An investigation of the use of EEG data for the purposes of sonification and visualisation in a creative environment

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"Fallom closed her eyes, the note was softer now and under firmer control. The flute played by itself, manoeuvred by no fingers, but moved by distant energy, transduced through the still immature lobes of Fallom's brain. The notes which began as almost random settled into a musical succession and now everyone in the hall had gathered around Hiroko and Fallom, as Hiroko held the flute gently with thumb and forefinger at either end, and Fallom, eyes closed, directed the current of air and the movement of the keys." (Asimov, 1986)

***Abstract*— This work demonstrates a currently available method for measuring human brainwaves in order to generate electronic music, visualisation and an elementary neurofeedback software. The aim is (1) to demonstrate the creative use of Electroencephalographs (EEG) with sound and visuals and (2) to gain a better understanding of the software Max/MSP, SuperCollider and of digital signal processing.**

***Introduction*—** This work surveys a currently available method for measuring human brainwaves in order to generate electronic music, visualisation and an elementary neurofeedback software. I started investigating the use of Electroencephalography (EEG) as altered states of mind always spellbound me. In the following I will attempt to give a short insight into the recent use of brainwave data in the fields of music and how I employ some of these in my submitted portfolio.

When we look at the evolution of music and the way in which people perceived music, we can see that as far back as the Greek philosophers, people have been aware of music's therapeutic effects (Henson, 1977). Antony Storr (2005) writes about how music is generally agreed to cause increased arousal in listeners and how this arousal is conditioned to heightened alertness, awareness, interest and excitement. These can manifest themselves in various psychological changes, many of which can be measured. In this study, the measurements are done with an EEG device.

How we comprehend music is very complex and has subjective and objective factors. Under some circumstances loud, fast music is arousing, whilst soft, slow music is relaxing. Research has shown that even infants are attracted to certain pitch and timbre changes and to simple repetitive rhythms. These are called primitive responses (Sloboda, 1993). The other responses depend on the following factors:

(1) listening to music in general (cultural differences, simple and open harmonies, major and minor keys, general rhythmic impetus),
(2) emotional significance of the circumstances in which the music happens to be heard,
(3) musical background and
(4) the mental state of the listener (Sloboda, 1993).

That emotional and perceptual musical experience changes functions in the human body has been known for many years (G. Harrer and H. Harrer, 1977). Music, amongst other things, changes pulse rate, blood pressure, respiration, the psychogalvanic reflex and other autonomic functions. Experiments have shown that by listening to African drumming the body reacts (Rouget, 1985) and that most of our body functions are operated from the brain (G. Harrer and H. Harrer, 1977). To follow from this, if music affects the way we feel and think, then music can be used for various purposes e.g. healing, enjoyment and even for propaganda.

My experimental work in this project seeks to demonstrate my simple knowledge of the use of EEG in both: obtaining reliable data and its utilisation to entertain the human senses. My portfolio consists of programming code for SuperCollider, MaxMSP and Arduino, and as some of the work cannot be used without the EEG device, the portfolio contains video and audio demonstrations as well.

I. Literature review

The activity of nerve cells has an electrochemical basis which is possible to record with sensitive instruments (Scott, 1976). The EEG device used in my work measure is called IBVA (www.ibva.co.uk).

Figure 1. IBVA Bluetooth device

It has two channels, one for the left and the other for monitoring the right hemisphere. The headband has 4 sensors: 3 sensitive medical electrodes measuring electrical activity in the front lobe and one ear-clip for ground. It is a bipolar recording system which means that the output of one channels is the difference between the middle (reference) and the electrode in question (active). The EEG fluctuations in the brain are rather small, much less than 1 millivolt and therefore they also need to be amplified with the device.

There are several ways of using brain data for musical purposes. The most commonly used ways involve the Fast/ Discrete Fourier Transform (FFT/DFT), the Hjorth and Barlow analysis (Miranda, 2007) and techniques where the raw EEG data is monitored for Event-Related Potentials (ERP) (Miranda, 2006).

My initial plans were much more ambitious than I could practically realise with my software. Bearing in mind the complications of working with brain-data, I was trying to prioritise the following features of the project:

(1) To be able to receive the two raw EEG signals (Left Ch, Right Ch) in Max/MSP and in SuperCollider,
(2) to gain a better understanding of the process behind power spectrum analysis so
(3) I can program my own patches/code that can provide me with the same data as the IBVA software and the [IbvaGet] object in Max/MSP,
(4) to read EEG data from text files into the audio software,
(5) to be able to distinguish thoughts manifested when thinking of a certain musical note (use of ERPs) and lastly
(6) to generate an interesting soundscape which has characteristic parameters of the person's mental state.

