which means it cannot be said with certainty that *individual* effects in phase B are due to progress rather than time. For this, at least three phase changes (ABAB) are necessary. This was compensated by using the multiple single-case design which eliminates the need to return to baseline (74), and enables to make conclusions about the intervention at group-level. Moreover, this study had a relatively small sample size. This was deemed fit for the type of research (an explorative feasibility study), and was chosen to not unnecessarily burden participants. Nonetheless, the small sample size could have affected the reliability of the results. The contrasting direction of the individual responses found in the level-one analysis of phase 2 of this study are also indicative of a greater sampling variability. Lastly, all participants were female and had followed higher vocational education or university. This could have influenced the representativeness of the user group in relation to the overall population.

A strength of this study is its user-centered mixed-method design. The end users played a central role in every iteration of the study and were involved in the developmental process of the integration of the ENYOY-platform and the smartwatch (co-creation). This provided a deeper understanding of psychological, social, and ergonomic factors related to the used technology. Though a pitfall of this could be that the end product would be too specific for general use and less transferable to other clients. Moreover, this method has been found to improve effectiveness, efficiency, and safety of technological products (47). The use of mixed-methods also provided us with rich, comprehensive data by integrating qualitative and quantitative data (84). The use of ecological momentary assessment further allowed us to measure in real-time, which minimizes recall bias and maximizes ecological validity (48).

Considerable efforts were made to increase and ensure quality control. The Sense-IT app has already been used in previous studies after being developed with well-recognized research methods (52, 57) which decreases the risk of statistical anomalies due to hard- or software factors. In addition, the Sense-IT was built in accordance with the Medical Devices Directive (MDD)

and Active Implantable Medical Devices Directive (AIMDD) ensuring that Sense-IT has to meet certain quality standards (54). Additionally, the SUS (60) and S-DERS (55) have shown adequate validity and reliability making it useful tools for this study. Furthermore, the Health-ITUES (62) which had no original Dutch version, was carefully translated back-and-forth (English-Dutch, Dutch-English, and English-Dutch) between four independent translators to limit diminished validity and reliability through mistakes in translation.

Future Research

For future research, foremost, usability studies are recommended to improve the smartwatch and integration with a digital platform. This study highlighted the need for research with the goal of full optimization, preferably in co-creation with end-users [see for example (52, 85, 86)]. It would be of further relevance to gain a better understanding of which individuals would, and which would not, benefit from a biocueing intervention (in addition to a digital treatment platform). In the future, it would be valuable to connect the ENYOY-platform to the smartwatch in such a manner that the activities of young people on the platform could be followed to see which part(s) of the platform is/are most effective to relieve stress. Moreover, multidimensional assessments of both stress and emotional awareness could provide valuable new insights [also see (69)]. It would also be of interest to investigate whether an optimized detection of stress and corresponding interventions lead to greater effects; and to evaluate via rigorous designs whether biocueing improves outcomes. Lastly, a positive psychology framework using ecological momentary assessment could be opted to see the effects on e.g., psychological wellbeing, since not all stress and 'negative' emotions are necessarily a bad thing.

Recommendations

All in all, biocueing could be a promising intervention to add to a digital treatment platform to help young people become more aware of their emotions. Be that as it may, notable improvements have to be made regarding the usability and acceptability of the smartwatch as well as more extensive integration of the smartwatch to a digital treatment platform before further implementing such an approach. Moreover, it is of importance to tailor the need to the individual of such an added intervention since large individual differences exist. The intervention might not work for all. It is of relevance to discover more about the contraindications before using a smartwatch. Finally, young people indicated that adding elements of gamification could improve learning and the use of the interventions.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by METC, AMC: NL66345.018.18. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MD, DN, TA, AP, MN, and MJ completed the initial study design. AM was involved with the execution of all phases of the study. DN, TA, MJ, AP, MN, and MA-J provided an expert assessment and feedback. The manuscript was written by MD, AM, and LN. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2022.871813/full#supplementary-material

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Virtual Reality for Distraction and Relaxation in a Pediatric Hospital Setting: An Interventional Study With a Mixed-Methods Design

Sylvie Bernaerts[1], Bert Bonroy[2], Jo Daems[2], Romy Sels[2], Dieter Struyf[3], Inge Gies[4] and Wessel van de Veerdonk[5]*

[1] Expertise Unit Psychology, Technology and Society, Thomas More University of Applied Sciences, Antwerp, Belgium, [2] Mobilab & Care, Thomas More University of Applied Sciences, Geel, Belgium, [3] Creative and Innovative Business, Thomas More University of Applied Sciences, Mechelen, Belgium, [4] Department of Pediatrics, Universiteit Brussel (VUB), Universitair Ziekenhuis Brussel (UZ Brussel), Brussels, Belgium, [5] Thomas More University of Applied Sciences, Mechelen, Belgium

Accumulating evidence supports the use of virtual reality (VR) as an effective pain and anxiety management tool for pediatric patients during specific medical procedures in dedicated patient groups. However, VR is still not widely adopted in everyday clinical practice. Feasibility and acceptability measures of clinicians' experiences are often missing in studies, thereby omitting an important stakeholder in VR use in a clinical setting. Therefore, the aim of this mixed-methods study was to investigate the feasibility, acceptability, tolerability (primary outcomes), and preliminary effectiveness (secondary outcome) of Relaxation-VR in both pediatric patients aged 4–16 years and clinicians. Relaxation-VR is a VR application prototype aimed to provide distraction and relaxation for a variety of patient populations and procedures and is used to reduce anxiety, stress (tension) and pain for children in hospital. Multiple measures of acceptability, feasibility and tolerability, and pre-to-post changes in measures of pain, anxiety, stress and happiness were assessed in pediatric patients. At the end of the study, acceptability and feasibility of VR use was assessed in clinicians. Results indicate that VR use (in particular, the Relaxation-VR prototype) for both distraction and relaxation is acceptable, feasible and tolerable for a variety of pediatric patients aged 4–16 years, as assessed in both patients and clinicians, and can reduce anxiety, pain and tension (stress), and increase happiness in a hospital setting.

Keywords: virtual reality, pediatrics, relaxation, implementation, anxiety, stress, feasibility, acceptability

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****Correspondence:***
Sylvie Bernaerts
sylvie.bernaerts@thomasmore.be

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INTRODUCTION

Virtual reality (VR) is a form of human-computer interaction technology that immerses an individual in a computer-generated environment. While earlier versions of VR have included the use of large screens or 3-D glasses (semi-immersive VR), nowadays, VR environments are mainly experienced through advanced head-mounted displays (also called headsets) with built-in motion tracking (immersive VR). The specific immersive nature of this technology has made VR an interesting distraction method in pediatric pain and anxiety management (research) for over 20 years. Seminal work by Hoffman et al. (1) assessing the effects of VR during wound care in two

case studies of adolescent patients with burn wounds suggested that immersive VR is an effective pain management tool. Following studies assessing the effects of immersive VR for pain management during burn wound care corroborated these findings (2–5). In addition, in pediatric patients (immersive), VR has been shown to be effective for alleviating pain and anxiety during post-surgical physical therapy (6), venous port access procedures (7), intravenous procedures (8–12), dental treatment (13), and for pain management of vaso-occlusive pain episodes in patients with sickle cell disease (14). In general, accumulating evidence has supported the use of VR as an effective pain and anxiety management tool for pediatric patients during specific medical procedures in dedicated patient groups [for review, see (15–18)]. In particular, a recent meta-analysis reported that the use of VR was significantly more effective in reducing pain (14 studies) and anxiety (7 studies) than standard care, with large effect size (17). Despite this growing evidence base, VR is still not widely adopted in everyday clinical practice.

To improve translation from research to practice, more knowledge on implementation factors is needed. A group of 21 international VR experts (Virtual Reality Clinical Outcomes Research Experts—VR-CORE) reported recommendations for research methodology on using VR in healthcare and defined three phases of VR clinical study designs: VR1, VR2, and VR3 (19). VR1 studies result in VR content development through a human-centered design with input from end-users. Afterwards, the product should undergo initial assessment in the target population within a representative clinical setting. This type of study, VR2, is aimed at assessing feasibility, acceptability, tolerability, and initial clinical efficacy. Lastly, VR3 trials involve clinical validation of the VR product, by means of prospective, adequately powered, methodologically rigorous randomized, controlled trials. In line with these recommendations, evidence on the feasibility, acceptability and tolerability of a VR interventions is growing. However, when these outcomes have been assessed to date, the measures to do so varied largely. For example, tolerability of VR has often been assessed in patients, seen as simulator sickness (or VR sickness) is a known side effect of VR use. VR sickness is similar to motion sickness and is thus characterized by symptoms such as nausea, dizziness, headaches or blurry vision (20). Some studies have specifically assessed nausea with a separate question or scale (1, 3, 5, 21), whereas others have assessed simulator sickness with a specific questionnaire (10, 22). In general, VR seems to be well-tolerated by pediatric patients with studies reporting no nausea or other side effects, and only mild when present. Concerning feasibility, this concept has been assessed by measuring experienced fun during VR use (3, 23), ease of use and understanding (usability) (8, 21), the occurrence of technical issues and procedure time (8). Together, these studies have shown that VR use is feasible for patients with burn wounds during physical therapy (3, 23), for patients with sickle cell disease (14), and during pediatric hemophelia care for distraction during intravenous interventions (8). With respect to acceptability, researchers have assessed this concept with open-ended questions or by measuring their intention or willingness to use VR again and found that VR use was acceptable for pediatric patients (14, 21). Taken together, these studies have each shown that various VR applications for distracting pediatric patients (from pain procedures) are feasible, acceptable and tolerable, each for use in a specific patient sample or during a specific medical procedure. Nonetheless, implementation of VR outside of the laboratory is lagging, and costs, user's attitudes and safety considerations (among others) are known implementation challenges (24). Therefore, an application intended for multiple uses, namely distraction and relaxation, and usable in pediatric patients of various ages and with various medical conditions, might prove to be more cost-efficient. With this study, we thus aim to assess the feasibility, acceptability and tolerability of a VR relaxation application to distract pediatric patients during various medical procedures as well as to provide relaxation during a longer hospital stay. Based on aforementioned literature, we hypothesize that one VR relaxation application for use in a varied patient sample is also feasible, acceptable and tolerable. To the best of our knowledge, feasibility and acceptability measures of clinicians' experiences are often missing in the aforementioned studies, thereby omitting an important stakeholder in VR use in a clinical setting. Therefore, the aim of our study was to investigate the feasibility, acceptability, tolerability (primary outcomes), and preliminary effectiveness (secondary outcome) of Relaxation-VR both from a patient and clinician perspective, which is in line with the VR CORE VR2 trial recommendations (19). Note, however, that this study does not aim to assess moderators nor predictors of VR acceptability, feasibility and tolerability for pediatric patients in hospital.

Relaxation-VR is a VR application (prototype) aimed to provide distraction and relaxation for a variety of patient populations and procedures, that is used to reduce anxiety, stress (tension) and pain for children in hospital. Also, no specific medical procedure, treatment or patient population is chosen in order to increase the generalizability of the findings and, therefore, the potential usability in clinical practice.

MATERIALS AND METHODS

General Study Design

This mixed-methods study was performed at the University Hospital Brussels (Jette, Belgium; further named as UZ Brussel) and the General Hospital Sint-Maarten (Mechelen, Belgium; further named as AZ Sint-Maarten) to assess the acceptability, feasibility, tolerability and preliminary effectiveness of Virtual Reality (VR) as a relaxation and distraction tool for children admitted to the hospital. To do so, we used the Relaxation-VR app, a VR application (prototype) aimed to provide distraction and relaxation for a variety of patient populations and procedures. Before and after one VR session with Relaxation-VR, multiple measures of acceptability, feasibility and tolerability were assessed in pediatric patients. In addition, pre-to-post changes in measures of pain, anxiety, stress and happiness were assessed in pediatric patients. At the end of the study, after using Relaxation-VR with multiple patients, acceptability and feasibility of VR use was assessed in clinicians. Written informed consent was obtained from all participants prior to the study. Consent forms and study design were approved by the Medical

TABLE 1 | Demographic information and baseline descriptives.

