Brain-Computer Interfaces and Creative Expression: Interface Considerations for Rehabilitative and Therapeutic Interactions

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By translating brain signals into new kinds of outputs, Brain-Computer Interface (BCI) systems hold tremendous potential as both transformative rehabilitation and communication tools. BCIs can be considered a unique technology, in that they are able to provide a direct link between the brain and the external environment. By affording users with opportunities for communication and self-expression, BCI systems serve as a bridge between abled-bodied and disabled users, in turn reducing existing barriers between these groups. This perspective piece explores the complex shifting relationship between neuroadaptive systems and humans by foregrounding personal experience and embodied interaction as concepts through which to evaluate digital environments cultivated through the design of BCI interfaces. To underscore the importance of fostering human-centered experiences through technologically mediated interactions, this work offers a conceptual framework through which the rehabilitative and therapeutic possibilities of BCI user-system engagement could be furthered. By inviting somatic analysis towards the design of BCI interfaces and incorporating tenets of creative arts therapies practices into hybrid navigation paradigms for self-expressive applications, this work highlights the need for examining individual technological interactions as sites with meaning-making potentiality, as well as those conceived through unique exchanges based on user-specific needs for communication. Designing BCI interfaces in ways that afford users with increased options for navigation, as well as with the ability to share subjective and collective experiences, helps to redefine existing boundaries of digital and physical user-system interactions and encourages the reimagining of these systems as novel digital health tools for recovery.

Keywords: brain-computer interface, multimodal communication, digital creative therapy, social technology, hybrid interfaces

INTRODUCTION

As the field of Brain–Computer Interface (BCI) technology continues to progress rapidly, it is anticipated to serve a vital role in future rehabilitation interventions for individuals experiencing neurological and/or movement disorders. Although there are various considerations for improving the accuracy and reliability of BCI systems, modern advancements within the field concern the potential of developing a system that allows immediate feedback for cognitive rehabilitation, as well

as a suitable hybrid BCI for enabling creativity (Tan and Nijholt, 2010; Nishimura et al., 2010; Bamdad et al., 2015; Botrel et al., 2015; Kübler and Botrel, 2019; Nijholt, 2019). Recent research suggests that hybrid BCIs may improve overall BCI performance through combing different features of brain signals, which can include the use of two BCI navigational paradigms (for example: SSVEP and imagined movement), or through integrating BCI and another system (for example, an eye-tracker) (Bamdad et al., 2015; Todd et al., 2012). Hybrid BCIs can either simultaneously process input or operate these systems sequentially and may offer an application that can improve overall performance and enhance user experience (Todd et al., 2012).

Despite the potential for BCI systems to serve as both rehabilitation and communication tools, art and creative expression are often overlooked in assistive technology (AT) development (Huggins et al., 2019). Exploring BCI and neurofeedback development through introspective approaches highlights how novel integrative applications may provide opportunities to improve well-being resources for less-explored populations of users and underscores the importance of the user (Rapoport et al., 2008; Zickler et al., 2013; Kübler et al., 2013; Kübler et al., 2015; Morone et al., 2015; Daly and Huggins, 2015). Adapting technologies to enable digital creativity by combining professional art and music therapy practices with technical components of a responsive closed biofeedback loop may contribute to meaningful and self-expressive processes. As such, it is important to consider how applying digital forms of creative participation in BCI-enabled spaces *via* the use of internal and external feedback (both visual and auditory) can shape meaning, enhance experience, and support wellbeing for users. Utilizing theoretical tenets of communication and creative arts therapies disciplines to help guide development of these systems as innovative digital health tools, we invite consideration of the communities of practice that envelop social and technological uses of these technologies. In applying hybrid forms of navigation to further increase successful user-system literacy rates as well as encourage neuroplasticity regeneration, this work suggests that integrating multifaceted design perspectives into the design of BCI interfaces will support opportunities for more inclusive and diverse interactions.

