EFFECTS OF USING BREATHING APPPLICATION AND EEG MUSE DEVICE TO ENHANCE STATE LEVEL BOWLERS' PERFORMANCE

By

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ABSTRAK

Memandangkan peranan yang penting untuk menangani strategi dalam sukan, kajian ini bertujuan untuk menentukan sama ada penggunaan aplikasi pernafasan dan latihan neurofeedback EEG-muse akan menyebabkan pengurangan tahap kebangkitan dan meningkatkan prestasi pemarkahan pemain tenpin peringkat negeri peringkat Malaysia. Selain itu, indeks HRV juga diukur untuk meramalkan prestasi prestasi. Bowens peringkat negeri beribu-ribu sukarelawan untuk mengambil bahagian dalam kajian ini. Para peserta terdedah kepada tiga keadaan penyelidikan iaitu kawalan, campur tangan pernafasan dan campur tangan muse. Kajian ini dijalankan selama tiga minggu, dengan keadaan penyelidikan setiap minggu secara rawak. Sebelum campur tangan, peserta dikehendaki menjawab soal selidik CSAI-2R; maka campur tangan itu diterapkan setelah itu para pemain melakukan tiga set tenpin bowling simulated competition. Soal selidik CSAI-2R sekali lagi diselesaikan oleh peserta selepas pasca-prestasi. Indeks HRV (SDNN dan RMSSD) juga diukur semasa keadaan berehat di dalam mangkuk (sebelum prestasi) dan serta-merta mengikuti campur tangan muse. Keputusan menunjukkan bahawa tidak terdapat perbezaan yang signifikan dalam tahap rangsangan pemain bolasepak yang mengikuti intervensi ($p > 0.05$). Prestasi boling bertambah baik berikutan intervensi kerana keputusannya signifikan ($p = 0.032$), yang menunjukkan bahawa campur tangan Muse mempunyai skor prestasi bowling tertinggi (359.09 ± 20.48), diikuti oleh intervensi aplikasi bernafas (354.64 ± 21.68), dan kemudian mengawal keadaan (344.27 ± 21.15). Keputusan untuk indeks HRV hanya signifikan untuk RMSSD ($p = 0.004$). Prestasi bowling of the bowlers meningkat setelah intervensi sementara intervensi tidak mempunyai pengaruh terhadap sub-skala CSAI-2R. Indeks HRV juga tidak kelihatan penting dalam meramalkan prestasi pemain bolasepak walaupun keputusan RMSSD berubah tetapi lebih tinggi daripada yang lebih rendah. Penemuan kajian mencadangkan terdapat kesan positif penggunaan EF-muse NFB dan aplikasi pernafasan dalam meningkatkan prestasi pemain.

ABSTRACT

Given the key role of coping strategies in sports, this study sought to determine whether the use of breathing app and EEG-muse neurofeedback training would cause a reduction in arousal level and to enhance the scoring performance of the Malaysian state level tenpin bowlers. Besides, Heart Rate Variability indices were also measured to predict performance outcomes. Eleven State-level bowlers volunteered to took part in the study. The participants were exposed to three research conditions namely control, breathing intervention and muse intervention. The study was conducted over three weeks, with a research condition each week at random order. Prior to the intervention, the participants were required to answer the CSAI-2R questionnaire; then the intervention was applied after which the players performed three sets of tenpin bowling simulated competition. The CSAI-2R questionnaire was again completed by the participants after post-performance. The HRV indices namely (SDNN and RMSSD) were also measured during the resting state of the bowlers (prior to the performance) and immediately following muse intervention. The results revealed that there was no significant difference in the arousal level of the bowlers following the intervention ($p > 0.05$). The bowling performance improved following the interventions as the results were significant ($p = 0.032$), which showed that Muse intervention has the highest bowling performance scores (359.09 ± 20.48), followed by breathing apps intervention (354.64 ± 21.68), and then control condition (344.27 ± 21.15). The results for HRV indices were only significant for RMSSD ($p = 0.004$). The bowling performance of the bowlers increased following intervention while the interventions did not have any effect over the sub-scales of CSAI-2R. The HRV indices also did not appear to be significant in predicting bowlers' performance although the RMSSD results changed but were higher instead of being lower. The findings of the study suggest that there is a positive effect of EEG-muse NFB and breathing app use in enhancing bowlers' performance.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Tenpin bowling is one of the popular sports among the Malaysian youth. It is played in every State in Malaysia. Over the years it has gained popularity among the disabled community as well. This is a sport in which bowler rolls a bowling ball down a wood-structure lane and towards ten pins positioned at the end of the lane. The objective is to score the highest pin fall by knocking down as many pins as possible. Three finger holes are drilled into a traditional bowling ball, and weights vary considerably to make the sport playable for all ages. Generally, the heavier the ball, the more pins that will topple on two equivalent shots (Diaz & Herrera, 2004). The pins are arranged in a triangular position by an automated machine. While professional ten-pin bowling tournaments are held in numerous countries, the sport is commonly played as a hobby by millions of people around the world.

