Investigating Novel BCI Displays that Support Personalised Engagement and Interpersonal Connections

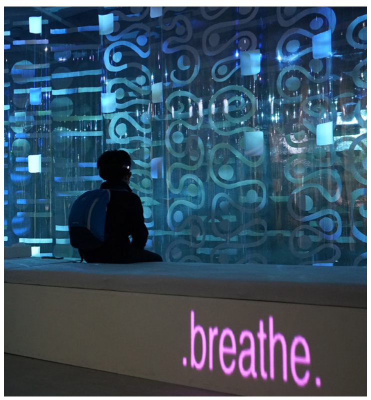

Figure 1: An audience member wearing an EEG headset. Audiences use their neural activity to alter the installation's audio-visuals.

Betty Sargeant
Exertion Games Lab
Monash University, Melbourne, Australia
betty@exertiongameslab.org

Justin Dwyer
Exertion Games Lab
Monash University, Melbourne, Australia
justin@exertiongameslab.org

Florian 'Floyd' Mueller
Exertion Games Lab
Monash University, Melbourne, Australia
floyd@exertiongameslab.org

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Abstract
DREAM 2.2 is an immersive art installation that gives form to our mind's ephemeral data. Participants wear an EEG headset and use their neural activity to alter visuals that are projection-mapped, in real-time, onto an explorable maze in an exhibition space. Their neural data also influences interactive audio. Audiences wear an EEG headset and help shape the installation audio-visuals, or they can explore the exhibition maze and be immersed in audio-visuals that are being shaped by another person's neural data. This case study investigates ways of personalising Brain-Computer Interface (BCI) displays so that people can feel a closer connection to their neural data. It also provides insights into how BCIs can support novel interpersonal engagement.

Author Keywords
EEG; Projection-mapping; Brain-computer interface

CSS Concepts
• **Applied computing →Arts and humanities**; *Fine arts; media arts; performing arts; Sound and music*

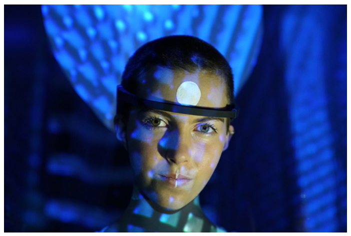

Figure 2: DREAM 2.2 performances feature two sleeping actors. This image shows performer one wearing an EEG headband.

Introduction

DREAM 2.2 is an immersive art installation that gives form to our mind's ephemeral data. Audiences wear an electroencephalograph (EEG) headset and use their neural activity to effect and alter the installation's audio-visuals (figure 1). Audiences can also walk around the installation's maze (figure 6), this structure is projection-mapped with abstract visuals that are controlled in real-time by another person's neural data. This original brain-computer interface (BCI) allows people to use their mind to help shape the aesthetic qualities of an art installation.

In this paper we describe the technical and physical design of the installation. We detail our use of EEG technology and projection mapping software. We also note the ways in which this project extends prior research relating to bio-sensing, sleep and EEGs [5, 11, 17 18, 22, 27], research into human-computer-interaction within participatory art [19], and research into technology and interpersonal interactions [21, 24]. This case study demonstrates how we personalised the display of neural data and provides insights into how brain-computer interfaces may support novel interpersonal engagement.

Related Work

DREAM 2.2 is situated in an interdisciplinary field of computer science and fine art practices [6]. It involves EEG technology [2] and participatory art methods [3].

Related Work in the Field of Art

Some interdisciplinary fine art projects involve participatory or co-design practices. These practices allow the public to work alongside artists in making creative projects [3, 4]. These practices often stem from community art methods [4]. Some contemporary art practices use virtual reality and social media platforms to help audiences uncover new levels of an artwork [6, 19]. Artists also use technology to allow people to contribute to aesthetic aspects of an artwork [8, 19, 20]. These practices uncover new ways in which audiences can be active participants in the formation of art. Building on this, DREAM 2.2 offers audiences a new way of participating with the formation of immersive art, through the use of a brain-computer interface.