	Pediatric patients (*N* = 51)	Clinicians* (*N* = 12)
Gender	30 F/21 M	12 F/0 M
Age (*M*, SD)	10.88 (3.17)	30.08 (8.00)
Study site	39 B/12 SM	9 B/3 SM
Prior knowledge		
No	26/51	
Yes	24/51	
Gaming	11/24	
Culture	8/24	
Owns VR headset	4/24	
Hospital	1/24	
Unknown	1/51	

M, mean; SD, standard deviation; B, UZ Brussel; SM, AZ Sint-Maarten.
Culture-related prior knowledge of VR refers to experience with VR in musea and/or exhibits.
**11 nurses and 1 remedial educationalist.*

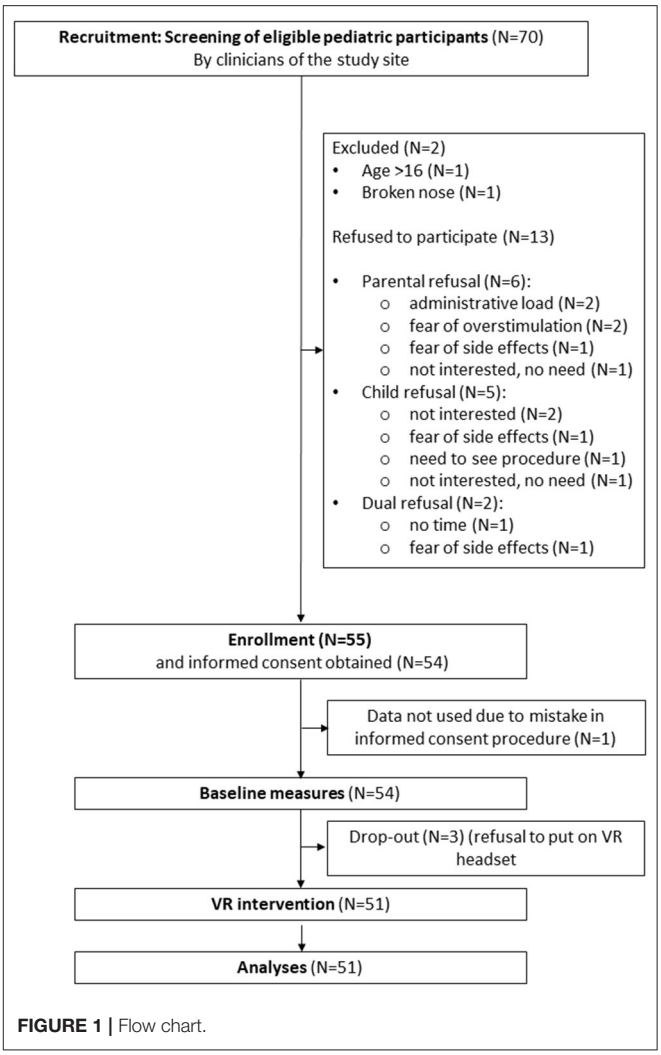

FIGURE 1 | Flow chart.

Ethics Committee of the University Hospital Brussels (EC-20202-305) as well as by the local ethical committee of the AZ Sint-Maarten in accordance to the Code of Ethics of the World Medical Association (Declaration of Helsinki). The trial was registered at ClinicalTrials.gov (NCT04666506).

Participants

Fifty-five pediatric in- and outpatients aged 4–16 years (M = 10.88, SD = 3.17, median = 11.00, minimum = 4, maximum = 16) were recruited between January and May 2021 from the UZ Brussel (N = 39) and AZ Sint-Maarten (N = 12) pediatric departments. Patients were included according to the following criteria: age between 4 and 16 years, normal or corrected-to-normal vision and hearing, in- or outpatient in one of the study sites and in need of relaxation or distraction before treatment of medical procedure, as assessed by the clinical staff. Exclusion was based on the following criteria: history of seizures, physical impairment that precludes VR intervention, need for medical procedures considered unsuitable in combination with the use of a VR headset, non-Dutch native patient or caregiver, or previous enrolment in the current study (during a previous hospital stay). Data from four participants were not included in the final analyses due to drop-out (N = 3, refusal to put on VR headset) or a mistake in the informed consent procedure (N = 1). Final analyses were therefore performed with data of 51 pediatric patients. Regarding clinicians, twelve women (11 nurses and 1 remedial educationalist) employed at the pediatric departments of UZ Brussel and AZ Sint-Maarten have participated in the study after informed consent was obtained. Demographic information of the study sample is described in **Table 1** and the study flow chart is presented in **Figure 1**.

Intervention

The Virtual Reality prototype application, named Relaxation-VR, is a VR application developed by Psylaris (25) aiming to reduce anxiety, stress and pain by distracting the patient in a relaxing environment. During the study, the Relaxation-VR app was made available *via* a commercially available Oculus Go VR headset (Meta, California, USA). By using the VR headset, participants are immersed in a novel, calming and distracting environment where they are asked to perform tasks that will help them to relax when distressed before and/or during a medical procedure or during their stay in hospital. The Relaxation-VR app consists of three modules or VR environments. The first module comprises breathing exercises; the second comprises meditation exercises (e.g., a body scan) and the third module presents a scene with different interactive animations and objects (i.e., catching falling apples, popping bubbles, and playing fetch with a dog) (**Figure 2**). Depending on their age, pediatric patients used either all three modules (aged 9–16) or only the third module (aged 4–8). This decision was based on prior discussions with the involved clinical staff and their experience in using relaxation exercises with (younger) patients. All participants received the VR intervention, which consisted of one VR session using the Relaxation-VR app.

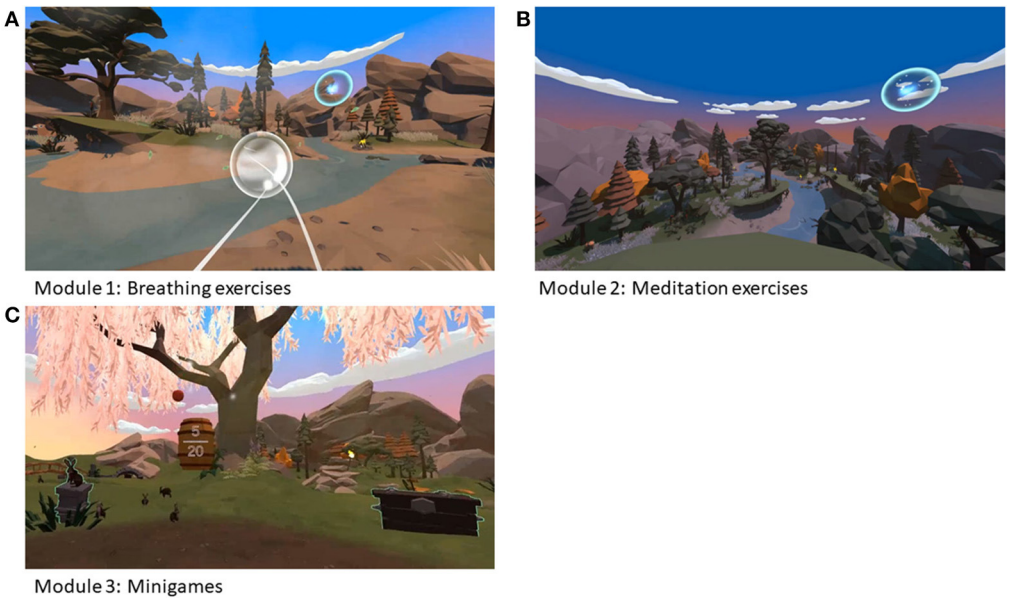

FIGURE 2 | Images of Relaxation-VR modules 1 **(A)**, 2 **(B)**, and 3 **(C)**.

Procedure

After initial screening procedures by the clinical staff, pediatric patients and their parents were approached by the clinicians involved in the study at the pediatric departments of the study sites. Subsequently, interested patients and parents received the informed consent form (for parents and children aged 12 years and older) and assent form (for children aged 4–12 years old). Study procedures and legally and ethically required information were presented and explained in an informative video that was shown on a tablet in the hospital, any questions were answered by the local investigators. After the informed consent was obtained, participants filled in an online questionnaire *via* a tablet for demographic and background data collection and a paper questionnaire to collect baseline data on anxiety, pain, tension (stress) and happiness. If needed, parents were allowed to help their child to fill in the questionnaires. Participants then received the VR intervention. Participants were seated on a hospital bed or chair and also remained stationary in the virtual environment. The user was able to look around in the virtual environment by moving his/her head and was able to interact with virtual objects by staring at them for a few seconds, but did not move around in the different environments (modules). Modules 1 and 2 took ∼6–7 min to complete, whereas participants were allowed to use module 3 for as long as needed. Afterwards, participants were asked to fill in the same paper questionnaire assessing anxiety, pain, tension (stress) during use of the VR intervention, as well as a self-composed paper and online questionnaire assessing acceptability, feasibility and tolerability of the intervention. Finally, at the end of the study (when the data of all pediatric participants was collected), the involved clinicians were asked to fill in an online questionnaire assessing acceptability and feasibility of the use of VR.

Outcome Measures

Outcome measures were based on the recommendations of the Virtual Reality Clinical Outcomes Research Experts (VR-Core) for development and evaluation of therapeutic virtual reality, specifically on the recommendations for VR2 trials focusing on acceptability, feasibility, tolerability (primary outcomes) and initial clinical effectiveness (secondary outcome) (19). Data were collected with both a paper and online self-developed questionnaire including validated instruments and open-ended questions.

Acceptability

In the context of this study, acceptability refers to the patient's and clinician's willingness to use the Relaxation-VR app (19). In pediatric patients, acceptability was assessed by collecting data on patients' and their parents' willingness to enroll in the study and their reason for enrolling in the study (collected prior to using the Relaxation-VR app). After using the Relaxation-VR app, the patients were asked to rate their willingness to use the VR intervention again using a visual analog sale (VAS) to answer the question "To what extent would you use the Relaxation-VR app again?". A score of 0 represented "I definitely want to use it again" and a score of 100 represented "I definitely do not want to use it again". Pediatric participants were also asked to rate the extent to which they would advise others to use Relaxation-VR with a score of 0 representing "I definitely advise it to others" and 100 representing "I definitely do not advise it to others". In addition, at the end of the study, clinicians' attitude toward Relaxation-VR was assessed with the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire based on Ebert et al. (26) and the Unified Theory of Acceptance and Use of Technology model (27). The Dutch version of this

qualitative 31-item questionnaire consists of the following scales: performance expectancy (4 items), effort expectancy (4 items), social influence (4 items), attitude toward technology (4 items), facilitating conditions (4 items), fear (4 items), intention to use (3 items), and self-efficacy (4 items) (28). Scores range from 1, representing "do not agree at all" to 5, representing "completely agree". Higher scores reflect positive attitudes, except for the fear scale, for which higher scores reflect increased fear. Mean scores and their standard deviation are calculated per scale.

Feasibility

In the context of this study, feasibility refers to the degree to which the VR intervention (Relaxation-VR) can be successfully integrated in the hospitals' usual care (19). In pediatric patients, feasibility was assessed by collecting data on likeability and usability, similar to Dunn et al. (8), after using the Relaxation-VR app. To do so, pediatric patients were asked to use a VAS to answer "How easy was it for you to use Relaxation-VR (VR headset)?" with a score of 0 representing "really easy" and 100 representing "really difficult". To assess usability, pediatric participants were asked to use a VAS to answer "How much fun was it for you to use Relaxation-VR?" with a score of 0 representing "really fun" and 100 representing "not fun at all". In addition, descriptive data on the use of the VR intervention was also collected, for example: the aim of VR use (distraction or relaxation), the medical procedures during which VR was used, the occurrence of technical difficulties, suggested changes to the intervention and early removal of the VR headset. At the end of the study, feasibility was assessed in clinicians with the Client Satisfaction Questionnaire (CSQ-3) (29, 30) and the System Usability Scale (SUS) (31). In short, the CSQ-3 consists of 3 items, scored from 1 to 4, examining client satisfaction with the received service or intervention. The questionnaire generates a total score ranging from 3 to 12, with higher scores indicating higher satisfaction. The SUS consists of 10 items with 5 response options ranging from "strongly disagree" to "strongly agree". Total scores for the SUS range from 0 to 100, with higher scores indicating better usability.

Tolerability

Tolerability refers to the evaluation of adverse events in pediatric patients, related to either hardware or software components (19). In pediatric participants, tolerability was assessed with the pediatric simulator sickness questionnaire (Peds SSQ) immediately after the use of Relaxation-VR. The Peds SSQ is a version of the Simulator Sickness Questionnaire (SSQ) (20) modified for pediatric use, as previously reported by Tychsen and Foeller (22). The questionnaire contains 13 questions comprising four symptom categories: eye strain (questions 1–4), head and neck discomfort (questions 5 and 6), fatigue (questions 7 and 8), and dizziness or nausea (questions 9 to 13). Participants are asked to indicate how much discomfort they experienced concerning a specific symptom on a numerical scale ranging from 0 (No) over 3 (A little bit) to 6 (A lot). The numbers 0, 3, and 6 are accompanied, respectively, by a happy, neutral or sad smiley face. In addition, adverse events were registered. Tolerability was only assessed in actual users, thus the patients.

Preliminary Clinical Effectiveness

In order to explore the potential clinical effects of the VR intervention on pain, anxiety, tension (stress) and happiness, the Revised Faces Pain Scale (FPS-R) was used, a VAS to measure anxiety and the Self-Assessment Manikin (SAM) to measure tension and happiness. The FPS-R scale is used to assess the intensity of a child's acute pain from the ages of four or five onwards (32). The scale presents six horizontally arranged cartoon faces with expressions linked to a numeric scale ranging from 0 to 10 with 0 representing "no pain" and 10 representing "very painful". Participants were asked to circle the face that indicates how much pain they feel. To measure anxiety (VAS), participants were asked to answer the question "How anxious do you feel right now?" with a score of 0 representing "not anxious at all" and 100 representing "worst anxiety imaginable". The Self-Assessment Manikin (SAM) is a non-verbal pictorial assessment technique used to measure the pleasure (sadness-happiness), arousal (tenseness-calmness), and dominance (mastery) associated with a person's affective reaction to a wide variety of stimuli (e.g., visual, auditory, and physical) (33). The measure consists of three single-item scales, of which each scale presents five figures (manikins) linked to a numerical scale ranging from 1 to 9, with 1 representing "very happy" and "very calm" and 9 representing "very sad" and "very tense". Only two of these scales were used in this study, namely the pleasure scale and the arousal scale, to measure happiness and tension (stress), respectively, as the dominance scale was not relevant for this study.