The EEG recorded on the scalp are the result of the brain's electrical activity conducted through the brain tissue. The distinct configuration of power distribution in the spectrum of the EEG signal is useful to indicate different states of mind. In other words, with power spectrum analysis we deconstruct the signal into partials and determine their relative amplitudes and frequencies within windows, FFT bins (Scott, 1976):

Delta (0 - 4Hz), theta (4 - 8 Hz), alpha (8 – 13 Hz) and beta (13 – 30 Hz) are the bands of EEG activity calculated by FFT/ DFT. Delta rhythms are associated with sleep, theta with drowsiness, trance, deep relaxation or meditation and hypnosis, alpha with relaxed wakefulness and beta with alertness, intense mental activity or stress (Miranda, 2006). In the figure below (Wise, 2004), the horizontal axis represents amplitude, the vertical axis frequency from 0hz growing exponentially from the bottom to 30hz.

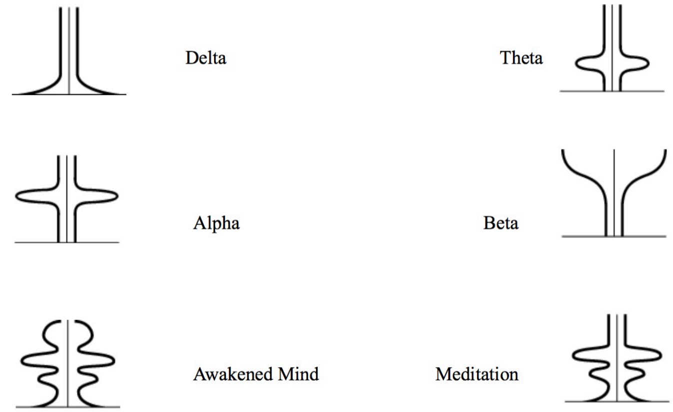

Figure 2. EEG and mental states by Anna Wise.

For this study I contacted many artists, teachers of music technology, programmers and also physiologists. One of them was Dr Mick Grierson, an experimental artist specialising in real-time interactive audiovisual research, with a specific focus on cognition and perception. The other one was Eduardo R. Miranda, a Professor in Computer Music in the Faculty of Technology (University of Plymouth) who is also an active composer. Grierson's work *Composing with Brainwaves: Minimal Trial P300 Recognition as an Indication of Subjective Preference for the Control of a Musical Instrument* presents a system that detects P300 ERPs with visual stimulation in a real-time recording environment. His study shows how EEG triggered by certain types of visual stimuli can be connected to MIDI notes in Max/MSP. In *Brain-Computer music interface for composition and performance*, Miranda (2006) demonstrates the use of EEG to control generative rules to compose and perform music with. His brain-computer interface (BCI) monitors the subjects' brainwaves in real-time and uses the activity of different frequency bands (delta, theta, alpha and beta) to steer musical scales for a MIDI piano. For the tempo and dynamic changes, he uses the signal's complexity, which was measured with the Hjorth analysis, a time-based amplitude analysis. The picture below is from the article (Miranda, 2006).

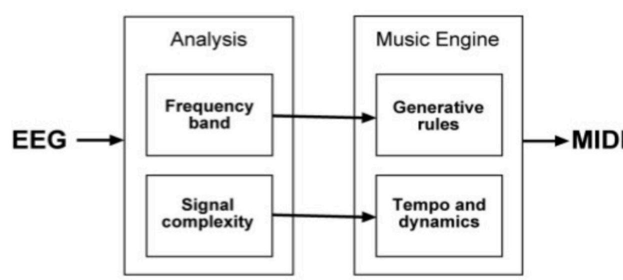

Figure 3. Process of a BCI from Mirada's article

Both, Grierson's and Miranda's work influenced my projects.

II. EXPERIMENTAL WORK

The EEG used in the following portfolio were recordings made on myself or on my friends, while listening to trance and ambient music or while meditating.

[1] Max Read EEG

This projects reads a text file containing raw EEG data exported with the IBVA app on OSX. To manipulate visuals in Max/MSP/Jitter, I looked for data repetition in this text file and used the results to alter

(1) volume of the audio embedded in the video,

(2) loop-points of the video clips and

(3) the rate of how fast or slow the clips are played.

The process: First the software checks where “Left” and “Right” data start and end in the text file (line number) to be able to use the EEG data with the same timing as when recorded. I used [regexp] to subtract the 2nd column into a [coll] object. The elapsed time between the lines is basically the same (0.133 – 0.134 sec).

One line in the text contains 16 consecutive EEG data (microVolt). I read all of them in exactly the same time and used their sum to recognise repeated patterns. The object used is [zl stream] in the [repetition] sub-patch. Repetitions found by the software trigger rules in the video and audio part of the patch.

