Faculty of Cognitive Sciences and Human Development

AN OPEN SOURCE METHODOLOGY TO DEVELOP GAMES FOR NEUROFEEDBACK TRAINING (NFT)

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(Cognitive Science)
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Final Year Project Report ☒

Masters ☐

PhD ☐

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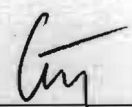
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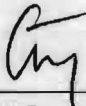
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AN OPEN SOURCE METHODOLOGY TO DEVELOP GAMES FOR NEUROFEEDBACK TRAINING (NFT)

RAYMOND NGOI YUNG TAH

This project is submitted
in partial fulfilment of the requirements for a
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ABSTRACT

Neurofeedback is a non-intrusive training in which individuals could control their own brain wave patterns and adjust it until it matches the desired pattern. It is claimed that this training is safe to be used because it will only collect the brain wave and no electric current will pass through the brain. In neurofeedback training, individual may require to play certain kind of specially designed game in which they would use their brain wave to control the game. In order to achieve success in the game, the individuals need to regulate their brain wave patterns to meet the required training pattern. The game is very interactive and hence, it would gain interests from the individuals. However, proprietary software and hardware of neurofeedback deter customized development of games. If the users do not buy new games from the developer, then they may need to play the same games over and over again which may end up with boredom. In this project, an open source methodology to develop game for neurofeedback training would be introduced. This methodology would involve the usage of OpenBCI to retrieve the raw brain data and Brainbay to do the brain signal processing. Through these, beta wave could be attained and it would be used to control the game. The game that is demonstrated in this project is being developed by using Scratch. Initially the game is being designed to be controlled by using the space bar on the computer keyboard. This methodology allows the keyboard to be replaced with the beta wave. In other words, the player would play the game by using his own brain power, which is beta wave.

Keywords: neurofeedback, brain, game, methodology, open source, OpenBCI, Brainbay, Scratch

ABSTRAK

Neurofeedback adalah latihan yang tidak akan membahayakan individu. Latihan ini adalah selamat untuk digunakan kerana instrumen untuk latihan ini hanya akan mengumpulkan gelombang otak dan tidak ada arus elektrik akan melalui otak. Semasa latihan neurofeedback dijalankan, individu perlu bermain sesuatu jenis permainan komputer dengan menggunakan gelombang otak mereka. Demi mencapai kejayaan dalam permainan, individu perlu mengawal corak gelombang otak mereka untuk memenuhi corak latihan yang diperlukan. Permainan ini adalah sangat interaktif .Oleh itu, individu akan tertarik dengan latihan ini. Walau bagaimanapun, perisian dan perkakasan neurofeedback proprietari menghalang pembangunan khusus permainan. Jika pengguna tidak membeli permainan baru daripada pemaju, maka mereka perlu bermain permainan yang sama berulang-ulang kali dan mungkin berakhir dengan kebosanan. Dalam projek ini, satu kaedah sumber terbuka untuk membangunkan permainan latihan neurofeedback akan diperkenalkan. Metodologi ini akan melibatkan penggunaan OpenBCI untuk mengambil data otak mentah dan Brainbay untuk melakukan pemprosesan isyarat otak. Melalui kaedah ini, gelombang beta boleh dicapai dan gelombang ini akan digunakan untuk mengawal permainan. Permainan yang ditunjukkan dalam projek ini adalah dibangunkan dengan menggunakan Scratch. Pada peringkat awal, permainan ini adalah dikawal dengan menggunakan bar ruang pada papan kekunci komputer. Metodologi ini membolehkan papan kekunci untuk digantikan dengan gelombang beta. Dalam erti kata lain, pemain akan memainkan permainan dengan menggunakan kuasa otak sendiri, iaitu gelombang beta.

Kata kunci: neurofeedback, otak, permainan, metodologi, sumber terbuka, OpenBCI, Brainbay, Scratch

CHAPTER ONE

INTRODUCTION

Background of the study

Neurofeedback is a method that could be used to treat many mental disorders such as attention deficit hyperactivity disorder (ADHD) and autism (Evans & Abarbanel, 1999). It exists in many structures and the most common one is called EEG Biofeedback (Coben et al., 2010). It works by placing electrodes on the individual's scalp to collect the brain wave patterns. One of the electrodes will be placed at the ear lobe to function as the reference point. Butnik (2005) has stated that the fundamental criterion of designing neurofeedback is based on the relationship between mental states and brain wave frequencies. This means every mental process will cause the brain to exhibit different frequencies and neurofeedback is able to collect the brain wave patterns for the usage of brain training.