Data Analysis

For the acceptability, feasibility and tolerability measures, descriptive statistics are reported in **Tables 2**, **3**. The answers to the open-ended questions were categorized and analyzed as descriptive data. For the FPS-R, VAS anxiety and SAM outcome measures, pre-to-post differences were assessed with separate paired samples *t*-tests. All statistics were executed with SPSS version 27 (IBM Corp., NY, USA). The significance level was set at $p < 0.05$. Cohen's d effect sizes are reported with 0.2, 0.5, and 0.8 indicating small, moderate and large effect sizes, respectively (34). Cronbach's alpha's were calculated for the UTAUT.

RESULTS

Acceptability

Patients

The majority of recruited patients (55/70) were willing to enroll in the study. Fifteen individuals [either the child ($N = 7$), a parent ($N = 6$) or both ($N = 2$)] refused to participate for reasons including fear of side effects ($N = 3$), willingness to see the procedure ($N = 1$), risk of overstimulating the child ($N = 2$), too much paperwork ($N = 2$), disinterest ($N = 3$), lack of time ($N = 1$), absence of need ($N = 2$), or an overlooked exclusion criterion ($N = 1$). Reasons for willingness to try the application and enroll in the study, range from a need for distraction or relaxation to boredom and curiosity. Future use of VR in a hospital context was favorably scored with a median score of 3.00 [interquartile

TABLE 2 | Descriptive statistics of pediatric participants.

Acceptability	***N***	***M***	**SD**	**Med**
Use again	50	16.10	26.19	3.00
Recommend to others	50	11.84	15.76	4.00
Feasibility	***N***	***M***	**SD**	**Med**
Usability (ease of use)	49	15.31	22.22	4.00
Likeability (fun)	50	13.92	21.12	2.50
	N	**Yes (*N*)**	**No (*N*)**	**Unknown (*N*)**
Quit prematurely	51	10	33	8
Technical issues	51	5	38	8
Suggested changes	51	18	33	0
Tolerability	***N***	***M***	**SD**	
Peds SSQ				
Eye	51	1.03	1.55	
Head/neck	51	0.76	1.43	
Fatigue	51	1.12	1.43	
Dizzy/motion sickness	51	0.77	1.39	

N, number; M, mean; SD, standard deviation; Med, median.

TABLE 3 | Descriptive statistics of clinicians.

Acceptability	***N***	***M***	**SD**	**Cronbach's α**
UTAUT				
Performance expectancy (4 items)	12	3.25	0.90	0.83
Effort expectancy (3 items)*	12	4.11	0.48	0.81
Attitude (4 items)	12	4.19	0.59	0.86
Social influence (4 items)	12	3.42	0.66	0.65
Fear (3 items)*	12	1.78	0.51	0.64
Intention to use (3 items)	12	4.11	0.88	0.77
Self-efficacy (4 items)	12	3.63	0.70	0.72
Feasibility	***N***	***M***	**SD**	**Med**
CSQ-3 (3 items)	12	9.42	1.88	9.5
SUS (10 items)	12	70.83	12.45	73.75

CSQ-3, Client Satisfaction Questionnaire-3; SUS, System Usability Scale, Unified Theory of Acceptance and use of technology questionnaire.

**Note that the Effort Expectancy subscale and Fear subscale originally consisted of 4 items. Based on the poor internal consistencies of the 4-item subscales (Cronbach's α effort expectancy= 0.61; Cronbach's α fear= 0.22), one item from each scale was excluded from analysis. The Facilitating conditions subscale (4 items) has been eliminated from analyses, as the Cronbach's α was negative.*

range (IQR) = 22, $N = 50$, $M = 16.10$, SD = 26.19]. Also, most pediatric participants would recommend the use of VR to others with a median score of 4.00 (IQR = 19, N =5 0, $M = 11.84$, SD = 15.76). Acceptability data is reported in **Table 2**.

Clinicians

Table 3 provides an overview of UTAUT scores. Generally, clinicians showed a positive attitude toward using technology and the expected effort needed to use VR, as well as an intention to use VR. Notably, healthcare professionals were not fearful toward using technology.

Feasibility

Patients

With respect to the specific use of the VR application, 30 out of 51 participants used the Relaxation-VR app as a relaxation tool during hospitalization and 19 participants used the application during a medical procedure (missing, $N = 2$), while 19 out of 51 participants used the app for periprocedural distraction: blood draw ($N = 9$), (veni)puncture ($N = 3$), tube placement ($N = 2$), lactose test ($N = 1$), wound care (N =1), circumcision ($N = 1$) and unknown procedure ($N = 2$). The majority of participants used all three modules (28/51), 15 out of 51 participants only used module 3 (minigames) (missing, $N = 8$). Most participants (33/51) used the VR application until the end, whereas 10 participants quit prematurely for reasons including discomfort ($N = 2$), disliking the application ($N = 1$), technical issues ($N = 1$), willingness to see the medical procedure being performed ($N = 2$), termination by nurse ($N = 1$), wanting to change the VR module ($N = 1$) (unknown reason: $N = 2$; missing data on premature termination: $N = 8$). Five out of 51 participants reported technical issues including start-up issues and low battery levels (missing, $N = 8$). Most participants (33/51) did not suggest any changes to the application, whereas 18 participants suggested changes regarding content (e.g., more games) or hardware (e.g., location of the start button). Ease of use of the Relaxation-VR application was favorably scored with a median score of 4.00 (IQR = 29, $N = 49$, $M = 15.31$, SD = 22.22). Also, likeability of the Relaxation-VR application was favorably scored with a median score of 2.50 (IQR = 25, $N = 50$, $M = 13.92$, SD = 21.12). Data concerning ease of use of two participants is missing as well as likeability data of one participant.

Clinicians

Participants reported a mean total CSQ-3 score of 9.24 (SD = 1.88, Cronbach's α = 0.91) (total scores range from 3 to 12 with higher scores indicating higher satisfaction) and a mean total SUS score of 70.83 (SD = 12.45, Cronbach's α = 0.76), indicating good usability (**Table 3**).

Tolerability

Concerning the Peds SSQ, reported simulator sickness was limited as mean item scores per subscale ranged between 0.76 and 1.12 (with 0 indicating no discomfort and 6 indicating a lot of discomfort) (**Table 2**). Note, however, that at least for some participants, the scores seemed to be linked to their pre-existing conditions, rather than symptoms related to VR use (e.g., indicating nausea when treated in hospital for a gastrointestinal condition). Another adverse event that was registered was bedwetting (not immediately) after using Relaxation-VR. Note, however, that clinical staff reported that bedwetting had also occurred earlier in this participant.

Preliminary Clinical Effectiveness

Pre-to-post changes in pain, anxiety, happiness and tension are visualized in **Figure 3**.

Compared to baseline ($M = 2.65$, SD = 2.37), pediatric participants reported less pain after using Relaxation-VR ($M = 1.55$, SD = 1.69), $t(50) = 3.80$, $p < 0.001$ ($d = 0.53$). Results

FIGURE 3 | Pre-to-post changes in anxiety **(A)**, pain **(B)**, tension **(C)**, and happiness **(D)**. The * symbol indicates the significant group difference at the significance level of $p < 0.001$.

indicate a significant decrease in reported anxiety after using Relaxation-VR ($M = 14.34$, SD $= 18.48$) as compared to baseline ($M = 32.82$, SD $= 28.09$), $t(49) = 5.53$, $p < 0.001$ ($d = 0.78$). Pediatric participants also reported significantly less tension after using Relaxation-VR ($M = 3.06$, SD $= 2.17$) as compared to baseline ($M = 4.86$, SD $= 1.90$), $t(49) = 7.28$, $p < 0.001$ ($d = 1.03$). Finally, results indicated that pediatric participants reported significantly higher levels of happiness after using Relaxation-VR ($M = 2.71$, SD $= 2.07$) as compared to baseline ($M = 4.06$, SD $= 2.03$), $t(50) = 4.99$, $p < 0.001$ ($d = 0.70$). Note that for the VAS and the SAM tension scale data of one participant are missing.

DISCUSSION

Findings

This mixed-methods study was performed to assess the acceptability, feasibility, tolerability and preliminary effectiveness of virtual reality (VR) as both a relaxation and distraction tool for pediatric patients in a hospital setting. To do so, data from both patients and clinicians were collected. With respect to acceptability, most patients aged 4–16 years and/or their parents were willing to use VR with the aim of lowering their own (or their child's) anxiety or pain, out of mere curiosity, or due to boredom during a longer stay in hospital. Our findings indicate that pediatric patients accept the use of VR as a distraction and relaxation tool in a hospital. They wanted to use VR again during future hospital visits and would recommend it to others. These findings are in line with prior research indicating that participants (children, parents and nurses) would like to use VR distraction again during future procedures (8, 14, 21). In contrast, some patients recruited for this study and/or their parents were, however, unwilling to use VR for a variety of reasons, including fear of side effects. These patients and parents might benefit from clear and open communication by hospital staff about the potential side effects (or lack thereof). In line with prior research (1, 3, 5, 10, 14, 21), our study showed limited discomfort or side effects related to VR use. Most studies, however, assessed side effects or symptoms of VR sickness to a limited extent, and mostly focused solely on nausea, by means of a single question or graphic rating scale (1, 3, 5, 21, 35). Similar to our study, other studies assessing symptoms of VR sickness categorized into head

ache, eye complaints and dizziness in addition to nausea, also revealed no or only mild symptoms (10, 14). Moreover, a recent study by Tychsen et al. (22) assessing the safety of VR use in young children (aged 4–10 years old) on visuomotor functions and posture showed that VR is tolerated without noteworthy effects on visuomotor functions or postural stability. Therefore, accumulating evidence seems to confirm the safety of VR use in a pediatric population. Nonetheless, the differences between these measures highlight the lack of a validated measure to assess VR sickness, side effects or safety of VR in children. Future research should, therefore, focus on creation of a measure of VR sickness in children. Our findings also revealed that clinicians accept the use of VR in clinical practice, reflected by a positive attitude toward using technology, the expected effort needed to use VR and intention to use it. However, comparable research on clinician attitudes toward or acceptability of VR use in hospital is lacking. Therefore, future studies should include acceptability measures to better understand why adoption of VR in practice is still limited.

Concerning feasibility, results revealed that the use of Relaxation-VR as a distraction and relaxation tool in pediatric clinical practice is feasible. Patients liked using VR and thought it was easy to use, which is in line with previous findings (3, 8, 23). Technical issues were limited and the majority of patients did not quit the application prematurely. Most participants did not suggest to make any changes to the application. However, the few suggested changes were similar to those found in prior research (14), including more games or environments and more interaction with the VR environment. As previously described, VR is mainly used and assessed as a distraction tool during specific procedures, whereas the potential of its use reaches further. Our results indicate that when given the instruction to clinicians to use the application as they see fit in their day to day practice, VR was more often used as a relaxation tool than as a distraction tool during medical procedures. Future research should therefore not only focus on pain and anxiety management through distraction, but also focus on incorporating and assessing evidence-based relaxation techniques for children in VR applications. The feasibility of using VR was additionally highlighted by the clinicians' reported satisfaction with and usability of the VR intervention. Prior research also indicates that clinicians (mostly nursing staff) are satisfied with VR use (36), but not necessarily more satisfied as compared to standard care (10). However, more implementation-focused research assessing feasibility, usability and acceptability from the perspective of clinicians is needed to gain insights in their perceptions and experiences with using VR.

With respect to (preliminary) clinical effectiveness, results revealed that pediatric patients reported less pain, anxiety and tension (stress) and higher happiness during VR use as compared to baseline measurements. Although different study designs have been adopted across the aforementioned studies, our findings are in line with prior research showing that the use of VR as a pain and/or anxiety management tool reduces periprocedural pain and anxiety levels in pediatric patients with various conditions and during various medical procedures (15–17). Evidence on the effects of periprocedural VR use on stress levels (tension) in pediatric patients is limited. Nonetheless, our findings corroborate previous findings by Piskorz et al. (9) indicating reduced stress levels during venipuncture in the VR intervention group as compared to the control group. A recent study investigating the effects of mindfulness-based VR (MBVR) in children with inflammatory bowel disease, showed that children felt more relaxed after using MBVR (similar to module 2 in the current study) and enjoyed its use (37), highlighting the potential of using VR as a relaxation tool for children in a hospital. The positive findings regarding higher reported happiness by the patients that VR use can improve a child's hospital experience.

Taken together, our results indicate that the use of VR is acceptable, feasible and tolerable, as assessed by both pediatric patients and clinicians, for providing both relaxation and distraction in a variety of pediatric patients as well as for periprocedural use and as a relaxation tool for children admitted to hospital for a longer period of time. The findings of this study confirm prior research indicating that VR is a relevant tool in a pediatric hospital setting and add to the evidence-base that VR use is also feasible and acceptable from clinicians' perspectives. Future research should, therefore, focus on potential barriers and facilitators to adoption of this innovation in clinical practice. Considering VR use was assessed in a varied population, during various procedures and for multiple purposes in one study, these findings also highlight that VR use in a hospital should not be limited to periprocedural distraction or specific patient groups, which might encourage adoption in clinical practice.