Related Work Utilising Similar Technologies

DREAM 2.2 performances involve two actors, who wear an EEG headset while they rest and sleep. This extends previous sleep-related creative projects. For example, in the 1990s, creative practitioners presented interactive sleep exhibitions involving video installations [23], and there were performance art installations where audiences observed people sleeping [25]. More recently, artists have created interactive beds that play music in response to a sleeper's physical position [14]. Researchers have also created digital systems that enable people to experiment with their experience of sleep [5]. EEG systems have been used to track and to further understand our sleep practices [18, 22]. This prior creative work helps us understand new ways in which technology can be used to draw connections between people and the sleeping or resting mind.

There is a field of research that reports on how technology can monitor and track people's actions and bodily functions [1, 2, 5, 9 11]. This research is prevalent in the field of game design [13, 15, 16]. EEG systems have been used to track participant experiences whilst they are engaged in playing digital games [2]. EEG systems have also been used as an interface that controls game play [24] and EEGs can

Figure 3: We use MUSE EEG headsets to read the electrical activity that is occurring inside the brain.

help us further understand human interactions with computers [11, 26]. Artists have used EEGs to create audio-driven media art performances [10, 17], to create non-digital visual representations of audience members' neural data [10] and to create immersive multi-sensory experiences [22]. This prior work shows how EEG technology can provide analytical and medical data on the awake and sleeping mind and how EEGs can be used to form audio performances and artistic, visualisations.

Method

The DREAM 2.2 Installation Design

DREAM 2.2 was publically exhibited for 5-months at the National Taiwan Museum of Fine Arts (2018). During the opening of the exhibition we presented a series of performances (figure 6), following this, the installation operated as an interactive audience experience. DREAM 2.2 features a "brain forest"; a maze that is 13m x 6m in size, made from 100 hand-painted transparent, 4-meter-high PVC panels that hang from the ceiling (figure 4). As people move through this "brain forest" they see abstract projection-mapped visuals that are displayed on layers of the transparent and painted PVC maze. The gallery walls are covered in reflective mirrored materials. The effect of the mirrored walls and the effect of the projection mapped maze creates a mesmerising, uncanny environment shaped by neural data, light projections, reflections and quadrophonic sound.

DREAM 2.2 also features a poem that is projected onto the front of the installation's bed (figure 5). The poem was displayed in English and Mandarin, as these are the main languages spoken by the museum's audience. The poem was written by performer 1 during the rehearsal phase. It is based on one of her dreams and it operates as a linguistic tool that may further assist audiences to immerse themselves in the otherworldly, dreamlike environment of the installation.

The DREAM 2.2 Performances

The DREAM 2.2 30-minute performance features two sleeping actors and two performers who are live mixing the neural data. The live mixing involves assigning visual and audio effects to the actors' neural data in real-time. This data is then projection mapped onto the exhibition's brain forest (figure 4). The data takes the form of abstract visualisations. The installation's audio consists of a 30-minute electronic music "foundation track". When the performers generate specific neural readings, new audio sounds are automatically triggered and layered over the foundation audio track. The triggered sounds are designed to be aesthetically compatible with the foundation track.

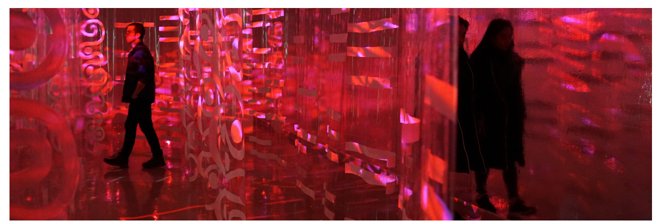

Figure 4: Audience members walking through the installation's projection mapped brain forest.

An extensive rehearsal period was conducted prior to the performances to ensure that the performers felt relaxed and comfortable whilst wearing the EEG equipment (figure 3). The performers wear eye masks to minimize light interference and wear ear plugs to help minimize sound intervention. Performer one did not always reach full sleep in every performance. She meditated, slowing her breath and focusing her mind;

Figure 5: A person lying down on the DREAM 2.2 bed whilst wearing an EEG headset.

she regularly produces neural signals similar to those commonly seen during early phases of sleep. Performer two reaches a sleep state within a couple of minutes of starting every rehearsal and performance.