The theory involved in neurofeedback is brain plasticity (Butnik, 2005). Kolb and Whishaw (1998) have defined brain plasticity as the ability of the brain to learn or adapt to new condition. Although many brain disorders such as ADHD and autism are born in nature, the possibility of improving their brain function is still very high because the brain does not restrict itself to certain function only, but to learn accordingly. Cowan and Markham (1994) have presented a successful case in which an 8-year-ol d autistic girl have improved her attention and decreased certain kind of autistic manners (as cited in Coben et al., 2010).

1

Problem statement

According to *OpenBCI* (2014), most of the brain-computer interface (BCI) that have been introduced previously could only be used within the specific device. This means the other creators could hardly retrieve the algorithms in it when they wish to take them as the references in creating new technology. In order to solve this problem, OpenBCI has been introduced. According to the description of *OpenBCI* (2014), this technology allows the creator to retrieve the raw data of the brain wave at real time and convert it to useful information for development of good system designs.

Purpose and objectives of study

Main objective:

- To develop a methodology for the use of open source for neurofeedback training (NFT).

Specific objective:

- To allow the users to regulate their own brain wave until the desired wave – beta wave exists for most of the time in frontal part of the brain. This continuous generated beta wave would be retrieved by using the OpenBCI device and at the same time, processed so that it could replace the computer keyboard in controlling the game.

- To develop a simple shooting game by using "Scratch". The users would use the mouse to control the direction of the cursor so that it could aim the moving ball. The shooting action could be achieved by pressing the space bar of the computer keyboard.

- To employ Brainbay as EEG signal processing software. OpenBCI would only retrieve the raw brain data and in order to extract the desired beta wave, some filtrations need to be carried out and this could be done by using Brainbay.

2

Conceptual/Operational definition

1) Conceptual definition of neurofeedback: Neurofeedback is a brain training technique which follows the operant conditioning method to inhibit the unwanted brain wave and enhance the preferred brain wave (Kouijzer, de Moor, Gerrits, Congedo, & van Schie, 2009).

2) Conceptual definition of computer game: Computer game is a game which "carried out with the help of a computer program (Smed & Hakonen, 2003, p.3)".

Significance of the study

To develop an open source methodology which can be used or modified by the developers in later days in building the games for neurofeedback training (NFT).

Scope of the study

Raw data of the brain wave patterns is obtained from the OpenBCI. Software is needed to convert the brain wave into useful information that can be used to control the game.

CHAPTER TWO

LITERATURE REVIEW

Neurofeedback

Figure 1. Neurofeedback session.

Neurofeedback is being used as training for individuals who are diagnosed to have unusual brainwaves patterns by using computer technology (Coben, Linden, & Myers, 2010). This computer technology may extract the brain wave from the individual's head and display it on the monitor so that appropriate protocols could be applied during the training session. Figure 1 has demonstrated a neurofeedback session. Holtmann et al. (2011) has mentioned that in order to take control over the cortical electrical activity, individuals need to learn how to regulate the brain wave by themselves. Neurofeedback does not change the brain wave patterns. What it does is it helps individuals to regulate the brain waves by themselves. When the trainees succeed in achieving control over the brain, Demos (2005) believes that the cellular levels of the brain would start changing and it would affect the brain functioning and behavioral cognitive

performance (as cited in Kouijzer, de Moor, Gerrits, Congedo, & van Schie, 2009). In the case of

Autism Spectrum Disorder (ASD) children, Holtmann et al. (2011) has mentioned that

neurofeedback would help them by adjusting their neurophysiological profile until it becomes

similar to normal children. The autistic behaviors and symptoms would thus be improved.

According to Coben, Linden, and Myers (2010), during neurofeedback session,

individuals would learn how to control the disproportionate brainwave frequencies. They would

decrease the frequencies that have been extremely produced and at the same time, increase the

lacking ones. It is necessary to do so because excessive frequencies would cause negative

symptoms and if the lacking frequencies are being improved, the positive symptoms could be

seen. This statement is being supported by other scientists. Lubar, Swartwood, Swartwood, and

O'Donnell (1995) have mentioned that

> neurofeedback training is designed to enhance certain types of EEG activity either by
>
> itself, or to enhance certain types of EEG activity and decrease other types of EEG
>
> activity when it occurs simultaneously, such as the enhancement of beta activity and the
>
> inhibition of theta activity in the case of Attention Deficit Disorders or the enhancement
>
> of sensorimotor rhythm activity (12-15 hz.) and the suppression of theta activity (4-8 hz.)
>
> for helping patients to decrease seizures or hyperactivity (p. 5).

