Neurofeedback During Creative Expression as a Therapeutic Tool

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1 Introduction

The relationship between art and medicine has a long-documented history. Dating back as far as the sixteenth century, artists such as Leonardo da Vinci used knowledge of human anatomy to depict the human form more accurately. Although the practice of integrating artistic elements with health and science concepts translates across cultures, it was not until the early twentieth century that, for example, the United States began to incorporate art within hospitals, mainly through the Works Progress Administration (WPA) efforts. Initial creative arts therapy practices began in the 1940s as a means for recovery of soldiers returning home from the second world war. Since then, various interdisciplinary and collaborative efforts have been put forth that focus on enhancing and humanizing the health care experience through integrating art within these endeavors [1]. Projects that incorporate the arts in ways that promote public health and enhance community engagement continue to be explored, but many arts and health scholars argue that there is a need for more research and exploration to be conducted within this field [2].

2 Embracing Social Technologies

Technological development presents opportunities for researchers and developers alike to explore innovative ways for increasing the likelihood of adoption and application of new methods of communication. Efforts directed towards improving the utility, efficiency, function, and design of new tools often support these efforts; however, these new technologies often undergo modifications and alterations which impact the ways in which a user participates and interacts with a given tool [3]. This fluctuation that occurs within the user/interface relationship depends not just on the properties of the technology itself, but also on the user's own needs and abilities. The individual variance emphasizes the importance of evaluating society's use of newer and more advanced methods of communication, as well as the ways in which this continual development can directly influence the ways we interact with one another. As such, it is especially important to assess how these tools are both designed and applied, because, as the technical properties of the tools themselves change, so too do our responses to them [4]. This presents the collective social with the possibility to create a new language through how we design the new tools that guide new types of interactions accompanied by new sets of meanings [5].

Although an initial objective of BCI research and technological development was to enable basic forms of social interaction for patients, the potential exists to not only restore and enhance communication for the motor-impaired, but to extend them to include opportunities for creative expression [6] and therapeutic care. This epistemological approach into the intersection of how these sophisticated technologies mediate communication, enable cognitively embodied interactions, and afford users the ability to share subjective and collective experiences through artistic interventions, can encourage new conceptual understandings as to how new boundaries of digital and physical user-system interactions can explored and further applied. Scholars argue that science and art can enrich and interact in ways that are meaningful and contribute towards positive social and cultural progress. They suggest that art provides a tool that enables us to enhance our knowledge about how aspects of how our minds work, and that this knowledge becomes realized through our experiences and the ways in which we interact with the world [7]. Similarly, they argue that this

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process is the key to observing and responding to art, in that it is not necessarily in our awareness, but that our reaction to art engages us [8, p. 13].

3 Towards Neurofeedback Drawing Canvases

Rehabilitative trainings and interventions potentially involve a high level of repetitions and may be accompanied by frustrations on both, the patients as well as the caregivers side. In this project, we explored the challenge to use neurofeedback, specifically the visualization of EEG band power, in a setting of artistic self-expression. Art therapy makes use of artistic expression as a therapeutic means and we aimed at addressing two points, (1) to promote (artistic) self-awareness, rehabilitation and recovery as well as (2) extend the storytelling lens for users in a way that impacts understanding and perspective of family and friends towards complex health technologies and complicated health issues. Recently, first evidence of the real-life applicability of neurofeedback therapeutic interventions has been provided [9]. Using a neurofeedback setup relying on motor imagery signals, the authors report that "patients enjoyed the training and were highly motivated throughout". These behavioral effects were observed alongside long term effects in both functional (EEG) as well as structural (MRI) measures comparing pre-and post-measurements. Self-directed plasticity [10, 11], the idea that intentionally perturbing distributed brain system dynamics in a desired direction or way of functioning, is the core concept of the benefits of neurofeedback training, see [11] for a comprehensive review. Framing neurofeedback training efficacy in this way provides a foundation to assess the effectiveness of training interventions by investigating pre- and post-effects (a) behaviorally (b) using measures of EEG, such as functional connectivity, as well as functional MRI and (c) structural MRI effects [10]. Moving towards establishing these metrics of training effectiveness is an important step for neurofeedback training towards widespread acceptance across the expert as well as the general population.