The neural data is delivered via Bluetooth from the headsets to a third party non-proprietary app. The app divides the neural signals into five signal bands; Delta, Beta, Gamma, Alpha and Theta. During the first 5 minutes of performances we show the performers' Delta signals, for the next 10 minutes we show their Beta signals, for the next 10 minutes we show a combination of Theta, Alpha and Delta signals, and conclude by showing Delta signals. This cycle helps us form visuals from a range of different neural data and it provides dynamic audio-visual effects. This performance structure also offers a dramatic arc that builds towards an audio-visual intensity at the 25-minute point of the performance.

The DREAM 2.2 Participatory Installation

Outside of performance times, DREAM 2.2 operates as a participatory public installation. Audience members sit or lie down on the installation's bed (figure 5). Before interacting with the system each person is assisted in wiping their forehead with a disposable wet cloth. This removes any oils and residue from the skin and allows the EEG's sensors to form a reliable connection with their skin. One person at a time can use the EEG system. They are able to use it for approximately 5 minutes, if there is not a queue of people waiting, they can use the system for a longer timeframe.

We supply audiences with a tablet that shows graphs of their neural data. Many EEG interfaces display graphs that visually track the electrical activity that is occurring in the brain (figure 7). The five graphs on our display track changes in Alpha, Beta, Delta, Theta and Gamma neural signals. When no one is wearing the EEG, the graphs lines are flat. As soon as the EEG is placed onto someone's head the graphical lines move, displaying changes in neural activity. This provides audiences with a traditional scientific display of their neural data, and a clear indication that the headset is working.

The Technical Design of the Performances

The DREAM 2.2 installation runs on two computer systems. System one controls three projectors that visually map the front of the exhibition's brain forest; this system also controls the installation's audio. The audio runs using TouchDesigner in combination with Ableton Live. The second computer controls two projectors that produce lighting effects in the back sections of the installation and another projector that displays the installation's poem. The two computers are networked.

The EEG headsets connect, via Bluetooth, to an app running on separate tablet interfaces. The app uses Bluetooth to direct the data to TouchDesigner on computer system one. The data comes into the computer via networked OSC. During performances these signals are routed through a crossfader, this gives us control over which of the performers' neural signals are displayed on the installation. The cross fader can also be placed in the '0' position allowing both of the performers' neural signals to affect the installation's audio-visuals.

Figure 6: The artists live mixing the neural signals from the two sleeping actors during the DREAM 2.2 performances at the National Taiwan Museum of Fine Arts.

Technical Details of the Installation

The installation's visuals are constructed from 28 different pre-programmed visualisations that self-generate in real-time (figure 8). These visualisations are imaginative recreations of the artists' own dream states. The visualisations are automatically displayed, each one is projected onto the brain forest for just over one minute. The visualisations operate on a loop of real-time generative content that lasts for 30 minutes. The DREAM 2.2 projections are programmed so that neural activity automatically triggers changes in the colour, contrast, amplitude, shape and position of the visualisations.

Findings

We learnt that due to the personal nature of neural activity, there was a huge range in the effects that people had on the installation. For instance, the Theta data from one person may fluctuate quickly producing a dynamic visual effect, whereas another person may have a "flat" or low Theta signal that produces no change in the visuals. Therefore, we programmed each visualisation and sonification to respond to a range of neural signals, for example a visualisation may respond to a level of Delta as well Theta data. This ensures that each person's data produces perceptible changes in the audio-visuals.

Audiences can instantly experience the effects that their neural data has on the immersive environment. When people who are wearing the EEG headset begin to relax, they often observe instantaneous changes in the surrounding audio-visuals. For example, the visuals often became more still, moving slowly downwards so that the visuals illuminate the bottom sections of the brain forest; and the audio often becomes sparse. After observing these instantaneous changes to the installation aesthetics, people often become excited and responded with verbal exclamations. Their excitement stimulates their neural activity and that in turn makes the visuals more intensely coloured and more animated, and this excitement also generates more intense audio stimuli. Following this, audiences often experiment with their own methods of altering the audio-visuals.