Kouijzer, de Moor, Gerrits, Congedo, and van Schie (2009) consider this phenomenon as a form

of operant conditioning. According to Watkins (1989), operant conditioning is similar to

reinforcement learning (as cited in Touretzky & Saksida, 1997). Individual would be rewarded if

they did the task correctly and punished if they did it wrongly. During a neurofeedback session,

normally children would be given some computer games to play with. Hence, in this case, the

reward given to the child would be the game scores. If he or she wants to succeed at the games,

then the brainwave patterns have to be improved (Coben, Linden, & Myers, 2010). Table 1

shows some basic type of brainwaves, frequencies, normal occurrence and significance. These

brain waves are normally used as the training protocol during neurofeedback session. This would

be further explained in session 2.1.5. Figure 2 shows the frequency pattern for every types of

brainwave.

Table 1

EEG Frequency Bands

Name	Frequency	Normal occurrence	Significance
Delta	0.5-3.5 Hz	- Babies (decreases as they age) - Adults who are in deep sleep	- Large amount of delta activity in awake adults is related to neurological diseases - Easily confuse with artifacts signals, which are caused by the large muscles of the neck or jaw
Theta	4-7.5 Hz	- Young children - Older children - Adults who are in drowsy, meditative or sleep states	- Meditative concentration - Cognitive processes such as mental calculation, maze task demands, or conscious awareness

Alpha	8-13 Hz	- Eyes closed, - Body relaxation - Self-awareness	- Excessive alpha during demand states can be a sign of difficulties with learning, emotional stability, relating to the environment or others
Beta	13-30 Hz	- Fast activity associated with alertness and activity	- Excessive beta is often associated with anxiety, irritability and poor integration
Gamma	Greater than 30 Hz	- May be associates with problem solving and memory consolidation	- Less commonly used in EEG-based BCI systems because artifacts such as electromyography (EMG) or electrooculography (EOG) are likely to affect them.

Note. From "Neurofeedback for autistic spectrum disorder: A review of the literature" by Coben, R., Linden, M., & Myers, T. E. (2010). *Applied psychophysiology and biofeedback*, *35*(1), 83-105.
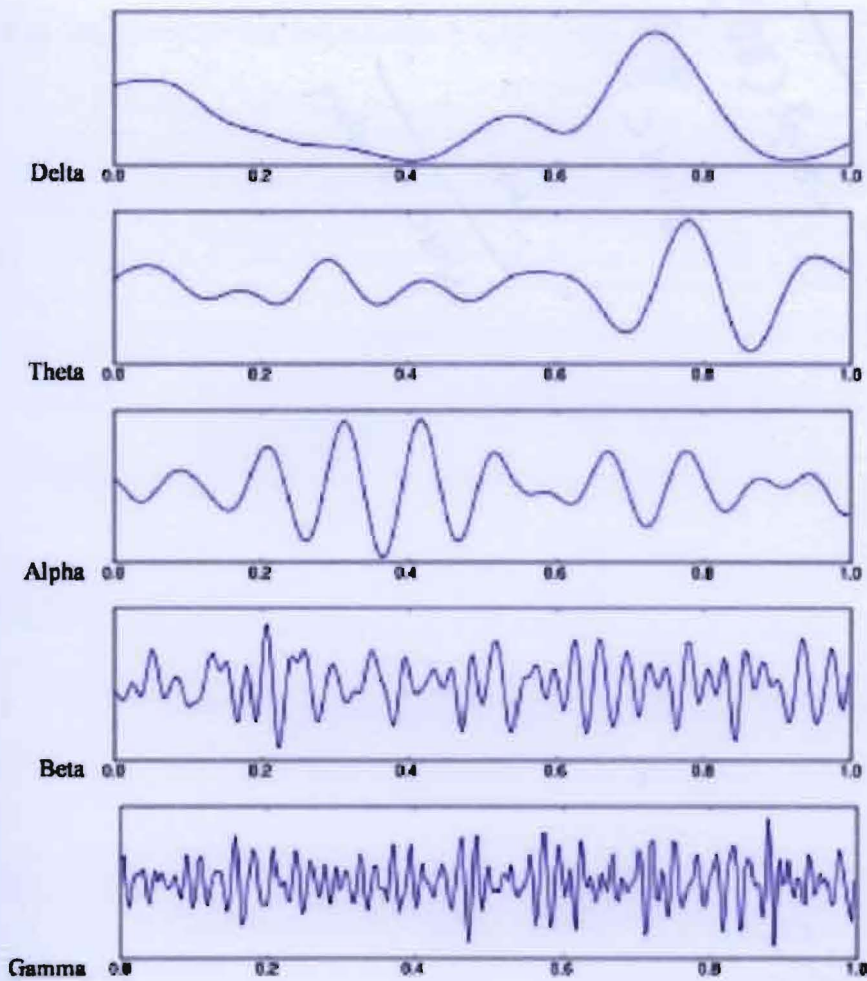
Figure 2. The frequency pattern for every types of brainwave.

