Using Experimental Filmmaking to Create an Engaging Brain-Computer Interface

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Fig. 1. Story Block #7 of the developed BCI experience. (©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

Inspired by storytelling ideas in surrealist creative productions and experimental films, we created a brain-computer interface (BCI) designed to offer users an exercise of the imagination. While many previous BCIs have used simple visual interfaces, we wanted to understand if an open-ended, story-based BCI experience could be helpful for allowing users to effectively interact with the story using their brain activity. We employed experimental storytelling techniques to prompt users to explore new thought patterns and ideas for changing brain activity. In our BCI, users were able to change the color of the main character in the story using their thoughts. We found that many users were able to change brain activity and enjoyed the BCI experience, while others were primarily frustrated. Based on our results, we offer ideas for future contributions to the development of engaging, story-based BCI applications.

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1 INTRODUCTION

Drawn to the mysterious way in which emotions and cognitive processes translate to specific brain activity, we became interested in brain-computer interfaces (BCIs) as a unique way to self-regulate emotion. BCIs often provide users with the ability to practice neurofeedback training. During neurofeedback training, users can learn to change their brain activity by receiving positive feedback when brain activity meets certain criteria [Kelley et al. 2017]. Neurofeedback protocols within BCI experiences often consist of short training sessions for users and examine novel ways in which users can change brain activity. Although neurofeedback in BCI applications may offer new methods for users to gain control of their emotional and mental processes, visual interfaces in BCIs are often not engaging for users, perhaps because many have been limited in complexity.

With a background in filmmaking, we were motivated to create an entirely new kind of BCI experience which would offer users an exercise of the imagination. We drew upon concepts identified within surrealism and avant-garde films concerning stylization, nonlinear temporality, and themes of memory to develop our BCI narrative. To inspire users with unique thought strategies for brain activity interaction, we created an experimental story BCI which allowed for multiple interpretations. We hypothesized that our BCI might be engaging for users as its visuals provided a narrative open to interpretation. Understanding how users experience new kinds of BCIs may not only inform design guidelines for enjoyable BCIs, but may help to understand how different kinds of users can effectively engage with brain activity interaction.

2 BACKGROUND: BRAIN-COMPUTER INTERFACES AND STORYTELLING

Neuro Art, also called Brain Art, dates back to the 1950s and 60s, when artists such as Alvin Lucier first used brain activity to produce music during a live performance [Straebel and Thoben 2014], and William Grey Walter explored neurofeedback by representing brain activity visually [Gingrich and Rahman 2022; Walter and Shipton 1951]. More recently, artists such as Mori [Mori 2003] and Abramovic [Abramovic et al. 2011] have explored brain activity across more than one person through various art installations. Throughout the years, artists in Neuro Art have explored brain activity for use in creative expression, as well as neuroscience education for the general public [Gingrich and Rahman 2022], and have contributed to BCI research via real-life BCI applications [Zioga et al. 2018]. Here, we focus on neurofeedback-based BCIs whose primary goal was to allow users to change brain activity.

Previous BCI environments have involved simple visual feedback such as status bars, shapes, and objects, and many have been limited in visual complexity [Kerous et al. 2018]. However, previous research has suggested that the imaginative properties of more complex neurofeedback environments have significantly contributed to user success in learning to control brain activity [Gruzelier et al. 2010]. Several studies have investigated increased complexity through the development of story-based BCI environments. For example, Aranyi et al. [Aranyi et al. 2015] explored anger expression in their BCI, and found that users could effectively change brain activity when prompted with an anger-inducing narrative. Additionally, Cavazza et al. [Cavazza et al. 2014] directed users to express positive thoughts towards an overworked character in their narrative environment, allowing users to change brain activity through feelings of empathy evoked by their story.

Work by Jensen et al. [Jensen et al. 2013] suggests exploring combinations of components in neurofeedback applications which may stimulate the imagination of the user. Because avant-garde and surrealist works typically provide viewers with novel psychological experiences, it is said that viewing such works necessitates "creative leaps of the imagination" [Taberham 2018]. Therefore, our experimental story BCI was developed with the goal of allowing users to explore new thought strategies for changing brain activity.