There are many claims to the origins of bowling. The International Bowling Museum suggests that bowling might date as far back to 3200 B.C.E. in Ancient Egypt, with more recognizable forms emerging in Germany in the fourth century C.E. and in England in the fourteenth century. Bowling was, undoubtedly, one of the more popular games brought to the British colonies in America, where it transformed from the more traditional game of ninepins into the modern-day tenpins format.

There is a range of psychological factors that contribute to successful performance in this sport, for example, motivation, self-confidence, arousal control, mood and emotion control and stress management (McCarthy *et al.*, 2013). However, sport psychologists, who are working with the bowlers, often strive to find new ways to develop the bowlers psychologically

and to help them to achieve success. One of these methods is by using technologies, for example, the apps from the mobile phone, or the portable device such as the EEG brain sensing headband – MUSE (also known as the brain-sensing headband).

It's a natural phenomenon that an athlete's vigour increases in a competition. The goal is to perform at maximum level within that period. But when this vigour enhancement changes into anxiety, this can have a negative impact on the performance. Instead of taking that nervousness over themselves intensely and performing poorly, many athletes could implement some strategies to implement over themselves in order to perform at their best. Recently, there are many new devices invented in an attempt to provide "real time" feedback to the athletes for reducing their stress and anxiety. These devices could be very useful in helping the athletes to achieve their peak performance. However, limited research had been conducted specifically for sports performance.

Whenever an athlete felt excessively nervous, breathing is the first thing which is disturbed. It is due to the body does not receive enough oxygen to perform at an optimum level. To lower the anxiety level, thus, the athlete is encouraged to take slow, deep breaths. Deep breathing has many advantages. It provides the athlete with enough oxygen so that the body can work at its best. By getting more oxygen in the body, the athlete will feel more relaxed and will attain control over their body. This will help him or her to get rid of emotional negativity like frustration or fear and will promote the positive attitude to regain strength over the task. In this way, the athlete will get off the things which were interfering with him or her and increased anxiety. Recently, there has been some research which has shown that deep breathing should be a part of their between competition routine. Particularly where deep breathing can play a vital role is before an athlete begins another task. If the athlete takes ten deep breaths of long breath, he or she will feel relaxed and will be more prepared for the next performance.

A way of understanding brain cognition is EEG (Electroencephalography). EEG is a test used to evaluate the electrical activity in the brain. It records the potential changes in electrical activity from electrodes usually on the surface of the scalp (Shelley *et al.*, 2006). Brain cells communicate with each other through electrical impulses. It tracks and records brain wave patterns. Small flat metal discs called electrodes are attached to the scalp with wires. The electrodes analyse the electrical impulses in the brain and send signals to a computer that records the results. Unfortunately, due to the complicated procedures of using EEG, many sports scientists and coaches alike have a difficult task in observing, measuring and controlling the mental processes of the athletes. There are different types of EEG test, and often it is time-consuming for setting up. However, recently a device known as MUSE (Brain sensing headband) has shown to utilise the concept of EEG, by giving accurate, real-time feedbacks to the athlete. There are increasing studies done using MUSE in meditation, however, limited studies had been conducted to use MUSE as a neurofeedback device, for enhancing sports performance for fine-motor skills sports. Thus, this study attempted to understand the effect of using portable breathing apps from the phone, and MUSE-EEG device, on the performance of tenpin bowlers, which is a fine-motor skill sport.