I have used a video extract from the last episode of Twin Peaks (1990) season one. Here the main character gets trapped in a place beyond logical. With the long movie file (15 min) I had to reject the use of the object [spigot] as it copies the audio from the movies too slowly. I used separate audio files with [groove] instead.

Video of the project can be found at https://khofstadter.info/twin-peaks-truth-business/.

[2] SC Read EEG

This project reads text files into arrays in SuperCollider software. The text files contain raw EEG data exported with the IBVA software, similarly as in the previous [1] Max Read EEG project. I separated the text file into two files, one containing the left the other the right hemisphere EEG and then sonified them.

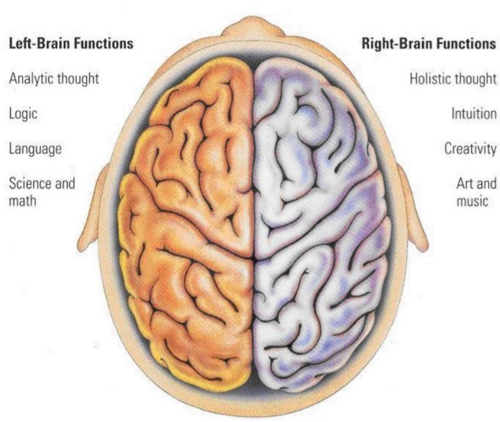

Figure 4. Hemispheres, source: http://brainchildco.wordpress.com/

Besides an interesting sonification approach, the main achievement was a better understanding of the SuperCollider software, for instance in the use of arrays instead of a large number of global variables.

[3] Max FFT EEG

I consider this projects as as a contribution to experimental music and as a tribute to John Cage, who worked with EEG when he assisted David Rosenboom in his work “Ecology of the Skin” in 1970-1971 (www.horizonzero.ca).

An external object [IbvaGet] is used for the FFT analysis, that provides us with the power spectrum of the raw signal and helps use the amplitude of each brainwave rhythm [delta, theta, alpha, beta]. The power of these rhythms are mapped to several audio sampling and audio synthesis parameters for instance to the rate of audio loops in the [groove] object.

This patch opened a new perspective for my work with EEG: neurofeedback training (NFT). NFT is often aimed at changing the amplitude of a selected frequency bandwidth, its goal is to change an unhealthy EEG pattern into a healthy one.

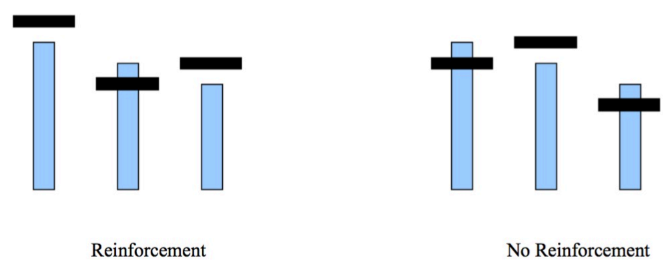

Figure 6. NFT with thresholds

In NFT both sounds and graphics are very important. “Most graphics tend to be boring and repetitive... there are only a few systems which can hold the client's attention unless they are highly motivated” (Demos, 2005). This statement helped realise that there is a gap to fill: NFT needs more audio features.

[4] Max Raw EEG

In this project, my goal was to understand more about the technical part of EEG data transmission. I needed to get the raw data into Max/MSP as I wanted to have my own FFT analysis and to experiment with ERPs. First I could only do this with the help of a patch in Quartz Composer and OSC.

After communicating with IBVA users on EEG protocols and posting questions on the forum for Max/MSP, (www.cycling74.com) I finally managed to parse the EEG raw data in Max/MSP from the device. I thought this had been the hardest part, but I was wrong as using FFT in the software to see the amplitude (power) of the partials (brain-rhythms) needs even more advanced skills.

[5] Arduino

“The Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software” (www.arduino.cc). The idea here was to alter a servo motors spin with brainwaves. In the future, I could add another bio-feedback element, which could use a piezo-disk to measure the heartbeat while the EEG device measures brainwaves. The relevant code on the attached portfolio are very basic, they just demonstrate one of the uses of EEG data.

A combination of [3] Max FFT EEG and [5] Arduino projects was exhibited at HCI2009 Conference, Cambridge: https://khofstadter.info/hci/

III. Conclusion

When we attach electrodes to the scalp we listen to a very complex organ. Since I started studying in England I went through a change. I used to be more idealistic and had nothing really in common with technology. I enrolled on the Creative Music Technology course without expecting to be working with such software like SuperCollider or Max/MSP. I believe the whole course and the EEG project was very beneficial for me as now I can imagine more what the Renaissance was about, where science met art. At meditation courses, I have heard this to be expressed by the harmony between the brain and the heart. Working on the project has taught me to be more patient if I want to get to know myself, which was a hidden aim overall.

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