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# *State.Scape*: a brain as an experience generator

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## Abstract

***State.Scape* is an interactive installation in which audio-visuals are generated from users affective states (engagement, excitement, and meditation). The installation relies on a brain-computer interface based virtual environment and sonification, which both served as a platform for the exploration of users' affective states. In this paper, we describe the aims, the system design, and the procedure for interacting with the artifacts and present the user experience gathered during interviews with the participants. Furthermore, we discuss the impact that this environment has on future real-world applications in altering affective states and its potential in meditation practice.**

## Keywords

EEG, brain-computer interfaces (BCI), Neurofeedback Art, Virtual Environment, Installation, Affective States, Emotiv EPOC.

## Introduction

The attention that brain-computer interfaces (BCI) and biosensors gained in past 10 years steered the development and application of these devices from medical fields towards art and entertainment. Availability of these devices on the market and their recent price decrease encouraged more artists to explore their potential in art applications. Artists, driven by the fascination with the brain and human cognition, are using biometric technological advances in their explorations of art generated by neurofeedback. Unlike other art forms, art generated by data from human brain activity connects the audience member and the art piece on a meta level in which the user's[1] internal affective states and neural activity become an integral part of the piece itself. However, most of these artistic explorations, to our knowledge, seem to stay at the level of mere explorations, without clearly identified goals in regard to the experience, or the exploration process itself.

In this paper, we present *State.Scape*, an artistic exploration of users' affective states in a virtual environment. Affective computing, as an interdisciplinary field is clearing its path towards application in various systems and designs that will allow us to understand and simulate human affect (Picard 1997). This piece takes a form of an audiovisual interactive installation, generated from participants' affective states collected from a brain activity. What we are interested in our work is to find the answer to: Are the users able to make the connection between changes in their brainwaves and the changes in the installation, if they are not given any instruction on how to use the system? This installation is a first step toward a deeper exploration of how inner states could be mapped in virtual space, what the meanings of those mappings are and how these changes are perceived by a user interacting with the system.

## Background and Related Work

The first use of brainwaves in art was not until 1965 when the scientist Edwin Dewan introduced Alvin Lucier to brainwave recording. This collaboration resulted in "Music for Solo Performer" (Straebel and Thoben 2014), a piece in which Lucier sonified his brainwaves in real-time on the stage, with the help of John Cage. Although some argue that Grey Walter was the pioneer in brainwaves sonification for performing his "Cerebral Music" in 1961 during a radio interview, there is no recorded evidence to support this claim (Luciana Haill 2014).

Since 1965, artists have been using brainwaves to generate art through various outputs, with the majority working on sonifications of the brainwaves. Some artists are creating more directed performances such as Eduardo Miranda's "Activating Memory" (Miranda 2014) in which each member of a Brain Computer Music Interface (BCMI) quartet was presented with four musical scores on the screen. By gazing at one of the scores for short period of time, the BCMI member was able to select the score that was then sent to the assigned member in the string quartet to perform. On the other side are pieces that are more exploratory and less structured, and in most cases focused on meditation practice and self-reflection. A piece that is representative of this type of works is George Khuts "Theta Lab" (Khut 2014), in which three participants are lying on bed-like pods while exploring their mental states through the sonification of their brainwaves.

After sonifications, the second most mapped by the artists are audio-visuals generated from brain activity. Most of these pieces, to our knowledge, are processing a data stream in real time. Along with the EEG [2] signal, some artists are using

[1] an audience member whose data is collected in the piece

[2] Electroencephalography - the recording of the electrical activity

other bio-data inputs such as galvanic skin response (for measuring stress levels, heart beat rate, breathing rate, etc. For instance, “The Auratic Body” (Dunning, Woodrow, and Hollenberg 2004) falls under a category of multiple input modalities as EEG and GSR data are combined to generate audio and visuals. BCI based audio - visual installations can differ in number of their users, differentiating between single and multi-user pieces. In Mariko Mori‘s “UFO wave” (Mori 1999), three users were positioned supinely in a egg-shape sculpture while the audio and visuals are generated by their neural activity. We can divide BCI installations into passive or active installations in regard to users’ interaction. Active is when users are performing task orientated activities, with pre-determined instructions of how the installation elements work. This approach requires calibration for each user and it is mainly used in BCI games in which users employ their brainwaves to make active choices in navigating through the environment or manipulating the objects. In contrast, more exploratory artworks tend to have a passive approach in which brainwaves and their patterns are mapped to certain events or changes in the installation without a specific task to perform.