1.2 Significance of the study:

Breathing techniques play a pivotal role in controlling and reducing stress. There have been some researches on implementation of breathing protocols as part of mental training program for athletes. However a lot of work is yet to be done. In this innovative era of technology many breathing mobile applications have been launched for which there is a need to take these into research studies. These applications can provide the athletes an awareness of how to control their arousal levels in order to deliver optimum performance. This strategy can be introduced before competition which can help in training the athlete with biofeedback mechanism. Neuro feedback involving EEG has been used extensively in studying cognitive

behaviour of athletes in sports such as shooting, golf, soccer, tenpin bowling etc. There is less use of portable neuro feedback system like EEG-MUSE application device. This device contains a wireless headset which can be put around athlete's head which record's EEG waves pattern displaying it on the mobile screen. In this way the athlete can easily move while performing and be fully aware in controlling his or her arousal level in peak performance. In addition, this research is designed to discover and to understand the effects of breathing applications and EEG muse application device, to give information to both athletes and coaches to understand the potential efficiency of using this new portable approach in enhancing bowler's performance by keeping an eye over the psychophysiological aspects. Although some evidence showed that neurofeedback training can enhance athletes' performance but much of it is yet to be identified. Thus, this purpose of the study is to examine the effect of using effects of using breathing apps or EEG Muse device to enhance state bowlers' performance in terms of mindfulness and flow.

1.3 Research Question

- Does the use of breathing exercises through app reduce arousal level among state level bowlers leading to enhanced performance?
- Does the use of portable MUSE-EEG device reduce arousal level among state level bowlers' leading to enhanced performance?

1.4 Objectives of the study

The main objective of the study is to investigate the effectiveness of using a breathing app, or MUSE-EEG device to reduce the arousal level among bowlers leading to enhanced bowlers' performance.

The specific objectives are:

1. To investigate the effectiveness of using breathing app in reducing arousal level among bowlers' and enhancing bowlers' performance.
2. To measure the effectiveness of using MUSE-EEG device in reducing the arousal level among bowlers' and enhancing bowlers' performance.
3. To measure the HRV indices as predictors of performance.

1.5 Hypothesis

Ho1: There is no significant effect of using breathing app on bowlers' performance.

Ha1: There is a significant effect of using breathing app on bowlers' performance.

Ho2: There is no significant effect of using portable MUSE-EEG device in enhancing bowlers' performance.

Ha2: There is a significant effect of using portable MUSE-EEG device in enhancing bowlers' performance.

Ho3: There is no significant difference in HRV indices as predictors of performance.

Ha3: There is a significant difference in HRV indices as predictors of performance.

1.6 Operation definitions

EEG: Electroencephalography (EEG) is an electrophysiological monitoring method to record electrical activity of the brain. It is typically non-invasive approach, with the electrodes placed along the scalp (Koubeissi, 2011).

Biofeedback: Biofeedback is the process of gaining awareness of many physiological functions primarily using instruments that provide information on the activity of those same systems, with a goal of being able to manipulate them at will. Some of the processes that can be controlled include brainwaves, muscle tone, skin conductance, heart rate and pain perception (McCraty *et al.*, 2001).

MUSE-EEG: It is a brain sensing headband which works by sensors on the forehead and behind the ears and tracks the brain activity. It is wirelessly connected to the muse app which can be downloaded on the android handset (Muse™, 2018).

Neuro feedback: Neuro feedback (NFB) is a type of biofeedback that uses real-time displays of brain activity—most commonly electroencephalography (EEG), to teach self-regulation of brain function (Hammond, 2007).

Breathing apps: Deep-breathing apps guide you through breathing exercises to help keep you alert, focused and productive (Chittaro & Sioni, 2014).

CHAPTER 2

LITERATURE REVIEW

This literature review provides the reader an insight of biofeedback and neuro feedback and its application in sports setting. It also highlights the importance of breathing techniques as a coping strategy for athletes. Moreover the significance of imagery in sports along with different imagery questionnaires has also been mentioned.