Limitations

The presented findings should be considered in view of the following limitations. The study was unblinded and no control group was included. In addition, the nature of the participant-reported and clinician-reported outcomes may have introduced bias and subjectivity. The combination of these factors may have lead both patients and clinicians to provide more pleasing answers when completing the questionnaires and scales.

Concerning tolerability measures, we noticed that some pediatric participants had difficulties in discerning symptoms of VR use from symptoms related to their hospitalization. We therefore advise, researchers to include measures at multiple time points (i.e., at baseline and post-VR) to assess potential changes in VR sickness.

As the current study was not designed to assess the impact of potential moderators on the included outcomes, we cannot provide reliable information on the potential impact of age, gender, VR usage, type of medical procedures or other factors on study outcomes such as acceptability, feasibility and tolerability. Researchers are encouraged to design and conduct studies to explore the potential impact of these factors.

Note that this study was performed during the COVID-19 pandemic. All Belgian hospitals were subjected to national, regional and local regulations. These regulations may have influenced the number or type of patients available at the study

sites. Regulations did not allow external researchers to visit the study sites to educate the clinical staff in study procedures, nor in VR use, so that the necessary education and support was provided online. Guidelines were developed to guide clinical staff in working with the technology and performing the research steps as planned.

CONCLUSION

Study results indicate that VR use (in particular, the Relaxation-VR prototype) for both distraction and relaxation is acceptable, feasible and tolerable for a variety of pediatric patients aged 4–16 years, as assessed in both patients and clinicians, and can reduce anxiety, pain and tension (stress), and increase happiness in a hospital setting.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Medical Ethics Committee of the University Hospital Brussels as well as by the Local Ethical Committee of the AZ Sint-Maarten. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

SB and IG have coordinated the study design. IG has coordinated data collection. SB has written the first and final versions of the paper. BB, JD, RS, DS, and WV have provided feedback on both the study design and the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The virtual reality prototype used in the study was developed by the Dutch company Psylaris. Psylaris was not involved in the study design, data collection or writing of this article.

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A Perspective on How User-Centered Design Could Improve the Impact of Self-Applied Psychological Interventions in Low- or Middle-Income Countries in Latin America

Alejandro Dominguez-Rodriguez[1] *and Anabel De La Rosa-Gómez*[2]*

[1] Health Sciences Area, Valencian International University, Valencia, Spain, [2] Faculty of Higher Studies Iztacala, National Autonomous University of Mexico, Mexico City, Mexico

Global technological progress has generated alternatives for psychological assistance, both for the evaluation and for the treatment of different emotional disorders. Evidence suggests that Internet-based treatments are effective for the treatment of anxiety and depression disorders. However, in Latin America online treatments are still scarce compared to developed countries and have similar problems as developed countries, such as high dropout rate. One possible solution to help decrease the dropout rate is to design and develop online interventions based on the needs and characteristics of the users. The user-centered design (UCD) is a fundamental concept to develop successful online interventions. The objective of this article is to provide a perspective overview on how UCD could improve the impact of self-applied psychological interventions in low- or middle-income countries in Latin America; however this proposal can also be applied in low- and middle-income countries in other regions of the world. The literature on UCD has demonstrated its efficacy when properly applied in online interventions; however, it is not common to see how this methodology has been applied in research in online interventions, and regarding Latin America, this is even more scarce with a very limited number of articles implementing the principles of UCD.

Keywords: user center design (UCD), Latin America, online intervention, double diamond design process, mental disorders

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***Correspondence:**
Anabel De La Rosa-Gómez
anabel.delarosa@iztacala.unam.mx

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INTRODUCTION

Before the Coronavirus SARS-CoV-2 (COVID-19) pandemic, the prevalence of anxiety and depressive disorders worldwide were already a matter of concern for international governments. According to the WHO, an approximate estimate of 322 million people suffered from depression and 264 million from anxiety disorders, with an increase of 18.4 and 14.9% respectively from 2005 to 2015 (1). In the same line, in the study of Santomauro et al. (2), published in The Lancet with data of 204 countries and territories during the pandemic of COVID-19, the authors indicated that there was an increase of 53.2 million more cases of major depression, and additionally, 76.2 million

cases of anxiety disorders. Regarding Latin America, before the pandemic the mental disorders were perceived as common (3), and during the pandemic the available scientific literature indicates that the population of Latin American countries exhibited an increase in symptoms of anxiety (4), depression (5), post-traumatic stress disorder (6), sleep problems (7), and alcohol consumption (8), among other problems.

However, a vast majority of individuals in low- and middle-income countries do not receive psychological treatment for mental health disorders, mostly because it is not perceived as necessary. This could be related to a lack of health literacy, and mostly due to lack of infrastructure available to offer psychological treatment to the population (9). According to the Pan American Health Organization (PAHO), the public expense on mental health in the region of the Americas is barely 2% and it is mostly focused on psychiatric hospitals (10). Also, it has been observed that most of the mental health research is conducted in high-income countries, producing with this an imbalance where population in low and middle-income countries do not receive a proportional attention to their mental health needs (11). For example, in the scoping review of Jimenez-Molina et al. (3), the authors highlight the huge gap in the treatment of mental disorders in Latin America, and that this gap is bigger among socially disadvantaged groups, when the authors analyzed 22 studies on online interventions conducted in Latin America, where it was observed that the results were promising, however, higher quality studies are needed, especially Randomized Controlled Trials (RCT's), since of those 22 studies analyzed, only 4 were RCTs.

E-MENTAL HEALTH: INTERNET-BASED SELF-APPLIED INTERVENTIONS

Global technological progress has generated alternatives for psychological assistance, both for the evaluation and for the treatment of different emotional disorders. Evidence suggests that Internet-based treatments are effective for the treatment of anxiety and depression disorders (12–14). Likewise, the meta-analysis data reveal that these interventions are as effective as face-to-face treatments (15, 16). Thus, on the one hand, there is evidence of the benefits shown by the interventions provided by the Internet and mobile applications by allowing: 1) accessibility: easy access at any time and from anywhere through the Internet, 2) flexibility: the intervention is adapted to the rhythm of the participant, and the consultation of resources and materials can be asynchronous, 3) personalization: the intervention can be adapted to the specific needs of the user, 4) availability of treatment: it allows to bring psychological care to people who need it regardless of distance, which constitutes an alternative when it is not possible to access face-to-face mental health services. In addition, 5) scalability since it can increase coverage and improve care as technology advances (17, 18). This means enhancing the scope and impact of psychological treatment programs for mental health problems (19). Due to these findings, online interventions are very accessible and can be used on a large scale, but they need to be further developed and implemented, especially focusing on the target population or users.

Abbreviations: EBPs, Evidence-based practice; HCD, Human-Centered Design; ISO, International Standards Organization; PAHO, Pan American Health Organization; RCTs, Randomized Controlled Trials; COVID-19, SARS-CoV-2; UCD, User-centered design; WHO, World Health Organization.

EVIDENCE-BASED PRACTICE: RELEVANCE OF USER OPINION, PERSPECTIVE, AND CONTEXT FOR THE EFFICACY OF INTERVENTIONS

From the framework of Evidence-Based Psychotherapy, on the one hand, it is recommended to rigorously analyze the available scientific evidence to measure the efficacy of an intervention, that is, the therapeutic changes produced in controlled clinical trials. On the other hand, to measure effectiveness, it is suggested to investigate the generalization of the results of the intervention to the particular and cultural context of the target population; this is known as Evidence-Based Practice (EBP) and involves the integration of research knowledge with the clinical experience of the therapist and the characteristics, opinions, preferences, interests, values, context, and culture of the patient/user (20). Thus, it is incorporated as a priority to consider the opinions and perspectives of the patients/users in their own intervention as possible moderators and mediators of therapeutic adherence, improvement of patient engagement/commitment, treatment outcomes and reduction of therapeutic abandonment (21, 22). It has been reported that effective cultural adaptations considers age, disabilities, religion, ethnicity, sexual orientation, gender identity, socioeconomic status, indigenous group membership, and nationality. Also, patients' activity preferences include types of homework assignment, completion of worksheets, etc., delivery of treatment, patients' preferences language, and incorporation of cultural explanations of the specific disorder or treatment, and so on (20–23).

Regarding the efficacy of technological-based psychological interventions, specifically self-applied interventions, they have a series of challenges that involve the interaction of a great variety of factors at different systemic levels (24). However, the design features and specific functions of Internet-based intervention programs often receive less attention than the contents, and therefore do not contribute to meeting users' needs. Thus, key design problems could affect the generalizability of the results of effective clinical interventions at the time of their implementation in the community context (25, 26). Challenges include flexibility, complexity, and effectiveness of interventions, as well as studying the one-way relationship between program development and implementation (27).

USER-CENTERED DESIGN IN THE DEVELOPMENT OF PSYCHOLOGICAL INTERVENTIONS

Even though online interventions have several benefits, one of their main problems is the high drop-out rate, with percentages

ranging from 1 to 50% for anxiety and depression treatments (24), and 43% for treatments for chronic diseases (28). In general, observational studies have higher dropout rates (49%, 95%), than RCTs (in more controlled scenarios) with 40% abandonment (29). Also, there is another issue related to the definitions of adherence not being well suited to the characteristics of e-interventions (28). Christensen et al., differentiate *adherence* as the extent to which individuals experience the content of internet intervention, and *dropout* describes an individual who fails to complete the research trial protocol associated with an internet intervention, and thus does not complete the trial assessments (28).

One possible solution to help decrease the drop-out rate and to increase the adherence is to design and develop online interventions based on the needs and characteristics of the user. Hence, the user centered design (UCD) is a fundamental concept to develop successful online interventions and decrease the drop-out rates. According to Abras et al. (30), "UCD is a broad term to describe design processes in which end-users influence how a design takes shape. It is both a broad philosophy and a variety of methods. There is a spectrum of ways in which users are involved in UCD, but the important concept is that users are involved one way or another" (30) (p1). In 2010 the standard ISO 9241-210 enriched the definition of UCD, referring to the UCD approach as Human-Centered Design (HCD) (31). Therefore, the ISO 9241-210 standard defines human-centered design as "an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques." (31) (p2). The term UCD was coined by Donald Norman in the 1980s (30). In his book, The Design of Everyday Things, revised and expanded edition, Norman indicates that there are 4 activities in HCD: 1) Observation, 2) Idea Generation, 3) Prototyping, 4) Testing (32). An excellent example of how to implement the HCD is the study of Harte et al. (31), where the authors carried out and evaluated with a sample of older adults a methodology of 3 steps that followed the flow of ISO 9241-210, which included: 1) Established context of Use and User Requirements, 2) Expert Inspections and Walkthroughs and 3) Usability Testing with End users.

DOUBLE DIAMOND PROCESS IN USER-CENTERED DESIGN

When planning the design process, it is fundamental to talk about one of the most used design processes, the Double Diamond (**Figure 1**).

The double diamond design process illustrates how the design process goes from thinking and possibilities abroad as possible to situations that are reduced and are specially focused on different objectives (33).

The double diamond phases are detailed in: 1) Discover, where the start of a project is a period of discovery, gathering inspiration and insights, identifying user needs and developing initial ideas, 2) Define, the second quarter represents the definition phase, in which designers try to make sense of all the possibilities identified in the Discover phase, 3) Develop, the third quarter marks a period of development where solutions are created, prototyped, tested, and iterated. This process of trial and error helps designers to improve and refine their ideas and 4) Deliver, the final quarter of the double diamond model is the Deliver phase, where the resulting product or service is finalized and launched. The key activities and objectives during this stage are the following: final testing, approval and launch, targets, evaluation, and feedback loops (33) (p7). There are excellent examples for developing online programs to deliver telehealth and that apply the double diamond model such as Banbury et al. (34), where the researchers aimed to develop a telehealth peer support program for isolated dementia caregivers. Another example is the study of Hardy et al. (35), where the researchers implemented the double diamond method to improve psychological therapies for psychosis. While there are benefits to designing and delivering interventions online following the double diamond process, it is still not the norm.

Regarding Latin America, the UCD is not commonly mentioned or indicated in online interventions, with only few exceptions such as Antelo et al. (36), where the authors presented a Counseling Mobile App designed on the UCD approach to women in low- and middle-income setting in Argentina aimed at the reduction of the psychosocial impact of the human papilloma virus. In Mexico, Dominguez-Rodriguez et al., (37) designed, developed, and implemented a self-applied intervention based on user experience (UX) principles in order to decrease the risk of developing complicated grief disorder, increase the life and sleep quality, and reduce symptoms of anxiety and depression. Also in Mexico, Pérez-Bautista et al. (38), designed and evaluated an online intervention for young Mexican deaf for transfer of sexual education using a UCD design and involving objective participants (deaf youngs) on the design process. In Colombia, Ospina-Pinillos et al. (39), adapted the Web-based Mental Health eClinic (MHeC) that was adapted for the Spanish population living in Australia (MHec-S) (40) and coming from the original version of the MHeC that was designed in Australia (41). The researchers adapted this tool to the Colombian population using participatory design methodologies. Also, there are some studies where online interventions have been delivered in Latin American populations, specifically in Chile and Colombia that did not successfully engage the users (42). The authors concluded that it is necessary to improve the intervention results by increasing its levels of customization and by developing strategies to achieve better adherence. Therefore, the importance of considering the UCD at the moment of proposing, designing, developing, and delivering online mental health interventions is highlighted. Further online interventions applying UCD principles in Latin America are scarce.

