Art and science unite in unique study of neurofeedback

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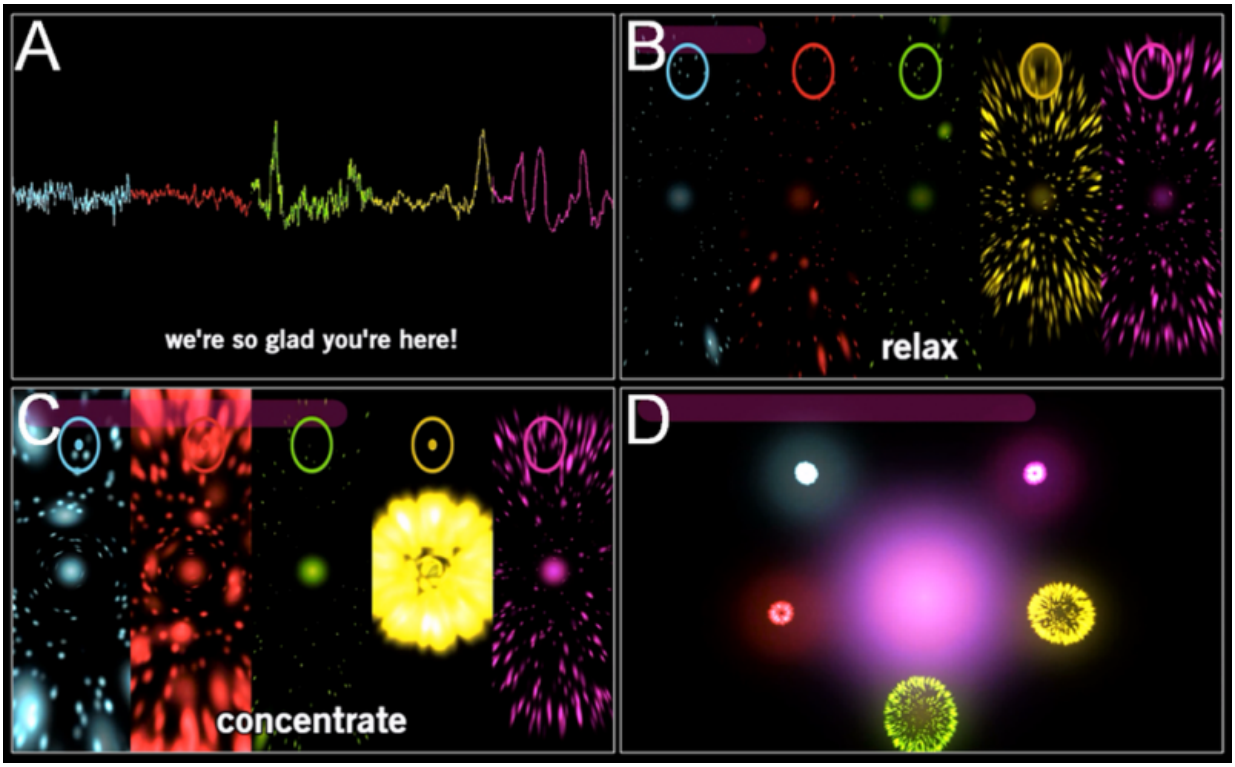

Figure 1: Screenshots of (A) initial training period and welcome message where brain activity was displayed as the signal (B) Solo game during relaxation period (C) Solo game during concentration period (D) Group game where giant orb in the middle is representative of participant's collective brainstates. Credit: Kovacevic et al.

In 2013, art and science merged like never before at Toronto's Nuit

Blanche art festival when guests were given the opportunity to participate in an scientific experiment investigating neurofeedback. Following the initial success of the "My Virtual Dream" project, plans are being made to scale-up the experiment as scientists take the project on a world tour. In 2015, the My Virtual Dream world tour will kick-off in Amsterdam and travel to San Fransisco. This blog post examines the original experiment conducted in 2013 more closely, and highlights some potential concerns around this innovative new approach.

On October 5, 2013, visitors entered a large scale art installation and participated in neurofeedback, a process where participants see their brain activity in real time, and based on the reading, modulate their behavior. This event not only introduced people to the power of EEG headsets, but also demonstrated that neurofeedback can have an impact on how people learn within one minute of initial interaction. EEG recordings are often taken in a lab, an environment that does not mimic the complexity that we encounter every day, but "My Virtual Dream" in Toronto proved that the collection of physiological data does not need to be limited to a researcher's workshop. Yet, as technology becomes more sophisticated and mobile, scientists will need to continue to consider the ethical implications of recording physiological data from the general public.

The "My Virtual Dream" Experience

Over the course of 12 hours, electroencephalography (EEG) data, a measure of electrical activity from the brain, was recorded and analyzed from a total of 523 adults. Groups of people were brought into a 60-foot geodesic dome to participate in a two-part interactive experience. The dreaming portion of the evening involved projecting animated video clips with prerecorded music over the surface of the dome for the volunteers. There were four dream themes with different audio and video pairings, but the environment changed based on the EEG

recordings from the participants. Only the gaming experience was reported in a 2015 *PLOS ONE* paper entitled "'My Virtual Dream': Collective Neurofeedback in an Immersive Art Environment". This blog post aims to serve as a recap of the event based on the paper, but I personally did not attend.