TECHNOLOGICAL CONSIDERATIONS FOR HYBRID INTERFACES

Advances in neuroadaptive technologies, specifically BCIs, have the potential to become a "major tool for people with disabilities to control locomotion and communicate with surrounding environment and, consequently, improve the quality of life for many affected persons" (Bamdad et al., 2015, p. 355). Electroencephalography, (i.e., electrical field recording at the scalp) has the most potential for clinical application, as it is relatively simple compared to other options, and is cost effective (Bamdad et al., 2015). However, several aspects of this technology will need improvements to assist efforts to uncover new patterns of brain activity underlying artistic creation. (Rapoport et al., 2008; Tan and Nijholt, 2010; Bamdad et al., 2015; Huggins et al., 2019). By

affording users equal opportunities to engage in creative activities for expression, these systems can serve as a bridge between abled-bodied and disabled users and help to reduce existing barriers between these groups (Todd et al., 2012; Kübler and Botrel, 2019).

Orndorff-Plunkett et al. (2017) suggest that experimental exploration of neuronal activity can benefit social neuroscience, arguing that processes such as neuro- and bio-feedback enable individuals to sense and interact with their own brain activity, from which causal conclusions in relation to individual behaviors, thoughts, perceptions, and experiences can be drawn (Orndorff-Plunkett et al., 2017). The notion of giving free and open choice of mental commands is notable since, on average, participants performed best with mental commands within a sensory modality they found more interesting and that corresponded to previous experience (Friedrich et al., 2012; Dhindsa et al., 2017a; Dhindsa et al., 2017b). More specifically, BCIs designed for artistic or creative applications, or BCIs that allow mental commands involving abstract visual or auditory imagery, may need to consider the artistic background of the user during training (Dhindsa et al., 2017b).

When incorporated into existing art-based BCI programs, designs focused on user-centered experience such as open-ended BCIs (Dhindsa et al., 2017a; Dhindsa et al., 2017b) and hybrid BCIs (Müller-Putz et al., 2015) have demonstrated the ability to uncover new patterns of brain activity underlying artistic creation and/or creative expression, further highlighting how applying insights from multiple disciplines can help identify gaps in interface design that reduce BCI usability (Kübler et al., 2013; Kübler et al., 2015; Müller-Putz et al., 2015; Cruz-Garza et al., 2019; Scott et al., 2019). Additionally, integrating neurofeedback applications within BCI offers clinical benefits to users through novel interventions grounded in psychological and neurosciences practices. The potential for BCI devices to facilitate general populations through neuro- and bio-feedback systems known as neurotherapeutic interventions "may give individuals a more active role in their own health care, utilize a holistic approach to body, mind, and spirit, are non-invasive, and elicit the body's own healing response" while also possessing the ability to inform social neuroscience and clinical communities" (King, 2016; Orndorff-Plunkett et al., 2017, p. 14; Scott and Gehrke, 2019; Scott et al., 2019).

CREATIVE APPROACHES TO INTERFACE AFFORDANCES

Acknowledging the reciprocal relationships between art, science and technology provides an opportunity to examine existing BCI interfaces from alternative perspectives, prompting additional research on how to improve, enhance, supplement, and allow BCI technologies to provide opportunities for creative expression and therapeutic care. (Wolpaw et al., 2002; Wolpaw and Wolpaw, 2012; Brunner et al., 2015). Expanding existing creative forms of expression for BCI systems in the form of digitally adapted creative arts therapies practices may provide different user groups the ability to communicate that which might otherwise go unexplored or un-interpreted, as it offers a medium for

conveying subconscious emotions through new forms of self-expression within a therapeutic relationship (Stewart, 2004; Angheluta and Lee, 2011; Ehresman, 2014; King, 2018).

Research has demonstrated that integrating artistic practices into rehabilitative treatments through which patients are able to create or co-create art themselves improves patient-physician communication, facilitates patient thinking, and improve clinical outcomes (Sonke, 2016). Additionally, creative arts therapies have been shown to positively impact various psychological and physiological outcomes through the interactive processes of action and experiential-based training (King and Pascuzzi, 2018; de Witte et al., 2021). Initial creative arts therapy practices have been redefined through various interdisciplinary and collaborative efforts to maintain a focus on enhancing and humanizing the healthcare environment (Sonke, 2016). More recently, research on clinical and evidence based creative expression in the form of creative arts therapies, which includes art and music therapies, has demonstrated the potential for better understanding of specific health conditions while offering a safe and cost-effective intervention as an adjunct to traditional medical management (King et al., 2019; Scott et al., 2019; de Witte et al., 2021; King and Parada, 2021).