2.1 Introduction to Biofeedback and Neuro feedback

Excessive stress and tension are major threats to optimal athletic performance. The goal is to help the athletes optimise the management of their stress response through self-awareness and self-regulation of the activation levels of their autonomic and central nervous systems. Intervening at the level of the nervous system through the use of biofeedback and neurofeedback assessment and training can enhance an athlete's competitive advantage (Dupee & Werthner, 2011). If the stress appears as tightness and rigidity, then simple relaxation or breathing exercises may be useful, including the use of the Jacobsen's deep muscle relaxation technique (Suinn, 2005).

Biofeedback means to give immediate information or feedbacks to an individual about his or her body's physiological operations of which that person is normally unaware. So in this way the person can get information about his blood pressure or brain wave produced at that moment in time. The range of feedback modalities has enabled the people to get an awareness about their psychological state and its resultant physiological response. Through biofeedback training, the sports practitioner can identify inappropriate biological responses of an individual and can implement psychological strategies such as, positive self-talk or emotional regulation

(McCraty *et al.*, 2001). The aim of using biofeedback training is to enable the client to self-regulate his or her physiological processes and to implement the strategies in their daily life situations without the use of modalities (Blumenstein *et al.*, 1995). Recently, biofeedback training has become increasingly popular for its proven success in peak performance training.

Biofeedback related to brain's physiological processes is known as neurofeedback. Neurofeedback training is brain wave biofeedback (Hammond, 2007). In other words it is a way to train brain activity. To understand neurofeedback it is essential to have a knowledge of brain waves. Brain waves are the electrical signals which are produced as a result of brain cells communication with each other (Van Berkum, 2008). These waves reveal us our feelings, stress levels and overall brain function. The use of sensors on the scalp as in the case of EEG (which will be explained in the upcoming topics) allows to measure and monitor the brain activity and identifies the specific activity related to the rise of specific symptoms. As the areas of concern are known then a training plan can be made and implemented to get the brain in order. That's what the neurofeedback training protocol involves (Brain Works, 2018).

2.2 Types of Biofeedback and Neurofeedback Modalities

Previously, we have discussed about biofeedback and neurofeedback, now let's have a look over the types of modalities related to the use of biofeedback and neurofeedback. For different physiological variables there are different modalities. The types of these modalities are as follow:

2.2.1 Electroencephalography (EEG)

The human nervous system works, coordinates and conveys messages through electrical signals called nerve impulses. These nerve impulses are conducted along specialised functional units known as neurons which surround the entire nervous system. A way to understand this electrical activity is via the use of electroencephalogram (EEG). EEG is a

physiological method to detect all the electrical activity generated by the brain from electrodes placed over the scalp of the human head. The activation of neurons causes the production of local current flows. EEG mainly measures the currents produced by the synaptic dendrites of the neurons in the cerebral cortex. The variances in electrical potentials are caused by summed postsynaptic graded potentials from the neurons that create an electrical polarity between the body of neurons and the neural branches. The action potentials in the neurons mainly consist of Na+, K+, Ca++ and Cl- ions which are pumped across brain cell membranes in the direction governed by membrane potentials (Teplan, 2002). Only the huge amount of active neurons can produce electrical potentials detectable on the head surface. The low amplitude electrical signals recorded by the electrodes on the scalp are amplified and then stored in the computer memory. The detection of normal and abnormal brain wave patterns through EEG has been found to be an effective tool in the areas of neurology, neurophysiology and psychophysiology.

2.2.2 Brain Wave Types in EEG

The primary brain wave patterns are obtained by instructing the individual to close his/her eyes and be relax. The brain waves are mainly sinusoidal in shape. These are measured from peak to peak and range from 0.5 to 100 microvolts in amplitude. The power spectrum of raw EEG signal is derived from the Fourier transform. The spectrum is continuous but the brain state of each individual can make certain frequencies more dominant. Brain waves have been classified into four fundamental groups as shown in figure below:

- beta (>13 Hz) generated in a state of physical and mental relaxation
- alpha (8-13 Hz) generated in a state of alertness and agitation
- theta (4-8 Hz) generated in light sleep or in highly relaxed state
- delta (0.5-4 Hz) emitted during sleep