We found that most audience members look at the tablet's graphical display of their neural data for a few seconds. Most audience members then turned their attention to the abstract creative visuals that are projected onto the brain forest. Audiences appear to focus on the projected visualisations for almost the entire time that they are engaged with the EEG system.

It is common for one person to wear the EEG headset whilst their friends or partner walks through the brain forest. People appear to actively enjoy the experience of being immersed in an environment that is being shaped by their friend/partner's neural function.

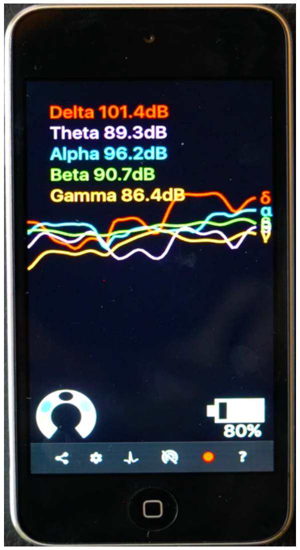

Figure 7: We provide our audiences with a tablet that shows graphs of their neural data. The data is divided into Alpha, Beta, Delta, Theta and Gamma signals.

We discovered that although the Muse headset is not a clinical grade EEG system it is a practical system for this type of installation setting. The headset is quick and easy for people to put on and creates an almost instantaneous connection between neural activity and the projected visuals (within approximately 2 seconds). However, the sensors on the Muse need regular cleaning and we replaced the headset during the installation, due to sensor failure. The headset is also mainly handled by a trained gallery attendant as it is not robust enough to withstand being regularly dropped or roughly handled by large numbers of people. We therefore would not recommend it for installations that do not have a gallery attendant available to assist audiences.

Discussion

This installation provided us with two main insights into the design of BCI systems:

1. *Designing BCI Displays that People Care About*

The DREAM 2.2 design allows audiences to alter the aesthetic qualities of an immersive audio-visual installation. They can use their neural activity to change the colour, speed, animation effects and the placement of the visuals. This provides them with a degree of personalisation. When compared with the visuals shown on the EEG's graphical display (figure 7), we offer more scope in the ways that audiences can alter and interact with the display of their neural data.

One of our previous studies [22] suggests that when participants interacted with a similar BCI system in a non-public setting they were interested in self-exploration. These participants reported the desire to freely explore the potentials of the "neurofeedback mechanics of the system" and some participants reported wanting to be able to "curate" their own experience [22]. A future DREAM 2.2 participant study may help us extend this existing research. Such a study may compare people's responses to traditional BCI graphical displays with the DREAM 2.2 audio-visual immersive display. The aim being to design personalised BCI displays so that people can feel a deeper, more bespoke connection to their neural data.

2. *Designing BCIs that Foster Interpersonal Connections*

The DREAM 2.2 design provides audiences with opportunities to explore an immersive environment that is being shaped by another person's neural activity. This may provide opportunities for new interpersonal connections to form. Our previous research into social interactions over shared mobile devices suggests that intergenerational audiences can gain a deeper connection to creative content, and deeper connection to each other when they experience the digital content whilst they are together [21]. A future DREAM 2.2 study may allow us to extend this prior research, helping us understand how immersive BCI experiences can help foster deeper interpersonal relationships. This is with the aim of designing technology that supports positive social engagement.

Conclusion

DREAM 2.2 is an immersive art installation that invites audiences to use their neural data to change and alter the installation's audio-visuals. Audiences can also explore the installation's maze and be immersed in audio-visuals that are being shaped by another person's neural data. DREAM 2.2 may help us further understand how to create alternatives to traditional, clinical BCI graphical displays and how this may create deeper, more personalised connections between people and their neural data. This case study may also help us design BCI experiences that may foster interpersonal connections. We recommend further studies that compare participant responses to traditional, clinical BCI displays with participant responses to immersive more personalised and aesthetically rich displays. We also recommend studies that investigate the potentials of BCIs to support positive interpersonal interactions.

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