Our primary objective was to promote (artistic) self-awareness during the process of painting. The concept originates in art therapy and we challenged ourselves to think of potential use-cases: (1) we conceived of patient populations, e.g., after stroke, potentially benefiting from having their own electrical brain activity visualized as a response to, or cause of, their own actions during therapeutic interventions; (2) to promote awareness of brain damage conditions in the medical field, patients social surroundings as well as in therapeutic care, and lastly (3) to situate this emerging technology in the realm of (art) therapy thereby hoping to alter potential misconceptions and fears by showing an alternative use as an interaction modality.

4 Proof-of-Concept

We recorded EEG data from 32 active dry electrodes (actiCAP Xpress Twist, Brain Products, Gilching, Germany) with the LiveAmp compact wireless amplifier (Brain Products, Gilching, Germany) sampled at 250 Hz. The data was streamed to the network using LabStreamingLayer's LiveAmp Plugin[1] from the recording computer. A LabStreamingLayer inlet on the presentation computer received the raw data in python,[2] data of 2s was buffered, then a bandpass filter (1–125 Hz) was applied on the 2s data window with a subsequent time-frequency decomposition using fast fourier transform to estimate power spectral density. Subsequently, we extracted power values for five typically selected EEG bands (delta, theta, alpha, beta, gamma)[3] and fed them to a visualization scheme, see Fig. 1.

Here, we used the power values to set the line height of consecutive lines to get an effect similar to Joy Division's Unknown Pleasures[4] album cover. The visualization output was projected onto a transparent podium paper holder using a projector connected through HDMI completing the closed-loop neurofeedback setup, see Fig. 2.

For the drawing, we gathered watercolors and brushes as well as a white drawing sheet put up on the paper holder. With this setup, we could maintain the desired see through effect. In this prototype, the participant did not receive any instruction concerning the drawing.

In future revisions, the following two points may be considered depending on patient condition and therapy goals. Firstly, we propose using source level instead of sensor level EEG dynamics using appropriate spatial filtering techniques [12]. To best target EEG features and/or source locations primarily affected by patient's condition, a good understanding of the affected EEG signatures is of high importance in maximizing intervention outcomes [13, 14]. Secondly, designing interfaces, here drawing surfaces, taking into account specific challenges various patient populations may face will have a significant effect on user's acceptance. We point out the possibility to use modern tablets with drawing pens as individualized drawing canvases.

[1] https://github.com/sccn/labstreaminglayer.
[2] Python Software Foundation. Python Language Reference, version 2.7. Available at http://www.python.org.
[3] https://en.wikipedia.org/wiki/Electroencephalography.
[4] https://en.wikipedia.org/wiki/Unknown_Pleasures.

Fig. 1 Hackathon participant, Stephanie Scott, wears a mobile EEG cap equipped with 32 dry electrodes. EEG activity is processed online and extracted band power values are used in a closed-loop neurofeedback application. The background of a drawing canvas is updated live in response to, as well as a cause of her drawings