3 DESIGN

3.1 Experimental Story Implementation

To develop an experimental story, we considered concepts which often arise in early avant-garde and experimental film works. *Meshes of the Afternoon* (1943), by Maya Deren, informed the dream-like, subconscious story world of our BCI, while elements of surrealism presented in *Un Chien Andalou*, written by Luis Buñuel and Salvador Dalí (1929), inspired the mystery and ambiguous meaning of our developed story. Our narrative was designed as a sequence of abstracted memories [Laxton 2019] in the form of eight distinct 30-second Story Blocks. Story Blocks consisted of slow-moving, textured backgrounds which were developed using live action footage of plants, shadows, reflections on water, and household textures such as wood and carpet.

In each Story Block, two characters were present and animated in slow motion. The secondary character was placed in positions of power to suggest dominance and control over the main character. In the first Story Block, the man watches the girl through a window, although she is unable to see him. In the second Story Block, he controls her movements as though she were a puppet. A shader program available on the Unity asset store was used to make the appearance of the secondary character dark, wispy, and water-like in its movements in order to further enhance the dream-like nature of the environment. In initial testing phases of our BCI design, user feedback suggested that the mood of the environment was appropriately dark to motivate interest in the main character's situation, but was not so negative as to be distressing.

Spatial logic was disrupted by positioning household items in illogical locations relative to the characters in order to create a sense of surreality [Taberham 2018] as shown in Fig. 2. Objects within the environment were made highly transparent to suggest their transience or imaginary nature, such as the door shown in Fig. 3. Following standard filmmaking techniques such as the rule of thirds to direct viewer's attention through shot composition, the main character was placed in the foreground, while contextual objects and the secondary character were often placed in the background.

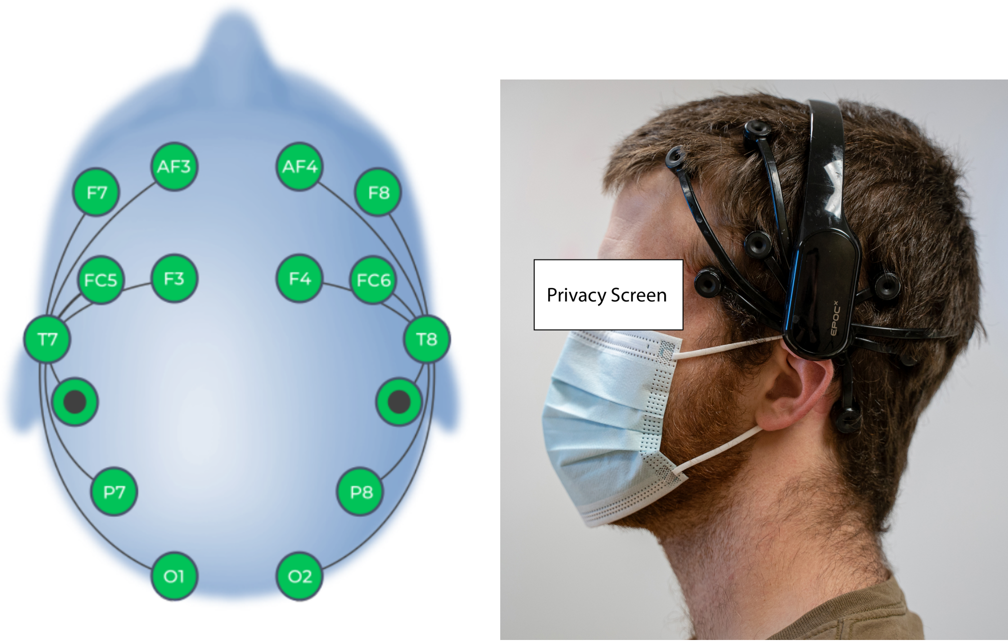
3.2 Brain Activity Measurement and Interaction