Figure 1: Virtual Environment: the detail: a flock of birds

## *State.Scape*: Concept and System Description

The name *State.Scape* comes from the desire to make possible an escape from certain affective states (anxiety, stress, excitement, boredom, etc.) that might have negative or unpleasant impact on us. The concept is inspired by the saying that “you can not escape your skin” which is always related to unpleasant personal feelings and emotions. Even though we cannot escape from our skin, we can escape from our mental states by transforming them. *State.Scape*, designed for a personal and intimate experience, allowing its users to access the representation and explore their inner states through the virtual environment and sonification generated from those states.

As a symbol of states, we elected to use the visual metaphor of birds (see Figure 1). The symbol of flocking birds reminded us of the generation of emotions; the overwhelming feelings that tag along with anxiety, excitement, or stress. As birds are free to fly anywhere, we wanted to let people comfort themselves by letting those birds/thoughts fly freely through the virtual environment. The idea is to map users’ inner states to the birds’ behavior. Therefore, our virtual environment consists of the flock of birds accompanied with a soundscape, with both being responsive to fluctuations in users affective states.

Like the projects described in the Background and Related work section, *State.Scape* is using real-time EEG data as a mono input and utilizes it in an art context. This work diverges from similar projects in that the sonification was not generated by changes in the virtual environment. Both of these elements, the sonification and the virtual environment were mapped to changes in affective states. The decision to design this piece as a single-user comes from the observation that the presence of others can influence and change the affective state of the user, as well as affect the interaction with the piece. Therefore, we wanted to create an intimate individual experience of exploration. Unlike other pieces that instruct users how to use the artworks, the lack of instruction in our piece was intentional. We wanted users to find their own way of interacting with the installation and experiencing the audio-visual artifacts.

As shown in (Figure 2), the installation consists of a PC running 3D computer-simulated virtual environment (made in Unity 3D) and sonification, a short throw video projector (BenQ W1080ST) and stereo speakers placed in a dark room. Input was provided by a consumer-level EEG system (Emotiv EPOC) with a Bluetooth connection to a PC with installed Emotiv Affective Suite for real-time affect recognition.

**Electroencephalography (EEG) Data Acquisition** Nowadays BCI devices differ in a number and quality of built-in sensors, hence not all of them can obtain the same spatial and temporal precision in EEG readings. Devices with fewer sensors, depending on where the sensors are placed, are in most cases focusing on only one affective state (such as meditation, for example). Generally, sensors are placed following ”10-20 International System of Electrode Placement” (Silva and Niedermeyer 2012) developed by Dr. Herbert Jasper in the 1950’s.

EEG signal obtained from the scalp falls under frequency range from 0.5 to 30 Hz. Following the guidelines provided by the International Federation of Electrophysiology and Clinical Neurophysiology (Steriade et al. 1990) all rhythmic activities can be sorted into one of six bands. The brainwave activity can tell us about the current state of the user: Delta (0.5 - 4 Hz) shows that the user is experiencing fatigue, is sleeping or his mental processes are severely slowing; Theta (4 - 7 Hz) is associated with meditation and slowed processes; Alpha (8 - 14 Hz) reveals that the user is in relaxation; Low Beta (15 - 20 Hz) shows intense focus; Medium Beta (20 - 30 Hz) is associated with anxiety; Fast Beta (called Gamma, over 30 Hz) shows hyper-alertness and stress. This knowledge of the relation between states and brainwave activity can be used as a guidance for analyzing particular user