There are several developments of digital mental health tools that are user-centered for several purposes. For example, the low-intensity intervention for Syrian refugees (43), part of the EU Horizon 2020 STRENGTHS (Syrian REfuGees MeNTal HealTH Care Systems) program (44), in which participants reacted positively to the prototype presented, making emphasis

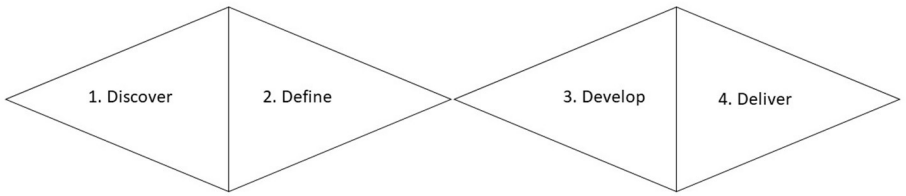

FIGURE 1 | Double diamond design process.

on the potential health impact of the intervention, the flexibility and customizability of it, the easiness to learn how to use it, and the aesthetic components. In other contexts, regarding online interventions but focused on adherence for medical treatments such as hydroxyurea for sickle cell disease, where the participants report poor adherence, Alberts et al. (45) used a user-centered approach to investigate the reasons for poor adherence and based on the health belief model analyzing the benefits, barriers, the researchers identified the possible reasons for poor adherence and adapted an mHealth solution to overcome these barriers through an App call *InCharge Health*. The study of UCD and attrition reduction is also being applied in other contexts such as web-Based Psychological Intervention for Patients with Myocardial Infarction with Non-obstructive Coronary Arteries, where the researchers designed a UCD web-based psychological 9-step program focusing on stress, worry, and valued action for persons with such health conditions, and among the several objectives of this tool was also to reduce the attrition of the participants on this intervention (46).

On the other hand, there are currently studies trying to implement interventions based on HCD in low-resource communities (47); however, the results are still not available.

DISCUSSION

The objective of this article was to provide a perspective overview on how user-centered design could improve the impact of self-applied psychological interventions in low- or middle-income countries in Latin America, however this proposal can also be applied in low- and middle-income countries in other regions of the world.

The literature is still being gathered, but there are excellent examples of how UCD can be implemented in online interventions (30, 31, 34–43). For countries in Latin America where the budget is limited for mental health interventions, we recommend that the researchers focus on learning and applying the UCD principles that were briefly presented in this article. Due to the COVID-19 pandemic, there is currently an urgent need for online mental health interventions, and we predict that other problematics such as economic, political, and/or climate change crisis will require the support of evidence-based psychological treatments that can widely reach the general population, and that will be perceived by the users as easy to use and enjoyable to return to use them and even to recommend them to other persons.

This manuscript has certain limitations that should be considered. For example, the literature on UCD has demonstrated its efficacy when properly applied in online interventions, however it is not common to see how this methodology has been applied in research in online interventions, and regarding Latin America this is even more scarce with a very limited number of articles implementing the principles of UCD and to the best of the knowledge of the authors, none clearly stating to be implementing the double diamond model. More research needs to be conducted to provide evidence-based treatments to the population of Latin America and the Caribbean.

In this regard, this article shows a perspective based on the review of the existing literature, it is suggested for future studies to carry out a meta-analysis on the effectiveness of the interventions and their relationship with the design centered on the user experience in the context of Latin America.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

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

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EDITED BY
Gerald Humphris,
University of St Andrews,
United Kingdom

REVIEWED BY
Mark Attridge,
Attridge Consulting, Inc., United States
Almira M. Kustubayeva,
Al-Farabi Kazakh National
University, Kazakhstan

*CORRESPONDENCE
Ferozkhan Jadhakhan
f.jadhakhan@bham.ac.uk

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Efficacy of digital technologies aimed at enhancing emotion regulation skills: Literature review

Ferozkhan Jadhakhan[1]*, Holly Blake[2,3], Danielle Hett[1,4] and Steven Marwaha[1,4]

[1]Institute for Mental Health, School of Psychology, College of Life and Environmental Sciences, University of Birmingham, Birmingham, United Kingdom, [2]School of Health Sciences, University of Nottingham, Nottingham, United Kingdom, [3]NIHR Nottingham Biomedical Research Centre, Nottingham, United Kingdom, [4]Birmingham and Solihull Mental Health NHS Foundation Trust, Birmingham, United Kingdom

Background: The impact of emotion regulation (ER) interventions on mental health and wellbeing has been extensively documented in the literature, although only recently have digital technologies been incorporated in intervention design. The aim of this review is to explore available published literature relating to the efficacy, barriers and facilitators of digital technologies in enhancing emotion/mood regulation skills.

Methods: A review of the literature was performed to explore the effectiveness of digital technology in enhancing ER skills. MEDLINE, CINAHL, PsycINFO and Web of Science databases were searched from inception to 31st August 2020. In addition, the first 10 pages of Google Scholar were examined for relevant articles. The following MeSH term and key words were used to identify relevant articles: "emotion regulation OR mood regulation" AND "intervention OR treatment OR program$ OR therap$" AND "digital technologies OR web-based OR mobile application OR App." Reference lists of retrieved papers were hand searched to identify additional publications. Findings were summarized narratively.

Results: Titles and abstracts were reviewed by one reviewer in two phases, and confirmed by a second reviewer; discrepancies were resolved through discussion. First, the retrieved titles and abstracts were reviewed to identify relevant studies. Full texts of retrieved studies were then read to determine eligibility. The search resulted in 209 studies of which 191 citations were identified as potentially meeting the inclusion criteria. After reviewing the title and abstract of the 191 papers, 33 studies were identified as potentially meeting the inclusion criteria. Following full-text review, 10 studies met the inclusion criteria. Findings indicated the potential effectiveness of online, text-messaging, and smartphone interventions for enhancing ER skills.

Conclusion: There is encouraging evidence that digital technologies may be beneficial for enhancing ER skills and providing personalized care remotely. Digital technologies, particularly the use of smartphones, were instrumental in facilitating assessments and delivering online self-help interventions such as cognitive behavioral therapy. Continued research is required to rigorously

evaluate the effectiveness of digital technologies in ER skills and carefully consider risks/benefits while determining how emerging technologies might support the scale-up of ER skills and mental health treatment.

KEYWORDS

digital technologies, emotion regulation, mental disorders, wellbeing, intervention, adults, treatment

Introduction

Digital technologies have become ubiquitous and integrated into everyday life, providing the potential to deliver mental health interventions more efficiently, while increasing accessibility (1). Since early 2020, to support the current public health response to the global coronavirus disease (COVID-19) pandemic, digital technologies are being harnessed at an unprecedented scale, for case identification, population surveillance and contact tracing (2).

Digital technologies include smartphones, virtual reality, wearable sensors, biofeedback techniques, web-based training programmes and mobile applications. Digital technologies generate, store and process numeric data using devices such as smartphones, computers, and multimedia (3). Interventions targeting ER using digital technologies have several advantages; namely, they provide researchers and clinicians with new platforms to offer support, monitor patient progress, as well as increasing patients' access to tailored treatment (4). Digital technologies are increasingly being used to manage and positively influence people's affective states including their emotions, mood, and stress levels. Several studies have found that digital technologies are a commonly used tool for ER, such as the use of videogames for relaxation, managing stress and controlling negative feelings (5). Social media and instant messaging services can provide a medium for ER, by regulating depressive emotions, reducing anxiety in stressful situations and/or reducing loneliness through social networking sites (6).

ER is a complex process which involves the ability to initiate, inhibit and regulate one's emotions in a given situation. ER is an integral part of how we feel, think about and experience our daily lives. ER is not aimed at eliminating emotions from our lives, but rather using them intelligently and flexibly to control their influence and produce desired responses to our mood (7). Several existing therapeutic approaches have been helpful with emotion regulation disorder. Such interventions are generally practical in nature and have a high success rate. One approach that is commonly used to help with ER is dialectical behavioral therapy (DBT). DBT is a type of cognitive behavioral therapy that focuses on enhancing ER and consists of individual therapies delivered by a trained therapist with occasional telephone follow-up consultations (8). Another approach involves acceptance-based behavioral therapy (ACT). This approach exposes individuals to experience problematic emotions in the context in which the function of language enhances the experience of unpleasant emotion in view to strip those emotions away. The focus of the treatment is facilitate individuals to adapt to those negative emotions and move toward a more fulfilling life (9). A further treatment approach is the mindfulness-based cognitive therapy (MBCT). This 8-week treatment programme targets emotion reactivity associated with stress by allowing individuals to break the dysfunctional cycle of rumination emotion regulation and self-criticism (10).

Digital technology can be used as a means to enhance positive emotion or help people to regulate their emotion at virtually any time and place, and this presents a unique opportunity to implement novel approaches or treatment mechanisms. Digital technologies allow for real-time measurement of cognitive, emotional, physiological, and behavioral responses in a variety of 'real-world' situations while allowing for full experimental control (11). They can improve an individuals' ability to positively enhance their emotion skills and better manage mental health issues by training them to adopt contextually adaptive ER strategies. ER plays a key role in the development, maintenance, and treatment of various mental health problems (e.g., depression, borderline personality disorder, substance-use disorders, eating disorders, somatoform disorders) (12). Thus, the delivery of ER using digital technologies may be an important therapeutic target.

However, the efficacy and benefit of ER intervention using digital technologies to address mild to moderate and sub-threshold mental health conditions in adults is not yet established. The area of digital ER intervention has not been

Abbreviations: ER, emotion regulation; MARIGOLD, mobile affect regulation intervention with the goal of lowering depression; CBT, cognitive behavioral therapy; DSM, diagnostic and statistical manual of mental disorders; iERT, internet-based emotion regulation training; DERS, Difficulties in Emotion Regulation Scale; SWLS: Satisfaction With Life Scale; App, Application; MBSR, effects of mindfulness-based stress reduction; MAAS, The Mindful Attention and Awareness Scale; GMBI, group mindfulness-based intervention; SDMBI, self-direct mindfulness-based intervention; CCT, computerized cognitive training programme.

comprehensively reviewed to date. We therefore aimed to explore the published literature to better understand the efficacy of digital technologies in enhancing ER skills.

Objectives

The objective of this review is threefold:

1. To summarize and map out the different types of ER interventions that are delivered using digital technologies.
2. To ascertain how diverse digital technologies can be applied to the delivery of ER interventions.
3. To explore barriers, facilitators, benefits, and caveats of using and implementing digital technologies in ER interventions (e.g., personalized care, blended treatment), and any impacts on clinical practice/services.

Methods

Search strategy

A literature search of the following databases MEDLINE, CINAHL, PsycINFO, and Web of Science was conducted from inception to 31st August 2020, and updated on 14th of October 2021. Additionally, the first 10 pages of Google Scholar were examined for relevant articles. The search included peer reviewed journals in the English language. The following MeSH terms and key words were used to identify relevant articles: (emotion regulation OR mood regulation) AND (intervention OR treatment OR program OR therapy) AND (digital technology OR web-based OR mobile application). A detailed Medline search strategy is provided (Supplementary Appendix 1). Reference lists of retrieved papers were manually searched to identify additional publications. The gray literature (opengrey.eu) was also searched to identify further relevant publications.

Study selection

This review considered randomized controlled trials, cohort studies (retrospective and prospective), case-control studies (including nested case control), cross-sectional studies, feasibility studies and pre-post within-study designs. Included studies focused on ER for wellbeing utilizing digital technologies in adults with a diagnosed mental health disorder. Since we are interested in the potential value of ER interventions using digital technologies, papers considered eligible for inclusion in this review included:

1. Interventions using digital technology (e.g., including, but not limited to, smartphones, virtual reality, wearable sensors, biofeedback techniques, web-based training programmes and mobile Apps).
2. Data sources from personal devices which are for non-medical purposes (e.g., smartphones, digital watches).
3. Web services and passive modes of data collection which do not require any specific action or intervention from the user associated with enhancing ER.

English abstracts of non-English articles were reviewed where available. One reviewer (FJ) conducted screening and article identification and a second reviewer (SM) was consulted to resolve any uncertainties by discussion. Papers were excluded if they: (1) lacked the necessary information for review in the full-text or the abstract; (2) reported outcomes of studies with health conditions unrelated to mental health; (3) reported outcome data not related to digital technology data capture; (4) were studies including non-human participants. The titles and abstracts of reviews were identified, screened and classified for extraction of full review for further analysis. Results of the search are presented in Table 1 and the findings described narratively.