We concentrated on frontal alpha asymmetry (FAA) within our BCI. FAA measures the difference between right and left prefrontal cortical activity. Greater left relative to right prefrontal cortical activity has been associated with reduced depression symptoms [Kelley et al. 2017] and better ability to regulate emotional responses [Cohen et al. 2016]. Therefore, BCI applications have operationalized FAA to investigate new opportunities for emotion regulation. Users wore the Emotiv Epoc X Electroencephalography (EEG) headset. Fig. 4a shows the electrode placements on the head, while a user wearing the EEG headset is shown in Fig. 4b. The user's brain activity was linearly mapped to the main character's color saturation values, which served as visual feedback

Fig. 2. Lack of spatial logic present in Story Block #3. (©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

Fig. 3. Main character in the lower third, foreground of Story Block #5 composition. (©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

for the user. Therefore, the main character's color saturation increased when brain activity reached a predetermined threshold for FAA values.



(a) Electrodes (b) EEG headset

Fig. 4. (a) Electrode placements. (©Emotiv Inc, 2022), (b) a user wearing the Emotiv Epoc X EEG headset. (©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

Each of the eight Story Blocks consisted of one *View* and one *Engage* component. During each *View* component, users counted backwards silently while viewing the Story Block. During *Engage*, users could try to change their brain activity using their thoughts, and could see the main character's color saturation change. Fig. 5 shows all components of one Story Block.

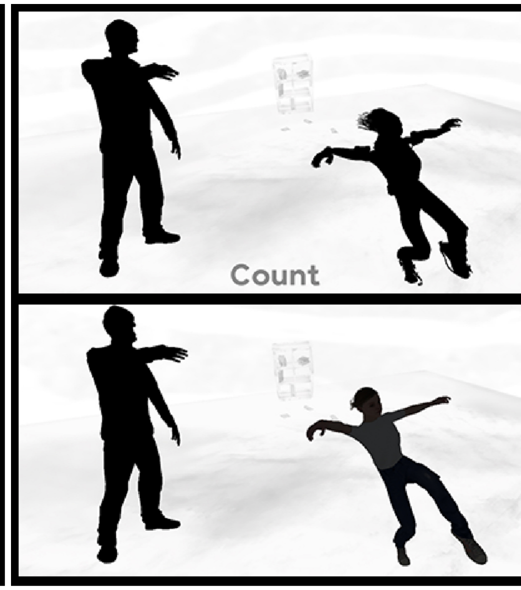
FAA values from each *View* and corresponding *Engage* component were compared to understand user brain activity interaction success within each Story Block pair. Two Story Blocks showing their *View* and *Engage* components are presented in Fig. 6.

Fig. 5. One Story Block in the BCI. Components include *Rest*, *Prompt*, *View*, *Prompt*, and *Engage*.One Story Block in the BCI. Components include *Rest*, *Prompt*, *View*, *Prompt*, and *Engage*. (©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

3.3 Imagination-Based Instructions

Users were provided with imagination-based instructions to promote thought strategies for successful brain activity interaction. Provided below, our instructions were designed to direct users

(a) Story Block #1



(b) Story Block #2

Fig. 6. *View* and *Engage* components of (a) Story Block #1 and (b) Story Block #2. *View* is directly above *Engage* in both Story Blocks. Story Block #1 *Engage* indicates greater brain activity interaction success than Story Block #2 *Engage*, as the main character reaches greater color saturation. (©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

towards imaginative thinking, ideas and feelings which might work for them in changing brain activity, while maintaining the often unconstrained nature of BCI instructions [Aranyi et al. 2016]:

> *In the experiment, you will observe the girl in her dream. Your goal is to help her escape from her dream. During Engage components, you may think about new objects, sensations, ideas and possibilities, or new interpretations of the story, which may help the girl escape from this dream environment. You may imagine interacting with the girl. You may try using positive thoughts. You may explore other strategies for changing the main character's color as well.*

3.4 User Experience

We invited students at our university to experience the developed BCI. A group of 19 users participated in our final iteration of the design. A user viewing the BCI on a large screen can be seen in Fig. 7. On our questionnaire, we provided several prompts with visual sliders which corresponded to 8-point Likert scales. We took one-item measurements of Enjoyment [Stevens et al. 2000], Frustration [Hart 2006], Flow [Jackson and Marsh 1996], and Mental Demand [Hart 2006], which are shown in Table 1. Using the scale developed by Weibel et al. [Weibel et al. 2018], we measured the user's level of Fantasy, which incorporates aspects of both Creative Fantasy, defined as "the activity of using fantasy to create new ideas," and Imaginative Fantasy, defined as "vivid imagination and absorption in these images and daydreams." Considering that our BCI presented a rather abstract narrative, we wanted to understand if Fantasy corresponded with the user's BCI experience as well.