produced by the brain

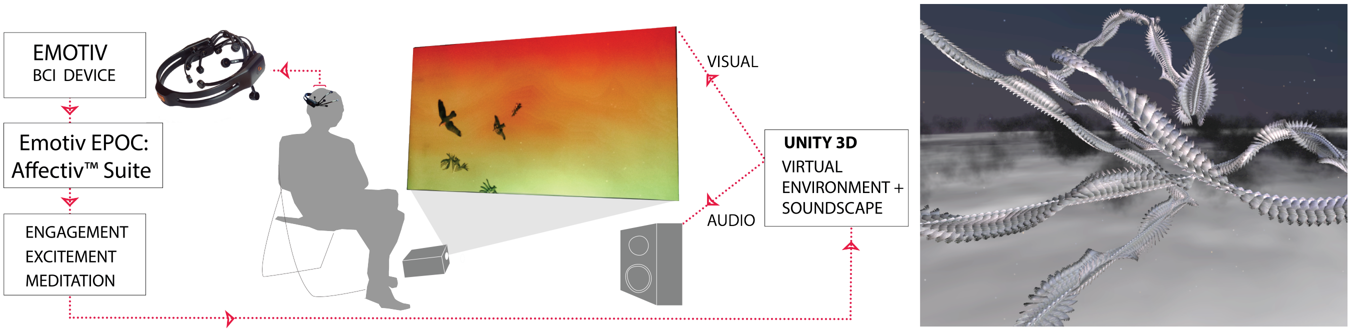


Figure 2: *State.Scape*: system parts (left). The capture of the last scene - a bird glitching (right)

experience.

**Emotiv Affective Suite** Regarding EEG data acquisition we used Emotive Epoc. This device has 14 EEG channels. Instead of using raw EEG readings (levels of alpha, beta,etc.), we directly used derived affective scores provided by Emotivs Affective Suite (levels of excitement, engagement and meditation). We calibrated the system for each user in order to track changes even if those were small on an absolute scale. To do so, we tracked running minima and maxima for each of the parameters, which allowed us to scale the parameters of the model properly for each new user. For example, if a user's meditation score remained almost constant for the duration of the participation, the system would keep track of this, and make it so that even minor changes in the EEG readings would produce visible responses.

## Virtual Model and Mapping

The virtual environment consisted of a flock of birds and environmental background that were purpose-designed using the Unity3D SDK. The birds followed a randomly determined path. We achieved this by mapping birds to follow an invisible pivot point that was randomly positioned in our model. We used three states provided in Emotiv Affective Suite: meditation, engagement and excitement to control the other parameters of the flock. Changes in affective states controlled the flock's position, the birds' speed and the number of birds. The level of the excitement was mapped to control the number of birds. The session would start with only one bird in the scene, but as the user gets more excited, more birds appear in the flock. Similarly, as the excitement level drops, the birds vanish from the scene accordingly. The meditation score controlled the speed of the birds, with more meditative states resulting in slower bird movement. Furthermore, if the user is in a meditative state, her/his excitement levels are low which visually equates to less birds in the flock. The engagement level controlled the height of the flock. The more engaged the user is in the scene the birds would fly higher in the sky.

Apart from controlling the flock properties, affective states were mapped to control the volumes of different audio tracks. The sound aspect to the model, similarly, consisted of three tracks: a deep droning bass track, a mid-high frequency instrumental track and a percussive ambient effect track. The selection of tracks was not determined by rigid criteria in regard to states but it was more of an artistic expression. All three tracks played in a synchronized way, with the volume of each being mapped to a different Emotiv state metric. The bass track's volume was tied to the level of the meditative component; the instrumental track was mapped to engagement, and the percussive effects were mapped to the excitement metric. This way, the spectral qualities of the soundscape constantly changed, reflecting the user's current EEG state through sonification.

Each session consisted of three camera views, each lasting 90 seconds. The first camera view was positioned outside of the flock, capturing the environment (the cloudy sky) and partially the flock as it moves across the scene. In this initial scene, we wanted the user to stay out of the flock in order to become familiarized. In the second scene, the camera was inside the flock, capturing the movement of the flock. By changing the position of the camera, we put the user in the middle of the scene, in order to make her/him part of it. This is the stage where we are symbolically allowing the user to relate to the birds and let inner states fly freely. The third camera was positioned above the flock. This is a closure scene in which user is getting ready to leave the experience and get back to the physical world. In the last scene, only one bird is flying across the model. Then a glitch occurs, and the bird leaves an abstract path made of its contours as it moves across the screen (see Figure 2 (right)). This glitch is a sign to the user that it is time to get back to the physical world, as the screen gets filled with abstract shapes.