Results

A record of the searches is provided in Figure 1. A total of 209 records were identified by database searches and a further 36 were sourced following the open gray database search. A further eight were retrieved by hand searching from references and one additional study was identified in the review update searches. Of the 209 studies, 18 were duplicates and the title and abstract of the remaining 191 studies were reviewed. Most exclusions were due to the article having no clear reference to ER intervention using digital technologies within the title or abstract. At this stage, 34 articles were further reviewed for inclusion, upon reviewing the full text of these studies, a further 23 were excluded specifically because they did not present ER interventions using digital technologies in an adult population. The remaining 10 studies were synthesized, a summary is provided in Table 1. Four randomized controlled trials (RCT) (14, 17, 19, 21), two feasibility studies (13, 15), two case-control studies (16, 22), 1 cohort study (18) and 1 pre-post within-study design (20) were identified. Five studies (13, 15, 16, 20, 21) were from the United States, one from Australia (14), one from Israel (17), and three from Slovenia (18), Portugal (19) and Canada (22) respectively.

A summary of the database searches that were performed during the process of conducting the review is set out below (Table 2). The search terms were reliable in identifying the most relevant articles related to digital technology relationship to ER.

TABLE 1 Characteristics of included studies.

Author	Year	Topic	Technology	ER module	Population	Sample size	Country	Study type	Intervention	Results
Mobile application										
Leonard et al. (13)	2018	This study examined a mobile application that specifically aims at enhancing ER through the integration of data from self-reports and electrodermal activity	Mobile App and wearable sensor band	Extended Process Model of Emotion Regulation (EPMER)	Homeless adolescent mothers aged (13–21 years)	40	USA	Feasibility study	Mindfulness App *(Calm Mom)* combined with a sensor band	Overall acceptability rating = median 3.5 (range 3.3–3.8). Qualitative: Participants were the App benefitted them
Hides et al. (14)	2019	This study aimed to evaluate a new App called *Music eScape,* developed to assist young people with identifying, expressing, and managing emotions using music from their own music library	Mobile App	Difficulties in Emotion Regulation Scale (DERS)	Participants aged 16–25 years, who reported at least mild distress in the past month	169	Australia	RCT	Immediate vs. 1-month delayed access to *Music eScape*	No significant differences between immediate and delayed groups on DERS: baseline: mean = 7.66 (SD ±2.45); 6 months = 7.62 (SD ±2.72)
Morris et al. (15)	2010	This study examined the potential of mobile phone technologies to broaden access to cognitive behavioral therapy technique and to provide in the moment support	Mobile App	Mood map scale	Employees aged 30–48 years rated as having stress on the Mayo Health Risk Assessment	10	USA	Feasibility study	Mood map (via mobile App) prompting participants to report their moods several times a day	Participants reported improved anger, anxiety and sadness ratings ($p < 0.01$)
Anand et al. (16)	2019	This study, used a smartphone application to monitor the effect of antidepressant on mood instability in terms of fluctuations between mania and depression, in young Major Depression Disorder (MDD) subjects who are at a high risk of developing Bipolar Disorder	Mobile App	Visual analog scale survey	Participants aged 15–30 years with bipolar disorder (BD) and unipolar major depression disorder (MDD)	40	USA	Case control study	Daily rating visual analog scale surveys capturing mood fluctuations	Daily ratings showed differences between groups (BD: 13%, HRMDD, 5%), ($p = 0.02$)

(Continued)

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TABLE 1 (Continued)

Author	Year	Topic	Technology	ER module	Population	Sample size	Country	Study type	Intervention	Results
Porat et al. (17)	2020	This study aimed to test the feasibility of a mobile App 'ReApp-, a mobile game designed to teach and train its users to regulate their emotions using cognitive reappraisal in participants exposed to the Israeli-Palestinian conflict	Mobile App	Emotion Regulation Questionnaire (ERQ)	Participants aged 29.8 years (SD ±9.6), exposed to conflict	70	Israel	Feasibility randomized controlled trial.	ReApp, mobile game	Results indicate that people who played ReApp experienced lower levels of anger ($\beta = -0.48$, $p < 0.01$) and disgust ($\beta = -0.43$, $p < 0.05$)
Cikajlo et al. (18)	2016	This study evaluated a novel system for remote acquisition of a meditation-based stress and anxiety reduction therapy, mindfulness	Mobile App	(1) Mindfulness Awareness Scale (MAAS) (2) Mindfulness based stress reduction course (MBSR)	Participants aged 27–40 years with stress and anxiety	8	Slovenia	Cohort study	Mindfulness-based stress reduction VR Immersive head-mounted display Samsung Gear + Samsung Smartphone S6 and Note 4	MAAS mean scores reduced from 4.3 (±0.7) to 3.8 (±1.0). No significant difference in MBSR
Web-based										
Fonseca et al. (19)	2019	This study aims to evaluate a self-guided web-based intervention (Be a Mom) to prevent persistent post-partum depression in adult aged (≥18 years)	Web-based	Difficulties in Emotion Regulation Scale (DERS)	Participants aged 18–50 years in the early postpartum period	98	Portugal	A pilot randomized; two-arm controlled trial	Web-based self-guided cognitive-behavioral therapy intervention	Participants in the intervention group showed a significantly greater decrease in the levels of ER difficulties ($p < 0.001$) and a significant greater increase in the levels of self-compassion ($p < 0.001$) compared to the control group

(Continued)

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TABLE 1 (Continued)

Author	Year	Topic	Technology	ER module	Population	Sample size	Country	Study type	Intervention	Results
Tsaousides et al. (20)	2017	This study sought to evaluate the efficacy of a Web-based group intervention (Online *EmReg)* to improve emotion regulation (ER) in individuals with traumatic brain injury (TBI)	Web-based	Difficulties in Emotion Regulation Scale (DERS)	Participants aged ≥18 years with Traumatic Brain Injury (TBI)	91	USA	Pre-/post-within-subject design with baseline, end-of-treatment, and 12-week follow-up assessments	Behavioral: Online Emotion Regulation Skills-training. 24 online emotional regulation skills-training sessions twice weekly and will complete online questionnaires sent every 4 weeks throughout baseline, the 12-week intervention, and 12-week follow-up	large effect size was found for the DERS at the 12-week follow-up ($d = 0.65$)
Online										
Addington et al. (21)	2019	The *MARIGOLD* (Mobile Affect Regulation Intervention with the Goal of Lowering Depression) study sought to test an online self-guided emotion regulation intervention for adults with elevated depressive symptoms	Online and mobile phone	Difficulties in Emotion Regulation Scale (DERS)	Participants ≥18 years with elevated depressive symptoms	137	USA	RCT	*MARIGOLD,* online self-guided positive emotion skills intervention	MARIGOLD participants showed significant increases in positive emotion over time, $b = 0.12$, $p < .001$, whereas positive emotion in the waitlist remained stable over time, $b = 0.05$, $p = 0.36$
Virtual										
Tong et al. (22)	2015	This study features an immersive virtual environment called "Virtual Meditative Walk." The system Simulated walking meditation through a forest, applied as therapy for chronic pain management	Virtual reality (VR)	Numerical Rating Scale (NRS) for Self-Report Pain Levels (values 0–10)	Participants aged 35–55 years old with chronic pain	13	Canada	Case-control	The Virtual Meditative Walk *(VMW)* + biofeedback	These findings indicate that the VMW (VR paired with biofeedback for MBSR training) was significantly more effective than MBSR alone at reducing reported pain levels among participants

EPMR, extended process model of emotion regulation; VR, virtual reality; DER, Difficulties in Emotion Regulation Scale; NRS, Numeric Rating Scale; BD, bipolar disease; VMW, virtual meditative walk; MDD, major depressive disorder; MAAS, Mindfulness Awareness Scale; MBSR, mindfulness based stress reduction; MARIGOLD, mobile affect regulation intervention with the goal of lowering depression.

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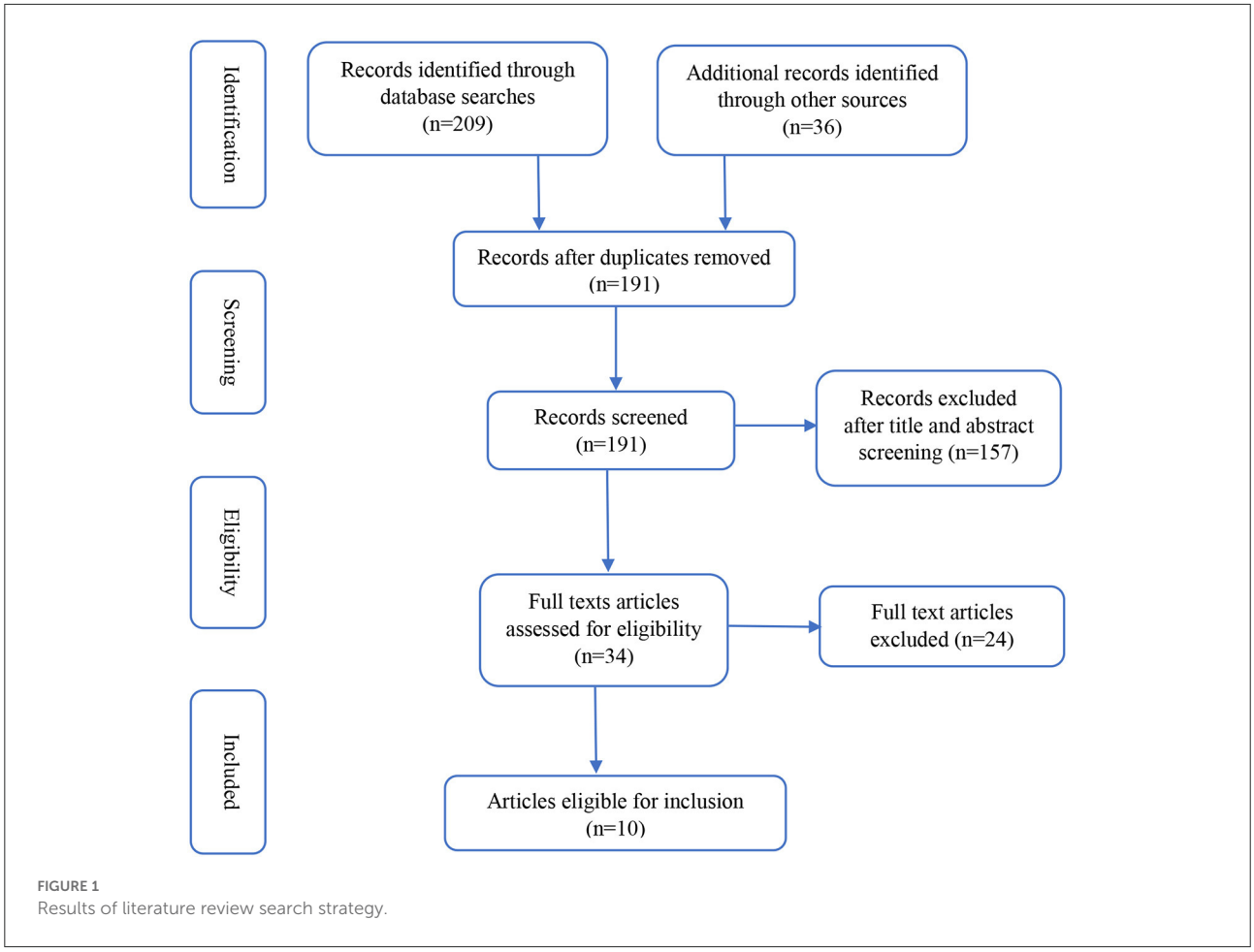

FIGURE 1
Results of literature review search strategy.

Mobile technologies

To date, only a few studies have examined the role of mobile applications in enhancing ER skills. These studies show that mobile phone technology usage varies according to types of intervention/approach and ER strategies. Six out of the 10 studies included in this review tested a psychological intervention module using different approaches such as social connection, text messages or a downloadable App. A mobile App is a type of application designed to run on mobile phones including smartphones or tablets/computer. Mobile health (mHealth) applications are contemporary approaches providing psychological support through mobile devices, without the involvement of a therapist or face-to-face intervention (10). mHealth allows the possibility of providing personalized interventions based on the current needs and affective state of the user. Many mHealth applications are mainly centered on cognitive behavior change (11), mindfulness (12) and cognitive behavioral therapy (CBT) (23). Morris et al. (15) examined the effect of self-reporting mood using the "Mobile Heart Health." The programme involved using a *Mood Map* (charting mood for at least 1 week by identifying good, bad and indifferent mood) to self-report mood as well as physiological sensors to measure heart rate. Ten participants were recruited and indicated having significant stress but were otherwise mentally healthy. The aim of the study was to explore whether usage of this App would help reduce stress and related risk of cardiovascular disease. Participants' mood was assessed every morning, evening, and several times during the day over a month using the mood map App prompted via their mobile phones. Results showed a significant improvement in stress and a greater control over their emotions compared baseline measured by mood reporting scales (24).

A recent mHealth technology *(Calm Mom)* consisted of a mobile App and a wearable sensor band specifically aimed at enhancing ER through the integration of data from self-reports and electrodermal activity (variation of the electrical properties of the skin in response to sweat secretion) measured during adolescent mothers' daily lives. Both the quantitative and qualitative data showed that participants highly valued the accessibility of the *Calm Mom* App, both alone and in combination with the sensor band. For many adolescent

TABLE 2 Medline database search strategy.