Some researchers have even mentioned on the mu rhythm. According to Lehtonen (2002), mu rhythm frequency is around 10 Hz and amplitude mostly below 50 µV. Although the frequency and the amplitude of the mu rhythm are similar to the alpha rhythm, the mu rhythm is topographically and physiologically different from the alpha rhythm. Mu stands for motor and the mu rhythm is strongly related to the functions of the motor cortex, but also to the adjacent somatosensory cortex. The mu rhythm is blocked by movements or light tactile stimuli. The fact

that the thoughts about performing movements and readiness to move can also block the mu rhythm, have made it important in BCI research.

According to Coben, Linden, and Myers (2010), neurofeedback is a technology which would not harm the users. It is safe to be used because during a neurofeedback training session, the electrodes are placed on the scalp and ear lobe of the users and it would only extract the brainwaves instead of sending the electrical current to the brain. Neurofeedback have been used by many people and until now, no acute or long-lasting side effects have been reported (Holtmann et al., 2011; Coben, Linden, & Myers, 2010). This means users would not be placed in a harmful situation when using neurofeedback if compared to other interventions such as medicine. According to Holtmann et al. (2011), users may sometime experience headaches and exhaustion due to muscular tension in the brain when they are paying concentration during training sessions. Hence, trainers would never allow the trainees to do many sessions in one day and it is advisable that trainee should get enough rest after each training session. Besides, the outcomes achieved through neurofeedback are also proven to be long lasting. "The therapeutic treatment outcomes of neurofeedback training with individuals with ADHD (increased attention, reduced impulsivity and hyperactivity) have been reported to be maintained over time and not reverse after treatment is withdrawn as in drug therapy and diet therapy" (Coben, Linden, & Myers, 2010, p. 94).

Case Studies for Effectiveness of Neurofeedback

First case. Cowan and Markham (1994) has presented a study which has proven the effectiveness of neurofeedback on individuals with Autism Spectrum Disorder (ASD) (as cited in Coben, Linden, & Myers, 2010). In one of the case, the trainers had performed an EEG analysis onto an 8 year old girl who is a high functioning autism. They had found out that she was having high alpha and theta wave in her parietal and occipital lobes. This analysis is carried out during eyes open and resting conditions. From the results, the trainer had designed a neurofeedback protocol in order to lower down the ratio of "thalpha" (4–10 Hz) to beta (16–20 Hz) EEG activity at central and parietal sites using a bipolar montage (two scalp electrodes and one ear ground electrode). After 21 neurofeedback sessions had been carried out, it is found that the girl had improved a lot in her attention and social interaction. At the same time, her autistic behaviors (inappropriate giggling and spinning) had decreased as well. Besides, some experts had also carried out the Test of Variables of Attention (TOVA) towards her and it had shown that she had improved a lot. The TOVA scores were maintained at the normal level even after two years. This had proven that neurofeedback training effect would last long and not bounce back.