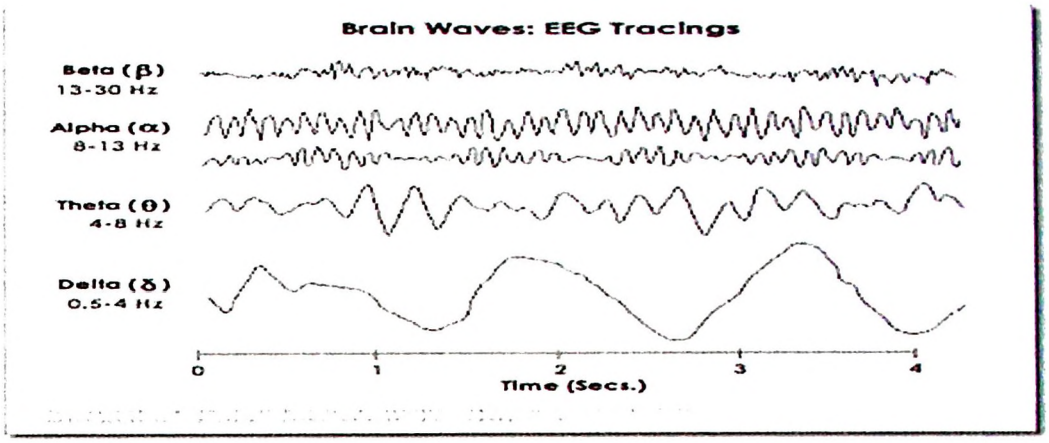

Figure 2.1 Types of Brain Waves

2.2.3 EEG Measurements

Electroencephalography involves recording system consisting of:

- Electrodes with conductive media
- Amplifiers
- A/D converter
- Recording device

Electrodes pick the signal from the scalp, amplifiers boost the low amplitude brain waves and computer stores and displays the obtained data. The recordings of brain action potentials from the head surface allow the measurement of changes over time in electric circuit conducting between active and a reference electrode (Walia *et al.*, 2015). A third ground electrode is required to get voltage difference by subtracting the same voltages at active and inactive (reference) electrode. Single-channel EEG measurement employs one active, one reference and one ground electrode. On the other hand, multi-channel configurations can consist of 64,128 or 256 active electrodes. EEG done via single-channel method is preferred since it can be easily used in sport settings. In this method, active electrode is placed properly

onto the scalp over the area of interest, for instance, the frontal cortex. The reference electrode is placed on a comparatively inactive area such as the tip of the nose or ear lobe.

2.2.4 EEG-headband (MUSE)

In this modern era of technology, there is more focus on the invention of portable devices. One such way has been implicated in the domain of EEG equipment as well. Since the standard EEG machine is big in size and requires a large room, so it is not feasible to incorporate it in every environment easily as it is not practical for the purpose at hand. Recently, EEG brain sensing headband has been launched which can measure brain activity in a similar manner to the complex design of it.