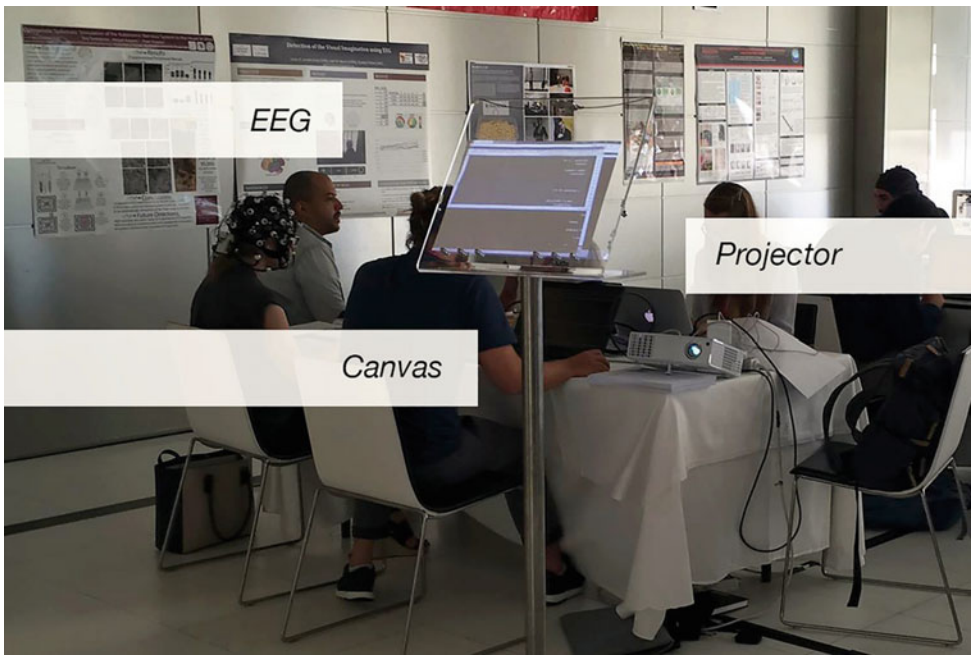

Fig. 2 Participant's EEG activity (32 channels) is wirelessly transmitted, preprocessed to extract band power and subsequently projected onto a transparent drawing canvas using the back projection setting of a projector. Band power values were displayed using a simple visualization adapted from the "Unknown Pleasures" album of British rock band Joy Division (not pictured here)

5 Outlook: The Future of "Neurodata" in Therapeutic and Rehabilitative Settings

Moving forward, development and implementation of new systems should consider a shift towards ideas that support technological mediation as a framework for design, and include analytical methods that support inclusive interactions. This type of shift would acknowledge the roles of technological, semiotic, and economic processes, as characteristics that constitute these mediums, and through a reflexive approach towards human and technological interactions, progress could focus on considerations that evaluate users' experience and agency through action. Reconfigurations and subsequent applications of the technology should explore new tools and boundaries of interface structures that emerge from conscious spatial design, allowing for participatory engagement with technology. This approach has the

potential to great benefit current and future users of brain–computer interface (BCI) systems mobile brain-body imaging (MoBI) systems.

Scholars argue that the arts are effective at communicating across language and other cultural divides, resulting in improved social learning. Studies have demonstrated that the professionals interviewed feel that the arts empower health communication by engaging with people's emotions, attracting attention, focusing and clarifying messages, facilitating dialog, and cultivating solidarity [15]. Science and health communication scholars posit the idea that science, to some degree, is shaped by social forces, thus suggesting, that a "multivalent" approach would be the most successful for being able to interpret community concerns and "understand their effects on the practices and policies of science" [16]. Parrott and Kreuter [17] propose a similarly constructed transdisciplinary approach to communicating health issues that allow for the "intellectual integration" of medical, epistemological and behavioral approaches that can "transcend disciplinary boundaries." Integrating this type of approach to BCI and MoBI technologies and subsequent digital interaction spaces would allow researchers to identify the various micro-level indicators that are encompassed within the more macro-level concerns.

Through combining new technologies with visual educational strategies, along with the integration of knowledge from other disciplines, more innovative strategies towards communicating complex information about new health communication technologies can be developed and implemented. The visual feedback loop that neurofeedback offers, extends a user's vision from discovering what is present in the world and where it is, i.e., this "is why appreciation of the music or painting or other works of the creative person is also a creative act on our part" [8, p. 22]. Biological information presented through a feedback loop can be thus considered as representative of a different identity; it offers a view into an individual biological identity, thus encouraging identity construction through unique representations. Feedback enables creative engagement through an interpretive and reciprocal learning process between user and system.