1	exercis*.mp
2	movement therapy.mp
3	exercise training.mp
4	physical activit*.mp
5	aerobic exercise.mp
6	physical exercise.mp
7	resistance training.mp
8	strength training.mp
9	endurance exercise.mp
10	cardiovascular exercise.mp
11	CV.mp
12	stretch*.mp
13	sport*.mp
14	PTSD.mp
15	exp. post traumatic stress
16	post traumatic stress disorder.mp
17	posttraumatic stress.mp
18	1–13 OR
19	14–17 OR
20	18–19 AND

mothers, the App became an integral part of the way in which they dealt with heightened emotions (e.g., fear, anger) in stress-inducing situations. The qualitative findings showed that the Calm Mom App helped to increase young mothers' understanding and ability to identify their emotions in a variety of stressful situations with their children, peers, and family, which in turn helped them engage in more adaptive ER and behavioral strategies (25). A recent study used a smartphone application to monitor daily and weekly mood ratings in young adults with bipolar disorder and healthy controls. Forty participants aged 18–30 years ($n = 35$ bipolar disorder; $n = 5$ control) were recruited and monitored for a total of 2401 daily and 744 weekly ratings. The researchers used The *Ginger IO* behavior platform to collect self-report data from participants (user input). The user receives notifications of available surveys and upon clicking they are transferred to the survey. The survey (visual analog scale) recorded time series scores collected from participants while under antidepressant treatment for mood instability. The primary outcome was to identify the number of survey ratings that can detect mood instability among Major Depression Disorder participants at high risk and those at low risk of developing bipolar disorder compared to healthy controls. A priory criterion to define mood instability included daily and weekly measurement of subthreshold hypomania scores in a clinical setting which consisted of a priori defined criteria for spikes in scores (>2 threshold and >25% increase from baseline) and fluctuations (change in two consecutive ratings of more than 25%).

Results showed that smartphone survey ratings can adequately capture mood instability in bipolar disorder and subjects at risk of major mood disorder compared to those at low risk of developing dipolar disorder and healthy controls (26). A study by Agyapong et al. (27) found that daily supportive text messages were a reliable and acceptable way of delivering adjunctive psychological interventions to people with mental health problems. *Text4Mood* is an innovative service designed to provide support to people on waiting lists for mental health services, or to individuals living in remote communities who have difficulty accessing care. Subscribers receive daily supportive text messages, for example:

1. Today, I will focus on what I have, instead of what I have not.
2. Within me lies the power to succeed.
3. I will work with what I have to reach my goals.

Upon receiving the text messages, 81.7% of users reported feeling hopeful in managing issues in their lives, 76.7% felt in charge of managing their depression and anxiety and 75.2% felt more connected to a support system. Text messaging could potentially be a useful service for delivery of remote care (e.g., in the context of a pandemic) to improve access to psychological care in a cost-effective and timely manner to individuals with a mental health issue who are unable to attend clinics (e.g., self-isolating). Short Messaging Service (SMS) mood monitoring has been validated against the Patient Health Questionnaire-9 (PHQ-9), a standardized measure of depression. Findings from a study by Aguilera et al. (28) demonstrated significant relationships between depression and daily mood scores, measured via SMS 1-week average mood scores and PHQ-9 scores captured on a daily basis controlling for linear change in depression scores. This study shows that SMS mood ratings could serve as a reliable proxy for in-clinic mood assessment (28).

Furthermore, Bush et al. (29) found that a smartphone application "*The Virtual Hope Box*" was more effective than print materials at improving military service men's ability to cope with negative emotions and thoughts and acceptability of treatment. Veterans in the study were receiving mental health treatment and had recently reported suicidal ideation. The App was modeled around a cognitive behavioral approach that uses a physical box containing various items which remind participants of positive experiences, reasons for living, coping mechanisms and people who care about them. Participants were randomly allocated to either the control (standard treatment and supplemental print materials) or intervention group (treatment as usual plus the *Virtual Hope Box* App). Compared to the control group, those assigned to the intervention group reported the App as being "somewhat helpful?" or "very helpful" (84%) and that they would be "somewhat" or "very likely" to use

it again (87%) or recommend it to others (90%). The most frequent reasons for using the App were to cope with distress, overwhelming emotions, and thoughts of hurting themselves as well as for relaxation, distraction, or inspiration (29).

The *Mood Mission* App (30), developed by a team of researchers at Monash University (Australia), was designed to provide standalone help to individuals in response to how they are feeling at that time. The App was designed as a supplement to conventional face-to-face CBT. It provides the user with self-help strategies aimed at reducing feelings of anxiety and depression (30). This mobile App serves the purpose of preventing and coping with low level anxiety and depression. Results showed that users of *Mood Mission* experienced decreases in their depression and anxiety compared to baseline (30).

Another study aimed to evaluate a new App named *Music eScape* (14). This App aimed to teach young adults who were experiencing depression, anxiety and stress symptoms ways to identify and manage their emotions using music from their own music library. Participants were randomly assigned to either the "Tuned In" intervention (*eScape* mood management music App) or a wait-list control receiving the intervention after a 1-month delay. Participants in the intervention group were emailed a link to the App. The study evaluated ER, distress and well-being at 1, 2, 3- and 6-months intervals. Potential moderators to App outcomes, including the amount of music use and healthy ("protective" music which gives participants the energy to get going) or unhealthy (reminding participants of bad memories) music use, were examined. No significant differences between groups on ER, distress, or well-being were found at 1 month between groups. Both groups achieved significant improvements in 5 of the 6 ER skills, mental distress, and well-being at 2, 3, and 6 months compared to controls (14).

A study by Porat et al. (17) examined the feasibility of a mobile App "*ReApp*," a mobile, multiplayer game aimed at training people in emotional regulation, specifically in cognitive reappraisal. Seventy Jewish-Israeli participants were randomly assigned to either an experimental (ReApp) or a control condition. Participants in the experimental condition played ReApp, while participants in the control condition played '*Connect Four'*, a two-player game played on a mobile device but which did not teach any cognitive skill. Results indicate that people who played ReApp experienced lower levels of anger and disgust compared to the control group.

Over the years, mindfulness-based interventions delivered via phone application have been examined. Tong et al. (22) showed mindfulness stress reduction in combination with virtual reality (virtual meditative walk) was significantly more effective in reducing reported levels of chronic pain and post-traumatic stress disorder compared to Mindfulness-Based Stress Reduction (MBSR) Meditation standalone. Furthermore, Cikajlo e al. (18) evaluated a novel system of a meditation-based stress and anxiety reduction therapy mindfulness and found that scores on both the Mindfulness Attention Awareness Scale (MAAS) and the Satisfaction with Life Scale (SWLS) improved after 8-weeks.

Researchers have reported that mindfulness-based smartphone App designed to assist people stop smoking was effective at reducing people's daily cigarette consumptions. Minami et al. (31) conducted a randomized controlled trail to assess the effectiveness of a smartphone assisted mindfulness intervention for smoking cessation in smokers receiving outpatient psychiatric treatment. Results showed that participants practiced mindfulness on average 3.4 times per day, completed 72% of prompted reports and submitted 68% carbon monoxide videos as requested. Participants reported that daily mindfulness practice was helpful for both managing mood and quitting smoking (31).

Additionally, Ying et al. (32) set out to examine the effectiveness of online mindfulness-based interventions on psychological distress (depression and anxiety). Seventy-six participants were randomized to either a group mindfulness-based intervention (GMBI), self-direct mindfulness-based intervention (SDMBI), discussion group (DG) or a control group (Blank Control Group). Results showed that participants in GMBI and SDMBI had significant pre- and post-test scores on mindfulness, ER difficulties, and psychological distress, with medium to large effect sizes in both groups.

Several studies have demonstrated the efficacy of App-based interventions to enhance ER. Morris et al. (15) developed an App that alert users to record their mood several times during the day over a month *via* their mobile phones. Users reported increased emotional self-awareness, and some were able to identify patterns of dysfunction and modify these patterns by modifying their routine. Anand et al. (16) used a smartphone self-monitoring programme to prompt users to complete a survey and report their emotional state on a weekly basis. Results showed that the mood ratings captured mood instability and offer a prudent way to monitor development of serious manic disorder. Both monitoring systems were, however modeled around the study participants and offered little constructive feedback about participant's mood history. A recent attempt using a mobile App specifically aimed at enhancing ER through the integration of self-reported data and electrodermal activity (13). Limitations of these studies were the small number of trial participants reporting mood disorders. There is a need to further investigate the impact of smartphone-based programme on larger more representative samples reporting ER and associated mental health outcomes which is also relevant to non-clinical users. Mobile phone technologies, in particular text messaging has transformed the way mental health interventions are delivered. Recent studies (27, 28) find text messaging interventions associated with reducing the stigma associated with mental health treatment and increase positive patient attitude and satisfaction as well as improved treatment adherence, increase appointment attendance (33). Despite high

accessibility described in these studies, their applications were limited to patients with anxiety and depression, services such as addictions service delivery is relatively limited.

Web-based interventions

Several studies have addressed the effectiveness of web-based and other computerized interventions in treating depression and anxiety symptoms (15, 23–26) but very few studies explored these technologies in supporting interventions to enhance ER. Internet technologies play a significant role in people's everyday lives especially social media and messaging App, and the remarkable uptake in video conferencing Apps, given people's widespread reliance of these technologies during the COVID-19 pandemic. Of the 10 studies included in this review, three reported web-based self-guided ER intervention, two were randomized controlled trials (RCT) and 1 was a pre-post within subject study. The use of the Internet an adaptation of face-to-face protocol is gradually becoming a favored platform in which ER plays an important role (34). A two-phase pilot project evaluating the *MARIGOLD* intervention (Mobile Affect Regulation Intervention with the Goal of Lowering Depression), a web-based, self-guided intervention based on "Stress and Coping" and "Broaden and Build" theories of positive emotion (21). The intervention was designed to teach individuals positive emotion skills for handling elevated depressive symptoms. Skills include noticing and amplifying positive events, gratitude, activation, mindfulness, positive reappraisal, strengths, and acts of kindness. Additionally, an internet-based ER training *(iERT)* aimed to enhance ER skills at reducing the risk of victimization in depressed patients is currently being investigated in a multicentre randomized controlled trial (35). Furthermore, researchers at the Traumatic Brain Injury Model System Center (New York, USA) enrolled 91 participants with traumatic brain injury in a study. Participants were enrolled in an experimental program, called Online *EmReg,* which was adapted from a face-to-face group therapy program. Over 12-weeks, participants received 24 1-h ER skills training sessions via videoconferencing, held twice a week for 12-weeks. The group sessions were held by experienced facilitators (i.e., rehabilitation neuropsychologists). The programme was designed to provide a learning platform for participants to learn how traumatic brain injury affects emotional functioning and provide strategies for improving ER skills in everyday life. During the final 16 programme sessions, participants practice their skills in individual and group exercises. At the end of the 12-week programme, participants showed meaningful improvements in ER on all aspects measured by the Difficulties in Emotion Regulation Scale (DERS) (20).

Motter et al. (36), in a double blind randomized controlled trial tested whether the Wechsler Adult Intelligence Scale focused computerized cognitive training programme (CCT) could out performed verbal ability focused CCT. This study aimed to explore the impact the cognitive functioning and mood of young adults with depressive symptoms. To test this, 46 young adults aged 18–29 years, with mild to moderate depression, were randomized to either the computerized cognitive training group or a verbal ability group. Participants trained on their mobile device 5 days per week for 8-weeks. Depressive severity, everyday functioning, and cognition were evaluated pre- and post-training. Results indicate that the computerized cognitive group had greater gains in executive functioning and processing speed than the verbal group. There were no di?erences between groups in mood or everyday functioning improvement.

Ouweneel et al. (37) evaluated the effect of an online positive psychology intervention to promote positive emotions, self-efficacy, and engagement at work. The online modules consist of three types of online assignments: happiness, goal setting, and resource building (intervention group) compared to a self-monitoring control group. Results revealed that the self-enhancement group showed a stronger increase in positive emotions and self-efficacy compared to the control group, but not on engagement. Additional analyses showed that the positive effects of the self-enhancement intervention are present for employees who are initially low in engagement (diary completion, survey, and online modules), but not for those medium or high in engagement.

Stubbings et al. (38) conducted a randomized controlled trial with 26, primarily Caucasian, adults aged 18–65 years. Participants were randomized to receive 12 sessions (60 min) of weekly sessions of CBT via videoconference ($n = 14$) or CBT delivered in person ($n = 12$) for participants with mood and anxiety disorders. Diagnoses were determined using the Diagnostic and Statistical Manual of Mental Disorders, 4th edition text revision (DSM-IV-TR). The Depression Anxiety Stress Scale (39) was used as the primary outcome measure. Significant reductions were found across time for symptoms of depression. The study found no significant differences between treatment conditions for any of the outcome measures.

Furthermore, Fonseca et al. (19) conducted a randomized controlled trial to test a self-guided, web-based CBT intervention to examine the feasibility, acceptability and efficacy of the "*Be a Mom*, web-based self-guided CBT intervention" an intervention aimed at preventing persistent post-partum depression in both at risk post-partum women and women presenting with early onset post-partum depressive symptoms. Eligible participants were either randomized to receive the intervention or randomized in a waitlist control group. Results showed a greater decrease in levels of ER difficulties in the intervention group and significant increased levels of self-compassion compared to the control group and significant decrease in depressive symptoms in the intervention group.