Exploring the connection between the brain and expression through feedback loops that initiate interactive processes, whether generated through bio-signals using a BCI system or via creative processes, requires an individual to become aware of information and learn how to use it in ways that enable communication. Furthermore, co-integrating both types of feedback loops within technological system designed to serve a therapeutic purpose may reveal a third type of loop that assumes a top-down approach; one which affords individuals the ability to rehabilitate the brain through guided feedback by using artistic and musical therapy as expression planes. This has the potential to help those who struggle with traditional learning practices to better communicate their experiences and promote their own processes of healing and recovery (Kaimal, 2019; King and Kaimal, 2019).

THEORETICAL PERSPECTIVES TOWARDS HUMAN-TECHNOLOGY RELATIONSHIPS

Acknowledging the relationships and interactions that develop via system engagement as unique exchanges between the human and nonhuman components highlights how technological artefacts influence the processes and production of scientific practices and knowledge. The process of recognizing material, social, and natural things invite analytical strategies that can assume more collective and habitable spaces for construing knowledge, as scientific discovery is bound by the material objects and things that compromise the scientific processes of experimentation and observation (Latour, 2009). By engaging an empirically open ethnomethodology that dissolves the boundaries between things that are considered "social" from those that are deemed "natural," Latour (2009) suggests this process of relocation and re-embodiment of science through organized "networks of actants" and allows access towards conceptualizing how the environment is assembled. In-depth analyses of user-system interactions from these combined perspectives presents the added opportunity of engaging

ethnographic methodologies, as well as interpretive and semiotic frameworks towards understanding user-system relationships as meaningful structures that are created and understood within cultural contexts (Geertz, 1973).

Engaging a postphenomenological approach towards articulating modes of knowledge as "embodied and situated" with mediated human-technological interactions enables analytical inquiry into the ways in which BCI engagement influences experience, shapes expression and impacts communication processes (Rosenberger and VerBeek, 2015, p. 1). Embodied relations through a mediated technology "simultaneously magnify or amplify and reduce or place aside what is experienced," shaping user perception and translation through "non-neutral" device characteristics (Idhe, 1990, p. 76; Rosenberger and VerBeek, 2015), implying that the ways in which knowledge and experience are construed through BCI user-system engagement is of moral and ethical importance.

A deeper understanding of why this philosophical lens is important comes from recognizing how this perspective integrates tenets from two separate yet complementary paradigmatic frameworks-*critical* and *constructivist* (Rosenberger and VerBeek, 2015, p. 9). From a critical standpoint, it encourages dialogue between an investigator and subjects, and acknowledges findings as value-mediated while emphasizing that "researcher-researched relationships" should be built on mutual respect between equals. In this, BCI researchers, engineers, designers, etc., should not be objectively distanced from the users that are contributing to their research objectives, and BCIs should be developed in way that lends agency and equal voice to users. From a constructivist viewpoint, it recognizes that knowledge is built through user constructions and reconstructions, as well as through engagement and active participation to stimulate changes. This concept reinforces cooperation between a researcher and a user, weighing the power structure of what is possible through device affordances is of consequence (Lincoln and Guba, 1989; Guba and Lincoln, 1994, p. 230; Nisbet and Scheufele, 2009). As these paradigms maintain similar epistemological assumptions, this approach allows for both analytical critique and inquiry towards the multifaceted components of BCI systems, recognizing these devices as a composite product of technological affordances, mediated interactions with the technology, and the communication that occurs between the user and the system, as well as with researcher (Scott et al., 2019).

EMBODIED DISCOURSE OF SOCIALLY INTERACTIVE SPACES

Situating our conceptual sense of realities as grounded through metaphor and language illustrates the ways in which the design of BCI interfaces can guide new interpretations for user-system interactions (Lakoff and Johnson, 2003). By using the framework of distributed cognition as a lens through which to unite the concept of technologically-mediated social aspects of communication enabled by BCI systems with the broader mind-body processes, researchers can account for the ways in which understanding, knowledge, and perceptions are integrally situated within the articles, tools and people within our surrounding environments.

