RemBRAINdt

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Contents

Description of device work principles and novelty of approaches application

Our device automatically generates dynamic art guided by the emotional and mental state of the user. It is built using the 16 channel Ultracortex Mark IV research grade EEG headset from OpenBCI, along with an original data interpreter program and user interface. The raw EEG data is collected by the headset from the user with 16 dry electrodes, and sent to a computer wirelessly over Bluetooth at a sampling rate of 250 Hz.

Our data interpreter program is written in Python and uses a custom made PyQt5 graphical user interface. Incoming EEG data is preprocessed live with averaging and bandpass filtering, then we extract basic bandwidth (alpha, beta, delta, theta) features and use a machine learning algorithm to extract salient higher-order brain features such as emotional state. Temporal fidelity is ensured through integration with PyLSL.

Before generating the art, a personalized baseline measurement is taken for a minimum of 2 minutes. During baseline recording, we use PsychoPy to present emotional stimuli to the user, which consists of words with positive, negative, or neutral emotional valence presented in random order at a rate of 1 word every 3.5 seconds. The resulting baseline data is used to train our machine learning algorithm to identify the emotional states of the user.

Once extracted from the live EEG data, alpha, beta, delta and theta wave input can each be assigned by the user to influence different aspects of the art generation. Dynamic art is then created on-screen by our art generation algorithm which is being continuously updated with EEG feature input. Everything is conveniently controlled through our graphical user interface.

Personalized art generation based on the emotional state of the user and interpreted by machine learning, with the dual application of visually displaying an emotional state, is to our knowledge a novel application of BCI technology.

Potential application areas

Our software was mainly intended as an entertainment application for the public, to be used with open-source electroencephalogram (EEG) devices such as OpenBCI or the Muse. This use case may be important for mental well-being and self-care, but artful visualization of EEG data could also potentially make tangible contributions in education and research/clinical settings.

Neuroscience is often viewed as a complex and difficult topic, especially for young students who have little to no basic knowledge of neuroscience. Nonetheless, there is evidence that early education in neuroscience can improve understanding of human biology (Marshall & Comalli, 2012), and educating patients about neuroscience seems to help with managing pain (Louw et al., 2015). Different methods to improve neuroscience education have been explored (MacNabb, 2000; MacNabb, 2006), but the current curricula do not incorporate those methods nor experiment with different means of learning. Our software is easily accessible by educators with minimal resources because it is open-source and can be operated with simple devices such as the Muse. As such, our software provides an opportunity for educators with an experimental nature to demonstrate some basic principles of neuroscience to the lay public in a visually compelling way, which may be able to improve both attentiveness and retention.

EEG analysis is still actively studied by researchers, often with focus on the visual properties of the data especially in clinical settings. Those studies experiment with using more and more complex computations to unravel the mysteries of the brain from EEG data, such as machine learning (Yao, Plested & Gedeon, 2018). However, what if the simpler images of our software could also tell as much about the user's brain as those complex methods? Even though our images are currently pseudo-randomly generated and are not able to represent the full complexity of the brain, some properties of the generated images could potentially visualize underlying cognitive processes or point toward specific conditions and disorders. As such, there is potential that those simple images could be used for clinical uses, with tweaks and fixes to the program that allows visualization of more properties of the EEG data. The simple nature of our images could potentially shorten the time it takes for therapists and clinicians to identify and diagnose conditions, while making the process less costly, simpler, and more accessible to the public. Our novel way of visualizing EEG poses research questions that could improve EEG analysis, which contributes greatly to the basic science of the human brain as well as clinical diagnoses.

At this current state of our software, it will require a lot of work to be able to apply it to different fields in meaningful ways. However, it promises interesting opportunities within the field of neuroscience and other associated fields, which could become reality with time and resources.

Technological restrictions of usage

Regarding restrictions of our project in a purely commercial and accessibility standpoint related to the technology that we utilized, we recognize that our access to an openBCI allows us to gather relatively precise information regarding alpha, beta, delta, and theta. This accuracy allows us to have a degree of specificity when it comes to the generation of an individual's art. That said, the headset itself may not be accessible to all and would not be nearly as portable as other more commercially available devices such as a Muse headband if considering the implications regarding ease of access in using the app. However, we believe that because of the multitude of features that a user can pick and choose, it would not be in the best interest of the application itself to sacrifice accuracy. It should be noted as well that, though our project was done and tested solely on an openBCI, utilization of a Muse headband should not prompt any major complications aside from a decrease in accuracy of measurements.

Further, compatibility of the app is currently limited to Windows Operating System and Macintosh OS. Though we have not given much thought into making our app into one accessible through an individual's smart phone at this stage, it is something that we can potentially consider pursuing in the future. As for now, insurance of functionality of the core app is our primary concern first and foremost. Implementation of the app to Android or iOS will likely require additional testing as well as a reconfiguration of the GUI to suit the mobile devices.

Finally, all measurements recorded are based on a baseline that the user provides through a baseline task. This step is crucial for calibration as it is near impossible to use one universal baseline amongst all users of the app, let alone be able to ascertain the emotional state required for personalization of the user's art work. Due to this, it is important that the user themselves successfully and correctly measures their baseline for optimal functioning of the app.

Competitive advantages compared to known analogues

Art of Zen (iOS App)**:** the app uses a commercial electroencephalogram to measure the strength of a user's meditative state, translating to an abstract visualization which provides feedback to the user during their practice. While Art of Zen is meant to be auxiliary to a meditative practice, our tool can appeal to a broader audience of anyone interested in creating interesting art pieces, perhaps to be used as backgrounds or wallpapers.

Further, the art generated by the app is organized into a circle, with colours dependent on a measure of relative meditative strength scaled from 1-100. In this sense, there is little flexibility in the pieces that users can generate. Meanwhile, our tool can create art based on high-level (relative emotions) and low-level (frequency band power) features, which can then modify several different parameters in the image, offering users a truly individualized experience.

The Art of Memory (Random Quark)**:** the tool allows users to visualize their current emotions through generated EEG art, gauging emotions based on relative activity in different hemispheres of the brain, assuming a “lateralization of emotion”. It has generated truly beautiful pieces, with some displayed in a London gallery.

But, to the extent that emotional activity is idiosyncratic, it is possible that our tool offers a more personalized experience, given that our algorithm predicts emotions based on the activity seen during each user's training session before the art is generated. Understating the nuances and individual differences in brain activity which contribute to behavioural outcomes is critical in building neurotechnologies, and our tool embraces this concept with the more personalized approach.

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