Second case. Another case is presented by Surmeli & Ertem (2009). In this study, a 48-year-old female who had already married and had 3 children in her family, was having the difficulty in controlling her anger. She often experienced mood swing as well. However, she did not know she was having problem. Instead, she kept on complaining her husband to be very aggressive and treated her bad. She felt wronged and wished to leave the family. She even had a thought of committing suicide. After carrying out 24 neurofeedback session, she gave the response that she became more relax and her restlessness had declined. After 40 sessions, the patient was no longer having insomnia. She did not feel like want to leave home anymore. In contrary, she cherished her family. Besides, her level of aggression had markedly decreased as well. After 80 sessions her anger and homicidal thoughts had disappeared, and she began to get pleasure from life. After 120 neurofeedback sessions her feelings of anger about her husband and paranoid ideations disappeared. All of these happened because her alpha hypercoherence had declined and relative alpha was also markedly decreased.
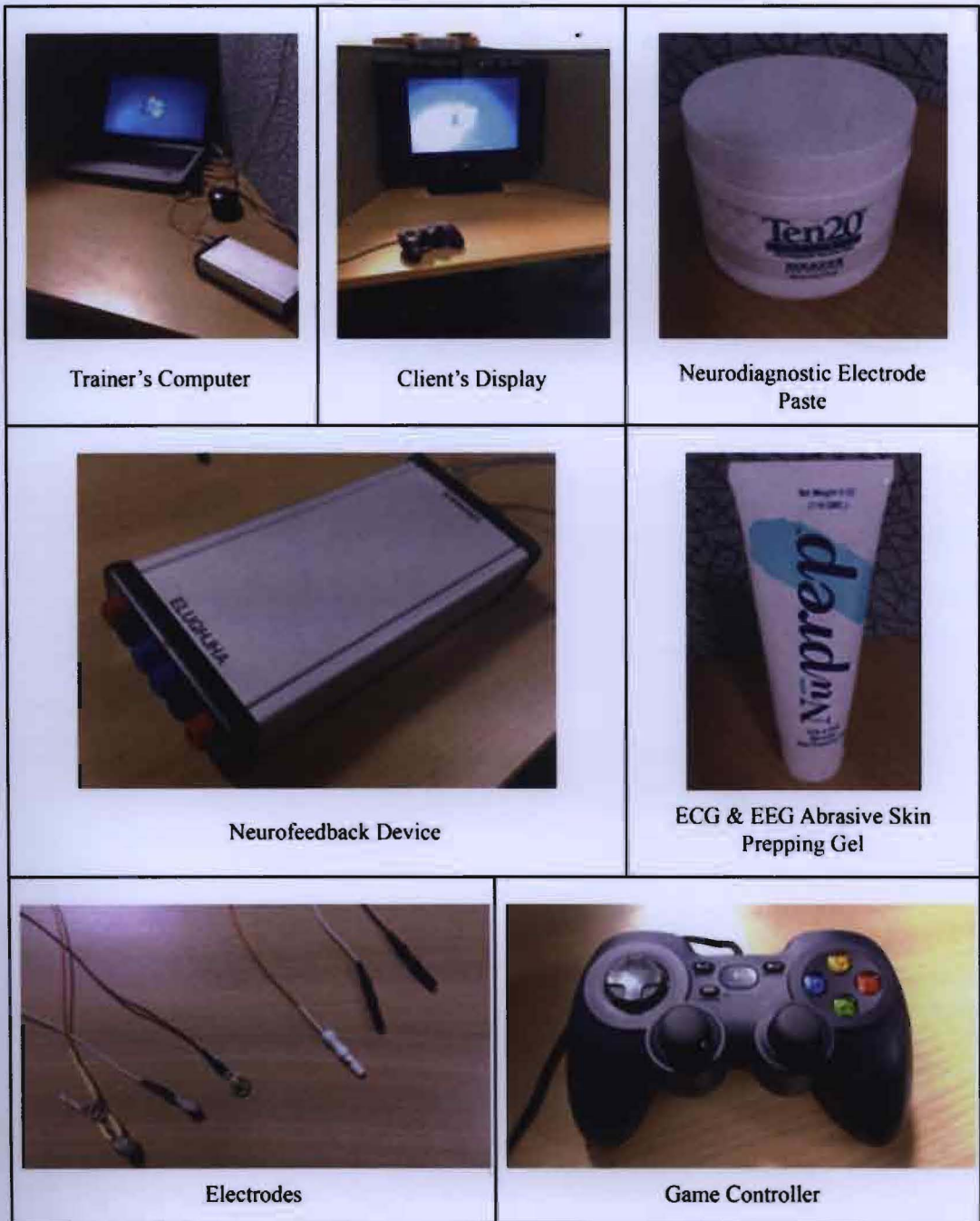
Neurofeedback Equipment

Trainer's Computer	Client's Display	Neurodiagnostic Electrode Paste
Neurofeedback Device		ECG & EEG Abrasive Skin Prepping Gel
Electrodes		Game Controller

Figure 3. Neurofeedback equipment.