Fig. 7. A user experiencing the BCI.(©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

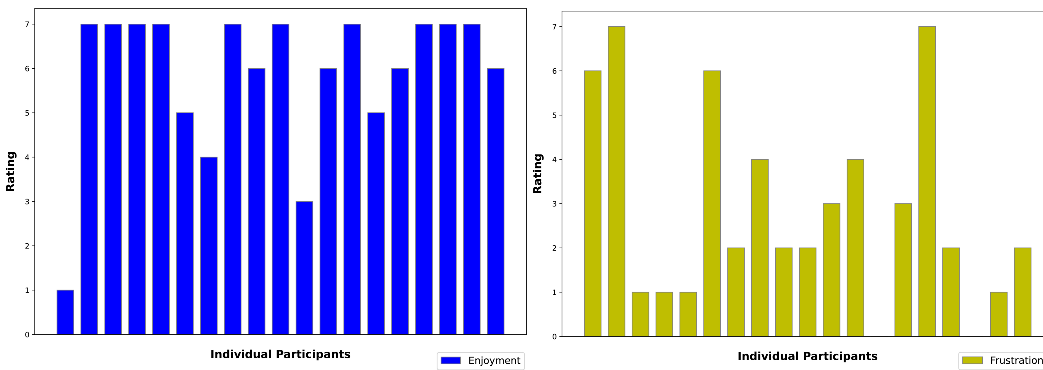
Table 1. Primary questionnaire.

Item	Variable	Avg. Score	SD
I thought the experience was really interesting.	Enjoyment [Stevens et al. 2000]	5.89	1.66
How insecure, discouraged, irritated, stressed, and annoyed were you?	Frustration [Hart 2006]	2.84	2.24
My attention was focused entirely on what I was doing.	Flow [Jackson and Marsh 1996]	5.26	1.73
How mentally demanding was the task?	Mental Demand [Hart 2006]	4.74	1.59

Lastly, we provided a space for users to discuss their interpretations of the story environment and describe thought strategies they used during the experience. After the EEG headset was removed, users filled out the questionnaire using our university's survey system. If the user had any questions about their experience, the researcher discussed these with the user at this time. Users consisted of five female and twelve male students between 18-22 years old.

4 RESULTS

Results indicate that multiple users were able to successfully increase FAA during the BCI experience. Most users (89%) reported that the experience was enjoyable and many (79%) reported high levels of flow. While a majority of users (also 79%) reported that trying to change their brain activity required a large amount of mental demand, only a few users (33%) indicated frustration with the experience. Fig. 8a shows the distribution of responses concerning Enjoyment, while Fig. 8b shows responses concerning Frustration.



(a) Enjoyment (b) Frustration

Fig. 8. For each of the 19 users, (a) the self-reported rating for Enjoyment and (b) the self-reported rating for Frustration.(©Claudia Krogmeier, Esteban Garcia Bravo and Christos Mousas, 2023)

Many users spoke at length with the researcher to ask about the meaning of the BCI story, strategies other users had tried, and how their brain activity was input into the BCI system. Despite high ratings of mental demand concerning brain activity interaction, these conversations support our questionnaire responses which indicate enjoyment was high. Users were interested in learning more about their performance as well, and several asked the researcher if they could have their brain activity data. However, a few users expressed frustration with the BCI experience. These users primarily stated that changing the main character's color was difficult, or that the story had no meaning.