Volunteers were given a lesson about the EEG technology and the overall tenets of the game, but once inside the dome were divided into groups of five, and hooked up to a wireless Muse EEG headset. Each group was positioned in front of a LCD screen that displayed the five brainwaves. Electrical activity of the brain can be measured and displayed as a signal that looks like a wave, and for this part of the experiment, participants saw the signals that coordinated to their electrical activity (Figure 1, panel A). For the remainder of the experiment, the brain activity was displayed as an orb or firework (Figure 1, panel B – D). The game was divided into solo and collective neurofeedback, and measured alpha and beta bands throughout. Alpha bands (8-12 Hz) are generally associated with wakefulness and relaxation, while beta bands (18-30 Hz) correlate to periods of active and busy thinking. After a tutorial, which recorded individual baseline thresholds for the alpha and beta bands to be used subsequently in the evening, volunteers moved on to the game. The first two games were individual and lasted 50 seconds. Volunteers were instructed to relax and the visual feedback was based on gathering particles into an orb (Figure 1, panel B). When participants were relaxed and the alpha power went beyond the baseline, particles were added to the center of the glowing orb. For the concentration period, this orb again acted as the visual feedback (Figure 1, panel C). When the beta power, or concentration level, surpassed the threshold set during the tutorial, the orbs glowed and brightened. To finish the cycle of relaxation and concentration, the volunteers watched their individual orbs explode like fireworks. The height of the firework correlated to the alpha achievement, while the brightness corresponded to the beta achievement. For the group portion of the session, every individual again had their

own orb, but were in a circle surrounding a group orb (Figure 1, panel D). The goal of the game was the same; participants were visually rewarded by gathering particles into an orb for the relaxation period and brightening the orb for the concentration period. The difference was that this time, the circle in the middle grew in size every time three participants were in the appropriate target state. This could be either relaxation or concentration, depending on what the game was asking for. After the game, the group orb was turned into a firework show that displayed the performance of the group as a whole. The final part of the game mimicked the previous group experience, except that there were no explicit instructions. The members of the group were told to attempt to synchronize with the other members, and the middle orb again grew in size if three members of the group were in the same target state. It didn't matter if three members were relaxing or concentrating, but the members had to be synchronous.

Results

EEG headsets are playing a more prominent role in the lab and as consumer devices. Examples include the Muse headset, the Melon headset funded by Kickstarter, and the Emotiv headset. EEG headsets are non-invasive, allow for mobility, and generally require a small amount of time for prep. In terms of applicability for both consumers and researchers who are studying EEG activity, it would be ideal if people learned how to modulate brain activity from EEG headsets as quickly as possible. Researchers had hypothesized, based on conducting the games with smaller samples (less than 10 people), that subtle, but detectable changes in brain activity would be observed during the neurofeedback training period. After analyzing the data, researchers reported that participants were learning to modulate their relative spectral power very quickly—within only 60 seconds for relaxation and 80 seconds for concentration. This was clear because there were gradual declines in the frequencies during the alpha period and gradual increases

when the beta activity was being monitored. The entire gaming session was only seven minutes long, but even within that rapid time period, these changes in brain activity could be observed. The ability to draw this conclusion relies partly on having a large sample size of more than 500 people.

Lab environments often do not mimic the complex experiences that we encounter every day. Although "My Virtual Dream" was still a research experiment, the environment inside the geodesic dome was completely unlike the muted, potentially bland, and less personable appearance of lab. While we may not encounter geodesic domes as part of our average day, the experience is at least more complex and stimulating that a typical lab environment, and this could be one reason why researchers chose this setting. "My Virtual Dream" functioned as a proof-of-concept that EEG headsets could feasibly be used to monitor brain activity in environments that we typically inhabit: our homes, social situations, and work.

Crowdsourcing for Neuroscience

As technology has become more and more sophisticated, crowd-sourcing for neuroscience research has become more common. There are a number of programs and apps, including Lumosity and the Great Brain Experiment, which rely on crowd-sourcing. These two outlets, although approaching data collection in an unconventional way, have published papers in peer reviewed journals. Also, the game Eyewire is a citizen science project that allows any user to help map 3D neurons in the brain, and websites like Kickstarter and Experiment.com are helping non-scientists play a larger role in funding and often participating in science. As exciting as these new methods for data assimilation are, the collection of brainwaves and physiological data could quickly become complicated. It is notable that the "My Virtual Dream" experiment was only tracking alpha and beta wavelengths, and the data were de-identified. Volunteers

were also given the option to remove their EEG recordings from the analysis, but only four participants selected this option. The event was organized by an academic center affiliated with the University of Toronto called Baycrest, and the event was in compliance with their Research Ethics Board. Tracking physiological data over a large sample size could become ethically problematic if we eventually come to a place where brain signals can be used as a signature for a neurological disorder. If EEG data could act as a biomarker for a disease state or even behavioral tendencies, the consequences for individuals could be severe.

Efforts have been made to protect genetic information under the Genetic Information Nondiscrimination Act (GINA), which state that genetic information cannot be used against someone for insurance or employment purposes. But these protections do not yet exist for neurological data. In my opinion, research could become ethically fraught if suddenly EEG data became a clue to a person's capacities or neurological state. As it stands now, the insight gained from the research of EEG data most likely outweighs any privacy violations, but as technology becomes more and more sophisticated, researchers should continue to consider the implications of collecting physiological data from the masses.

Plans are being made to take "My Virtual Dream" on a world tour beginning with Amsterdam, followed by Washington, D.C. and San Francisco, CA. Toronto's Nuit Blanche art festival will again take place in 2015, and although the specific events have not been announced yet, more than 45 novel, interactive, and engaging art installations will be displayed.

More information: "The largest human cognitive performance dataset reveals insights into the effects of lifestyle factors and aging." *Front Hum Neurosci*. 2013; 7: 292. doi: 10.3389/fnhum.2013.00292

"'My Virtual Dream': Collective Neurofeedback in an Immersive Art Environment." *PLoS ONE* 10(7): e0130129. DOI: 10.1371/journal.pone.0130129