## Procedure

One user at a time enters a dark room and sits on a chair facing the projection screen. The facilitator restarts the Emotive Affective Suite a priori, and places the Emotiv EPOC Headset on the participant's head. As soon as all the sensors are in the place and connected, the facilitator simply asks the user to explore the system and leaves the room. After five minutes long session, the facilitator enters the room and helps the user to remove the device. After the session, users complete an exit interview.

## *State.Scape*: User Experience

*State.Scape* was exhibited in April 2014 at the Medium: Play (Installation Art and Contemporary Digital Practices showcase), organized by the Centre for Digital Media in Vancouver, Canada. The users were simply asked to ”explore the system” without any further explanation of how the system works and what exactly they were controlling. Obtained qualitative data demonstrate the distinct connection between changes in birds' behavior and changes in users' mental states. Some of the users assigned meditative qualities to the installation. These users who were exploring meditation during the session reported high levels of control over the system which directly affected their degree of immersion in the environment. Few users reported high level of arousal. This can be due to the anticipation of what is coming the next and what they are supposed to do, caused by the lack of given instructions to the users. Their relaxation, as they described, was interrupted by the curiosity and engagement in understanding how the system was controlled. Additionally, the level of immersion was high, and most of the users found their way to release and explore their inner states.

In addition, we wanted to find out whether users were able to see the difference in VE that was generated by the brainwaves and VE that was generated by random numbers. To do so, we randomly assigned users to two groups, both wearing Emotiv headset, with the only difference that one of these two groups was exposed to the VE that was generated from random numbers. Our post-interview showed that users in ”random” group were able to tell that system is behaving independently and that they have little or no control over it. The majority felt that they did not influence the system. However, this was a pilot study and the sample size of users will be expanded in further studies in order to draw stronger conclusions.

Overall, data from the exit interview demonstrated that participants felt calm and more relaxed after the session. The anxious feelings occurred to a few participants as they worried about their brain data being collected. This can be prevented in the future by letting users know about what system can and what cannot do in terms of collecting data.

## Conclusion and Future Work

The authors' intention behind the *State.Scape* was to create an exploratory system in form of an installation, in which users will reveal and explore their affective states upon the virtual model. We did not aim to create pleasant nor unpleasant experience. We were curious to know what is the overall experience of the users while interacting with the system.

We recognized the potential of designing effective BCI supported interactive environments in the future. From the overall quality standpoint, the results show the potential of this installation in creating immersive, enjoyable environments that will evoke pleasure and arousal. One of the participants expressed his opinion about this installation by saying that the experience was “calculated sense of complexity being somewhere within a curated elegance”.

Insights gained from the interviews will help guide the development towards our long-term goal of creating an interactive installation that not only reads user's states but creates a feedback loop between the user's state (assessed, e.g., via EEG) and the perceived environment. Such system will allow us to shift the user's emotional state in the direction that the user desires (e.g., more relaxed or more engaged states). To this end, we will research how to migrate from virtual to physical spaces, and investigate which aspects of a physical/virtual environment are most effective in steering the emotional state in the desired direction. We are aware of the length of the road that we are taking in pursuing our goal, and we are hoping that with this study and future research we are getting closer to the design of the user personalized experiences.

## Authors' Biographies

Mirjana Prpa is a PhD candidate at the School of Interactive Arts  Technology (SIAT) at SFU, and a virtual realty enthusiast. She received a Master Degree in architecture from the University of Novi Sad, Serbia, and has worked mainly on ephemeral designs for performance art projects including projects for theaters and open public spaces. Her current research is in user personalized environments that are created based on user's emotional states.

Bernhard E.Riecke is an assistant professor at SIAT,SFU and associate member of the SFU cognitive Science Program. He is one of the leading experts on self-motion illusion and its implementation in immersive Virtual Reality, regard to natural embodied spatial perception, cognition, and behavior. Rieckes scholarship is exemplified by more than 70 peer reviewed papers/book chapters, including four best paper awards (ACM  IEEE conferences).

Svetozar Miucin is a PhD student in the School of Computing Science at Simon Fraser University. Aside from his main research path, which is currently oriented to improving memory behaviour of complex software systems, he is interested in the places where computing science meets areas like interactive arts, neuroscience and social studies.

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