A wide range of interventions targeting ER has greatly benefited from incorporating online-based interventions. These

recent developments include computerized (21) and (35) studies and videoconferencing technology (20). These technologies have a range of advantages, such as the possibility to reach larger audience in need of psychological treatment and hard to reach group, particularly young adults (40). In addition, online based interventions have increasingly been found to be cost effective in comparison to face-to-face active treatment (41), although some literature shows inconclusive results in this regard (42).

Virtual environment

The rapid emergence of new technologies and the growing interest in applying them in the field of psychology have led to the development of novel virtual reality technology in the field of neuro-rehabilitation (43) and the treatment of various mental health disorders (44). Virtual reality uses computer technology to create a simulated environment in which a person can interact within an artificial three-dimensional environment using electronic devices such as head mounted display or biosensors to increase realism in the virtual world (13). To date, very few studies explored the potentiality of virtual reality impact on enhancing ER. Furthermore, the available studies are often small and conducted on specific populations. Evidence suggests that effective ER strategies lead to several important outcomes associated with mental health and psychological wellbeing (45). Therefore, beneficial changes in ER are crucial outcome in mental health interventions and the availability of new technology such as virtual reality technology can facilitate or even increase positive outcome of such strategies (46).

Tong et al. (22) showed that virtual meditation in combination with mindfulness-based stress reduction (MBSR) was significantly more effective in reducing reported levels of chronic pain (e.g., fibromyalgia) and post-traumatic stress disorder and a higher level of participants satisfaction and experience of higher level of satisfaction. This virtual reality system was designed for chronic pain patients to learn mindfulness based MBSR and incorporates biofeedback sensors, an immersive virtual environment and stereoscopic sound. Additionally, Cikajlo et al. (18) evaluated a novel system, the Realizing Collaborative Virtual Reality for Wellbeing and Self-Healing *(ReCoVR)* system for remote acquisition of a mediation based stress and anxiety reduction therapy and mindfulness course. The system is based on a cloud server web-interface and remote clients, using immersive head-mounted display Samsung Gear and Samsung Smartphone S6 and Note. The application enables group sessions in the virtual world, 3D videos and real-time interactions, as well as standalone meditation. An 8-week mindfulness-based stress reduction course was designed for this virtual reality application. The course was tested with 8 participants: 4 employees (age range 27–40 years) and four patients (age range 24–48 years) with traumatic brain injuries. Their outcomes were evaluated using the Mindful Attention Awareness Scale (MAAS), the Satisfaction with Life Scale (SWLS), and the Mini Mental State Examination (MMSE). The results were encouraging, patients achieved very high level of satisfaction (SWLS) at the end of the study. A slight increase in MASS score was also noticeable. Most patients had MMSE score of 30 suggesting normal cognitive function.

Although virtual reality (VR) is not new, the recent incorporation of such technology into ER treatment delivery is rather novel. In the studies presented, virtual reality has been utilized in various ways to deliver ER strategies to promote mental health and wellbeing. Some authors (18, 22) used mindfulness-based stress reduction intervention as a non-pharmacological approach to enhance participants ER and boost their wellbeing. Additionally, Tong et al. (22) showed that immersive virtual reality can be used to manage and control chronic pain in the long term.

Discussion

This review aimed to investigate the available digital technologies that may be used to enhance ER skills and reduce the risk of mental health disorders or attenuate their effects. All the described digital technologies in this review were utilized to offer a different avenue of managing ER or enhance a current approach to improving knowledge about ER skills. Based on the reviewed studies, the current evidence suggests that most digital ER approaches lead to beneficial effects in reducing/enhancing ER by providing people with the ability/opportunity to regulate their emotions through enabling these practices at virtually any time and place. Only one study (14) did not report a significant difference between intervention and waitlist control on mean Difficulties in Emotion Regulation (DERS) scale at 1 month post intervention. Yet, both groups achieved significant improvements in 5 of the 6 ER skills, mental distress, and wellbeing at 2, 3, and 6 months compared to controls. However, other research suggests that some ER approaches can lead to poor outcomes based on how and when they are used (47), which highlights the need for future research to further explore issues of implementation and engagement. Our review included mostly feasibility studies and RCT's with small sample sizes and non-diverse populations, limiting the generalisability of the findings.

Emotion regulation intervention delivered using digital technologies

In recent years, advances in information technology have facilitated the emergence of several digital mental health interventions, delivered via the internet, smart phones, virtual reality and videoconferencing. The wide use and availability of mobile technologies such as smartphones means that a

wide range of people are able to access these technologies; this increases research opportunities in digital ER (34). Recent application of digital platforms to study ER has provided some fresh perspectives about this process (48) and a more complex representation and understanding of how people regulate their emotions (49). Considering the multi-faceted construct of health and well-being, this review provides an overview of the available literature and seeks to unravel the complex picture provided by the included studies. Overall, these studies show that digital technology is a promising method of delivering a group or individual intervention to improve ER following newly diagnosed or recurrent mental health disorders. Digital technologies can provide an effective alternative approach for diagnosis, assessment, and management of mental health disorders that appears to be comparable to in-person care. Furthermore, the connectivity, mobility and multi-functionality afforded by digital technologies provides greater access to a multitude of affordable technologies than ever before and the ease with which the user can navigate through apps allowing people to fine-tune their own strategies for particular situations and to engage in digital ER (50).

Five of the studies in this review applied mobile technologies in depressive disorder, traumatic brain injury ER and stress reduction (13–16, 21). Overall, most of the studies included in this review had design and/or methodological limitations (e.g., feasibility studies, no control group, small sample sizes). In addition, it is unclear which elements of the mobile application were the most beneficial, for example, the short therapies which were delivered in addition to the mobile application intervention, or the mobile application intervention itself as the mechanism for intervention delivery.

It will be of utmost importance to integrate dissemination and augmentation, particularly using mobile and ubiquitous technologies. For instance, there are some examples of integration, like VR through fully automated self-administered applications, which can be delivered remotely or digital augmentation through mobile technologies. This can represent an improvement for the clinical practice, either to increase the therapeutic content with the same amount of time with a therapist or decrease the time spent with the therapist but still having the same therapeutic content.

Diverse digital technologies application in emotion regulation intervention

There is growing interest in the application of psychological interventions using digital technologies, likely because they are highly effective and scalable. This section describes some of these existing digital technologies used to enhance ER. Illustrative examples include web-based intervention such the Online *EmReg* (20) and *Be a Mom* mobile app (19) or the emerging field of virtual reality (18, 22). For instance, the Online *EmReg* has been shown to help people with traumatic brain injury improve their ER skills and reported high satisfaction with the intervention, as it provided treatment and support that these people would not normally have access to. Furthermore, virtual reality technique has been used to allow participants to learn mindfulness-based stress reduction technique and has been shown to significantly reduce pain in users (22). This goes to show that technological platforms such as web-based technologies and virtual reality can make evidence-based ER intervention that are currently conducted in therapy sessions more accessible and scalable with a far wider reach. Furthermore, advanced technological progress meant that seldom heard populations are now more accessible. For example, the "*Be a Mom*" intervention for postpartum women to prevent persistent postpartum depression symptoms (PPD) in at risk women presenting with early onset postpartum depressive symptoms. This self-guided web-based intervention grounded in cognitive behavioral therapy (CBT) has demonstrated a decrease in the levels of ER difficulties and a greater increase in in the levels of self-compassion in postpartum women receiving the "*Be a Mom*" intervention, compared to a control group (19).

Barriers, facilitators, and potential benefit of digital technologies in emotion regulation intervention

This review identified some important facilitators and barriers to the use and implementation of digital emotion regulation. The main benefit of digital technology interventions targeting emotion regulation is greater dissemination of treatments (51), treatment customization and self-help treatments (52). Researchers have recently started to explore how individuals shape their affective states using digital technologies such as smartphones. The vast majority of digital emotion regulation approaches are in the form of cognitive behavior therapy. Most have been adapted from face-to-face treatment modalities; some are simplified versions of the original treatment whereas some combined both the treatment procedures and the strategies that govern their use. However, application of digital technologies has a number of benefits. Digital technologies make treatment more accessible, for example, CBT may be more feasible to deliver in remote and rural areas through widely used technology, such as smartphone. Furthermore, information gathered via digital technologies can be stored and accessed quickly and shared with patients and healthcare professionals. These data can be analyzed, and accurate reports can be derived making clinical decision-making easier. Additionally, digital technologies may

lead to greater treatment adherence due to the accessibility of biofeedback participants receive in real time. "*Do-it-Yourself*" (37) is an example of the positive effect of digital solution to promote positive emotion, self-efficacy and engagement at work that allow participants to complete online modules including happiness, goal setting and resource building while gathering biofeedback reports for healthcare professionals to always monitor progress. Although it is clear that digital technology has great potential within emotion regulation interventions, there are significant barriers preventing uptake of such mode of delivery. For example, digital literacy and accessibility barriers are often overlooked in the drive toward digital communication. Digital communication is effective only when it is inclusive in design - when recipients feel comfortable using technology with relation to their health, and when people of all abilities can access and understand the information being communicated. For example, some participants in the *MARIGOLD* study preferred to use pen and paper to record the study skill lessons instead of the *MARIGOLD* study website (21). There are technical considerations, for example, stable internet connectivity and in the case of mobile app, android with Bluetooth may be the only system supporting ER modules, which could be problematic for some participants to access. Most of the ER modules have only been designed and written in the English language limiting scalability across communities and geographical regions.

Strength and limitations

This review has some limitations which should be acknowledged. The review primarily focuses on published articles, although gray literature and Google Scholar were searched, only articles published in the English language were reviewed, possibly missing peer reviewed papers published in other languages. Secondly, there is significant variation in the terminology of ER which may have led to omissions in our key words and MeSH terms. Thirdly, only 10 studies met our review criteria. The small number of available studies and the design and methodology limitations of included studies limits the potential for in-depth synthesis. The strength of this review includes searches across a broad range of medical databases, gray literature and Google Scholar and that study types were used to identify potential papers for inclusion. Our broad search strategy encompassed a wide spectrum of search terms, including emotion/mood regulation, digital technology, including mobile application, virtual reality, sensor bands and web-based psychological treatment modalities. The present review was broad in its approach because the main emphasis was on emotion regulation strategies using digital technologies, rather than the broader context of enhancing ER to better manage mental health disorders. The review considers individual differences in the digital approach used to enhance emotion regulation. For instance, if an emotion-regulation strategy is commonly used by certain individuals using a particular digital technology approach to target specific symptoms, highlighting this can bring into sharper focus the best treatment approach involved. Future studies may explore personalized treatment approaches targeting specific ER symptoms, as digital technology and assessments tools becomes more sophisticated so will our ability to provide better and more personalized treatment.

Conclusion

Despite differing approaches that have been used to conceptualize ER and the use of various digital technologies to deliver complex ER strategies, ER using digital platforms has a broad and significant heuristic value in mental health research. The studies examined show that digital technology is likely to be an appropriate mechanisms for assisting individuals to enhance their ER skills and manage mental health issues better by accessing more adaptive ER strategies. The use of digital technology in this sense is promising because it allows the user to learn complex emotion regulation strategies in the context of life-like digital environments. For the aforementioned reasons, the pursuit of integrated prototypes of technologies could lead to a successful understanding, assessment, and training of emotion regulation and reduce the risk or better manage pre-existing mental health problems. The review highlights the importance of diverse digital technologies as platforms for enhancing emotion regulation and conveying individually tailored, emotional, physiological, and behavioral responses in a variety of 'real-world' situations in 'real-time'. There remains a need to explore which types of digital technologies provide better results, and why.

Author contributions

FJ developed the search strategy, the review, and produced drafts of the manuscript. SM, HB, and DH provided input into the design and development of the manuscript. All authors contributed to and approved the final manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2022.809332/full#supplementary-material

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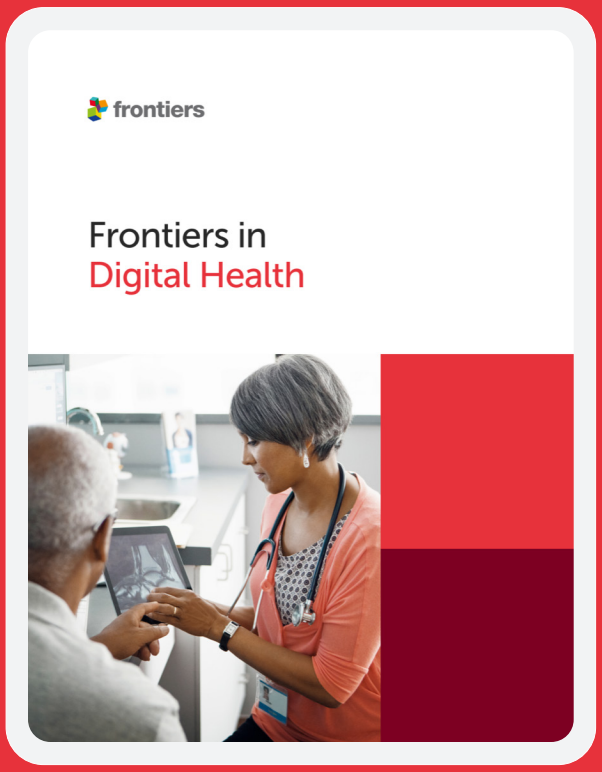

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