Acknowledging BCI interactions as embodied symbolic spaces through which both internal and external representations work together to specify the distributed representational space offers insight towards how these processes negotiate intrinsic (user) and environmental (technology) structural affordances in order to share information and build knowledge. Interactions cultivated through system engagement allows relationships to form and offers sites of meaning that can co-create knowledge potentials between "an individual mind and an external artifact and between individual minds" (Zhang and Patel, 2006, p. 333). This view invites further inclusive and perceptual consideration by offering a perspective that extends essentialist and normative assumptions towards use and development of these systems (Zhang and Norman 1994; Salomon, 1997; Sutton, 2006).

Assuming a translational method, otherwise referred to as "multimodal communicative competence" to analyze interactions between a user and a technology, allows researchers to understand the mediation effects on the communication processes (Royce, 2002, p. 192). Through considering the type of language used and the semiotic resources deployed, as well as various intrinsic and extrinsic structural affordances of the given medium, research can explore how meaning manifests within the bi-directional relationships fostered by BCI user-system interactions. Using an architectural model of physical spaces through three functions of analysis (experiential, interpersonal and textual), O'Halloran (2004) describes how a systemic-functional approach, or a "social semiotic" approach to interactions that occur between a user and a technology, can offer a way to build knowledge and enhance meaning (p. 27), and further inform "somatechnological" conceptualizations of these tools as user-specific sites for embodied communicative exchanges (Eco, 1976; Rosenberger and VerBeek, 2015, p. 21).

MEDIATION OF EXPERIENCE THROUGH TECHNOLOGY-ENABLED COMMUNICATION TOOLS

As the social means of communicating become increasingly intertwined with practices within medical industries, we find ourselves relying more on these technologies to both educate and assess our own personal health and manage our personal relationships, as a key component of technological implementation rests on the ability to effectively demonstrate how emerging innovation may function within the larger context of a technologically dependent society (Tarhini et al., 2015). Technological development is often accompanied by a process that involves modifying and altering emerging technologies in ways that improve functional considerations, measures of efficiency, ease of use, technical properties of a new device or system; however, these changes can introduce intermediary shifts that can occur surrounding existing practices and uses for a given technology. This adjustment occurs in part, because of technological characteristics that have changed, but also due to evolving user needs (Webster, 2002; Schulz, 2004; Cox and Depoe, 2015). The dynamic relationship between new and existing technologies is translational, in that the future impact of a technology is largely determined by its perceived use value as well as how it is received amongst professional and general communities.

BCIs are communication technologies as well as social technologies which require in-depth social, cultural, and technical analysis of the characteristics of the tools themselves, as well as the behavior that surrounds device use. Research analyzing BCI systems as social-communicative mediums emphasizes the potentiality of these to improve modes of agency and expression for users. However, additional consideration should be given to ethical and moral issues that can arise when technical changes are made to corresponding mediated environments. When specific technical constraints reinforced by digital architectures are placed upon the communication processes, it may lead to dependency and heteronomy amongst users (Dijck, 2013). This suggests that interface architecture plays a role in identity formation through the process of social interaction, and as such, efforts to examine the relationship between a specific environment and self-expression as it relates to BCI systems should not be conceived with a "one-size-fits-all" approach (Lowery and DeFleur, 1983; Postmes et al., 2005; Nisbet and Scheufele, 2009).

CONCLUSION

By its nature, BCI is a multidisciplinary field. Assuming an epistemological approach towards exploring the intersection of how these sophisticated technologies mediate communication, enable cognitively embodied interactions, and afford users the ability to share subjective and collective experiences can encourage novel conceptual understandings as to how new boundaries of digital and physical user-system interactions can explored and further applied (Scott et al., 2019; Hackett, 2008). With a focus on developing ways to contribute to therapeutic care, the goal of this work is to support the integration of creative art therapies into technological affordances of hybrid BCI systems, as this type of intervention could provide more engaging and expressive forms of treatment options to different populations, improve existing treatment options and access to care, and offer therapists a new treatment modality. By developing BCIs in a way that serves as a digital health intervention; one that engages brain activity and real-time interaction with therapeutic activities, it offers an application that combines creative expression with traditional neurofeedback practices to provide an alternative tool to improve emotional and physiological healing and recovery.

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.

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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