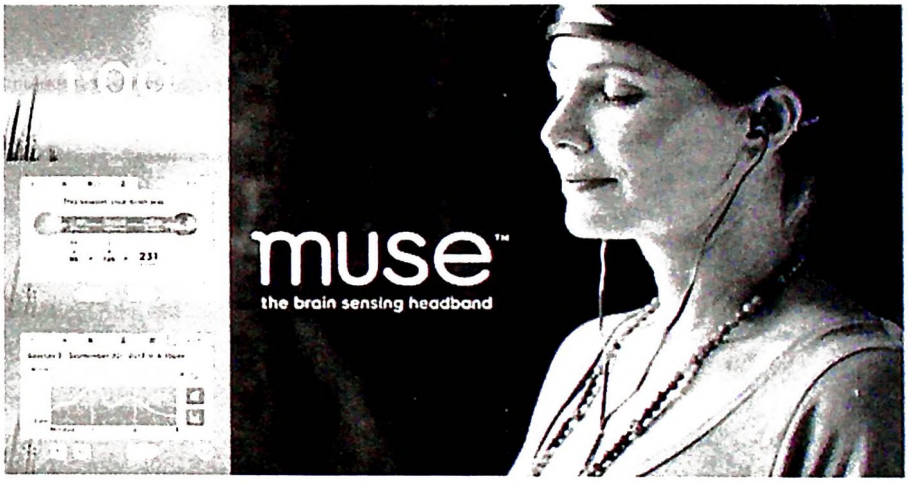

Figure 2.2 Muse device demonstration

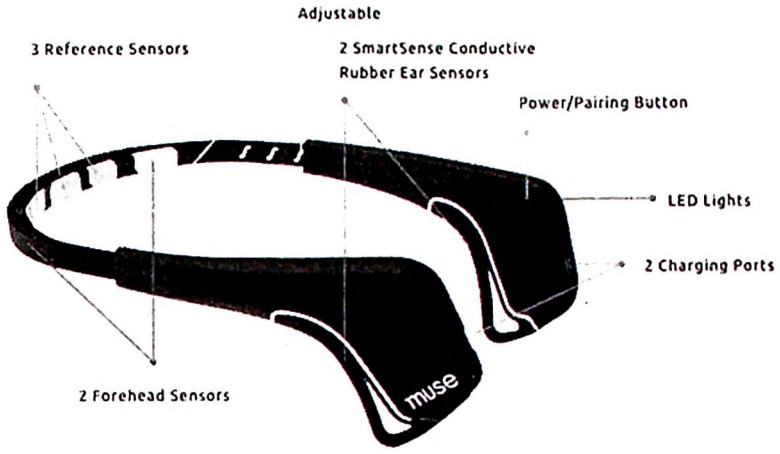

Figure 2.3 Muse headband

2.2.5 Measurement of brain activity with Muse

Muse headband consists of 7 finely calibrated sensors, two on the forehead, two behind the ears and three reference sensors. These sensors detect the brain activity. Firstly, the Muse mobile app has to be downloaded into the mobile hand set which is available for both the android and the ios operating systems. Secondly, the muse headband is connected by the Bluetooth to its app in the mobile. Finally, the headband is placed on the person's head, the headband detects the brain activity and displays it on the mobile screen in the form of waves providing a real-time feedback of the mental state (Muse™, 2018).

2.2.6 Muse reliability

It is essential for the tool to be reliable in measuring what it is supposed to measure. In a study to identify vigilance lapse using sparse EEG electrode arrays (with only 4 electrodes: 2 electrodes at the forehead and 2 electrodes behind the ears) known as muse headset. It was observed that it can detect vigilance state with 95% accuracy (Armanfard *et al.*, 2016). In another study to investigate mental state recognition through wearable EEG headset, it was

observed that there was a significant potential of wearable EEG devices in differentiating cognitive states between situations with large contextual but subtle apparent differences (Bashivan *et al.*, 2016).

2.2.7 Muse application in sports

Since the EEG detects the brain activity and displays it on the screen so it helps in the interpretation of brain states in terms of increased arousal, anxiety and stress. This is of significant importance for sports psychologists as they have to check athletes' mind states pre and post-performance and train them through neurofeedback training protocols. The use of complex EEG systems is impractical in the sports settings so a portable approach like Muse headband is highly desirable for the sports psychologists. In a study to investigate the effects of sports training on sleep characteristics of the Asian adolescent athletes using EEG-headband together with other modalities, it was found that EEG-headband successfully provided data for the sleep patterns of the athletes as it was revealed that high intensity athletes obtained more amount of deep sleep than low intensity athletes (Suppiah *et al.*, 2015). Sports psychologists can also incorporate mindfulness meditation with Muse headband since a research study supports that, in this study effects of mindfulness meditation neurofeedback on Stroop performance were analysed and it was found that participants made fewer errors in the Stroop task after going through the intervention (Balgemann, 2015). In another study which investigated prediction of baseball batting performance using background EEG with Muse headband, it was found that predicting the baseball batting performance with portable EEG system is highly credible (Pluta III, 2017). There are not enough studies in the sports domain regarding EEG Muse headband, so more studies should be conducted in order to support the idea of usage of this device in the sports setting.