4.1 Strategy Type

We also wanted to understand how user strategies may have influenced brain activity. Therefore, we divided strategy types reported on the questionnaire into two groups: *Direct* and *Indirect*, as in work by Aranyi et al. [Aranyi et al. 2016]. *Direct* strategies included thoughts which involved an active engagement with the story, such as "*speaking with [the main character] using my thoughts.*" *Indirect* strategies included thoughts which were internally focused, such as thinking about "*something that makes me happy, like... my friends.*" We determined a significant correlation between Fantasy and Strategy Type $r(19) = .462$, $p = .023$, which suggests that users with higher Fantasy may be more likely to use a *Direct* strategy. Table 2 shows questionnaire items and descriptive statistics for Fantasy.

4.2 Story Interpretation

Considering that user Fantasy may have played a role in choice of strategy, we questioned specifically if the way in which users interpreted the story was influential in allowing them to successfully change brain activity. To test our assumption, we categorized story interpretations as either *Speculative* or *Closed*. *Speculative* interpretations consisted of new ideas and meanings for the story which were not provided to users by the researcher, such as "*the girl saw an armed robber inside her room.*" *Closed* interpretations did not include an interpretation of the story, such as "*a bunch of*

Table 2. Self-reported Fantasy ratings.

Question	Avg. Score	SD	Min	Max
Sometimes I remain apprehensive or fearful long after watching a scary movie.	3.00	2.52	0.00	7.00
Sometimes I become so involved in a daydream that I'm not aware of things happening around me.	3.95	2.37	0.00	7.00
Many of my fantasies are often just as lively as a good movie.	4.37	2.01	1.00	7.00
Many of my fantasies have a realistic intensity.	4.05	2.09	1.00	7.00
My daydreams are often stimulating and rewarding.	4.11	2.13	1.00	7.00
I am the kind of person whose thoughts often wander.	4.68	2.08	1.00	7.00
I am a creative person.	3.79	1.90	0.00	7.00
I have many ideas that are unusual and novel.	3.84	1.64	0.00	7.00

moving images." Results suggest that a majority of both successful and unsuccessful users reported *Speculative* interpretations. Although we determined no significant correlation between story interpretation and successful brain activity interaction, $r(19) = .224, p = .178$, we found that the user who had the most success in changing brain activity also provided the most detailed *Speculative* story interpretation:

> "*I [interpreted] the story in a bit of a darker tone. I saw the story arc of a child in an abusive household with a father who had lost his wife and was unsuccessfully dealing with the grief. It was rather dark in my head, but that was the way it needed to be so I could help envision saving the girl.*"

5 DISCUSSION AND NEW DIRECTIONS

Using ideas from experimental filmmaking, we created a BCI designed to motivate users to seek novel thought strategies for brain activity regulation. Our results suggest that this BCI experience may help some users increase FAA, but factors such as the user's Fantasy may also play a role concerning choice of strategy. Considering the detailed story interpretation of the most successful user as discussed in Section 4.2, the relationship between story interpretation and brain activity interaction could be examined in future work to better understand the role of user traits and preferences. It would be important to include a larger, more diverse group of users as well in the future.

Although a certain level of ambiguity in art and aesthetic experiences can be considered interesting [Jakesch and Leder 2009], it is likely that the ambiguous nature of our story was more frustrating than enjoyable for some users. Is there an optimal level of story ambiguity for both enjoyment and brain activity interaction success? Additionally, how might user preference and affective style mediate enjoyment for varying levels of story ambiguity? To better understand factors which contribute to the enjoyment of a BCI experience, our work could be expanded to examine BCI narratives along a spectrum of story ambiguity. Investigating story parameters such as Story Block order, character realism, and animation speed could be explored to understand the role of specific story design choices in user engagement as well. In a second iteration of the design, we would like to consider creative elements found within BCI games, as well as performative aspects of neuro artworks in the development of the abstract story environment.

With continued combinations of neuroscience and artistic approaches in BCI research, we think BCI experiences which are both enjoyable and effective in guiding users towards successful brain activity interaction are possible. Collaborations between writers, filmmakers and researchers may open new doors for understanding how experimental story-based BCIs can inform creative practices for emotion regulation.

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