This type of system could encourage and empower health communication by engaging with people's emotions, attracting attention, focusing and clarifying messages, facilitating dialog, and cultivating solidarity. Some research has found that art can bridge understanding of specific health conditions [8]. Integrating the process of making art with biological feedback allows the space for different types of information to be expressed, exposed and combined, leading to the possibility of new interpretations. This type of application could offer users a unique type of self-reflexive lens as well as an alternate perspective towards the user and system relationship. Embodiment is not just a state of being, but an emerging quality of interactions, and conscious technical design can provide innovative, inclusive and engaging spaces for users. Forward thinking, this type of application could be set to other forms of artistic engagement, such as music, and could also be extended and implemented in Brain–Computer Interface systems, thus offering users a full feedback loop through participation [18]. Additionally, these types of applications could eventually be paired with virtual environments that allow users to interact with one another in a gallery setting, allowing individuals to display and share their creative expressions. Facilitating the development of these types of digital spaces could allow new narratives and dialogues to emerge, and thus, mirroring the overarching goal of what transdisciplinary collaboration strives to create.

> Personal statement and reflection of impact of engaging in art while having direct feedback from my individual neural signals-
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> "It was representative of information I had not been granted access to before. It served as an extended lens into information my body was creating to and responding to, but that I had never been privilege to. It was a tool that helped me identify with my health situation, but it also enabled me with a sense of self-efficacy through changing my perception of my own brain's mobility. The crude brain signals meant more to me than just being representative of raw data and signal acquisition."
>
> -Traumatic brain injury (TBI) and Post-traumatic stress disorder (PTSD) patient/user-

6 Summary: Experiencing Multidisciplinary

This report summarizes the hackathon project entitled "neuroCanvas" at "Your Brain on Art Conference 2017" held in Valencia Spain. Throughout the four-day event, our project conceptualization and participation was focused on answering questions about how to effectively generate a multidisciplinary collaboration between our different concentrations. Including both scientific and artistic approaches towards creative problem-solving, helped us to identify the importance of combining artistic expression within educational and scientific research endeavors. This process helped us realize that the ways in which we perceive, respond and react to information and experiences are different, and although more difficult, it resulted in designing a project that we feel can have a definitive positive impact on users emotional and biological responses to their surrounding environments. The exercise of coding and decoding our different methodologies with one another through dialogue and experiment helped us to design an application that embodies a holistic approach to exploring the intricate intersections of our interpersonal experiences with one

another, as well as with the world around us. Our participation has led us towards a better understanding of how important it is for scientists, artists, educators and therapists alike to recognize that a shared space for trust and exploration should be established in all collaborative endeavors. These communities must work together to identify research goals and objectives, and clearly identify the intent behind their efforts in order to create meaningful research and generate positive impact. Both scientists and artists need to reimagine and modernize their boundaries to create shared meanings and to have supportive spaces created and designed to foster these important types of multi-modal discourses.

7 Summary: Lessons Learned

This chapter summarizes the efforts and methods used to design an innovative neurofeedback application that integrates EEG and neurofeedback technologies with art therapy techniques. This proof of concept aims to provide users with a tool for exploring their individual biological data through creative means. It also extends the lens of self-discovery by pairing neurofeedback technologies with art therapy interventions. Additionally, this tool can be applied to existing training techniques and serve as a point of entry learning approach for users of Brain–Computer Interface systems.

This project was conceptualized and tested by the authors while participating in a sponsored Hackathon. Engagement with this event provided the authors with valuable insights; primarily the need for development of a roadmap necessary for promotion of future collaborative and interdisciplinary efforts. It also provided the space to explore how this could best be created between the authors. Likewise, it illustrated the unique value that each participant had to offer in a multidisciplinary setting. By allowing participants to share ideas and varied approaches to the assigned task, it initiated creative thinking as well as a willingness to expand existing frameworks towards the design process. Most importantly, this event highlighted the need for understanding the level of commitment, patience, and respect that is needed to take part in interdisciplinary endeavors. Working with individuals within different academic and professional fields can be challenging; however, truly innovative and inspiring work can result from participants taking the time to listen to and engage one another.

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