THE EFFECT OF FIBOD SMART BALANCE WITH “ENDLESS RUN” GAME IN IMPROVING MEMORY AND ATTENTION IN HEALTHY YOUNG ADULTS: AN EYE TRACKING STUDY

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by

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LIST OF SYMBOLS

<	Less than
>	More than
=	Equal

LIST OF ABBREVIATIONS

AOI	Area of Interest
BESS	Balance Error Scoring System
FIBOD	Fitness Balance Board
kg	Kilograms
LCR	Lure Correct Rejection
LDI	Lure Discrimination Index
LFA	Lure False Alarm
LTM	Long-term Memory
ms	Milliseconds
MST	Mnemonics Similarity Task
STM	Short-term Memory
USM	Universiti Sains Malaysia
VST	Visual Search Task

LIST OF APPENDICES

KESAN KESEIMBANGAN PINTAR FIBOD DENGAN PERMAINAN "ENDLESS RUN" DALAM MENINGKATKAN INGATAN DAN PERHATIAN DI KALANGAN ORANG DEWASA MUDA YANG SIHAT: KAJIAN PENJEJAKAN MATA

ABSTRAK

PENGENALAN: *Exergames* merupakan permainan video secara fizikal yang dilihat sebagai pendekatan latihan yang menarik untuk meningkatkan fizikal aktiviti serta memberi manfaat dalam peningkatan fungsi kognitif melalui neuroplastik.

OBJEKTIF: Kajian ini bertujuan untuk mengkaji kesan latihan keseimbangan pintar FIBOD yang merupakan sejenis *exergame* merangkumi alat papan keseimbangan pintar FIBOD serta permainan "*Endless Run*" dalam meningkatkan memori kerja dan perhatian visual orang dewasa muda.

METODOLOGI: Kajian ini merupakan sejenis kajian kawalan rawak dengan reka bentuk ujian pra dan pasca dimana kesan latihan keseimbangan pintar FIBOD dinilai setelah tempoh intervensi sebulan. Seramai 34 orang peserta (umur min = 22.41 ± 1.2 years) dari Universiti Sains Malaysia (USM), Kampus Kesihatan, Kubang Kerian, Kelantan telah mengambil bahagian dalam kajian ini. Peserta dibahagikan secara rawak kepada dua kumpulan (Kumpulan Eksperimen, n = 17 dan Kumpulan Kawalan, n = 17) dan menjalani ujian pra dan pasca penilaian Sistem Pemarkahan Ralat Imbangan (BESS), tugas kesamaan mnemonik (MST) dan tugas carian visual (VST) dengan memakai penjejakan mata. Kumpulan eksperimen menerima 12 sesi latihan keseimbangan pintar FIBOD dengan tiga kali seminggu selama empat minggu di mana setiap sesi berlangsung selama 15 minit sementara tidak ada intervensi yang diterapkan pada kumpulan kawalan. Ujian pra dan pasca ketepatan tindak balas dan masa reaksi yang diperoleh dari tugas MST dan VST dianalisasi antara kedua-dua kumpulan.

DAPATAN: Ujian statistik parametrik (ujian *Repeated Measured ANOVA*) menunjukkan perbezaan yang tidak signifikan bagi ketepatan tindak balas (F (1,32) = 3.17, p = 0.085, ηp2 = 0.09) dan masa reaksi (F (1,32) = 0.03, p = 0.856, ηp2 = 0.001) memori kerja selepas latihan keseimbangan pintar FIBOD. Selain itu, tidak ada perbezaan yang signifikan bagi ketepatan tindak balas (F (1,32) = 3.13, p = 0.087, ηp2 = 0.09) perhatian visual namun terdapat perbezaan yang signifikan bagi masa reaksi (F (1,32) = 4.52, p = 0.041, ηp2 = 0.12) perhatian visual setelah latihan keseimbangan pintar FIBOD dimana perbandingan dengan menggunakan ujian *Paired Sample T-test*, menunjukkan bahawa kumpulan eksperimen mempunyai perbezaan yang signifikan dalam masa reaksi [*mean difference* = 48.35, 95 % CI = (19.68, 77.03)], p = 0.003 mereka.

KESIMPULAN: Latihan keseimbangan pintar FIBOD boleh dianggap sebagai satu latihan keseimbangan yang berpotensi untuk meningkatkan fungsi kognitif perhatian visual di kalangan golongan orang dewasa muda.

Kata kunci: Imbangan, Latihan keseimbangan, Memori Kerja, Perhatian Visual, Penjejakan mata.

THE EFFECT OF FIBOD SMART BALANCE WITH "ENDLESS RUN" GAME IN IMPROVING MEMORY AND ATTENTION IN HEALTHY YOUNG ADULTS: AN EYE TRACKING STUDY.

ABSTRACT

INTRODUCTION: Exergames are physically active video games that regarded as an attractive training approach to promote interest in physical exercise while also enabling improvement in cognitive function through neuroplasticity.

OBJECTIVE: This study aimed to investigate the effect of Fitness Balance Board (FIBOD) which is a balance-based exergame composed of smart balance board and video game "Endless Run" in improving working memory and visual attention of young adults.

METHODOLOGY: A randomized control trial study with pre- and post- test design was applied where the effect of FIBOD intervention was measured after one-month. A total of 34 participants (mean age 22.41 ± 1.2 years) were recruited from Universiti Sains Malaysia (USM), Health Campus, Kubang Kerian, Kelantan. The participants were randomly allocated into two different groups (Experimental group, n = 17 and Control group, n = 17) and underwent pre- and post-test of Balance Error Scoring System (BESS) assessment, Mnemonics Similarity Task (MST) and Visual Search Task (VST) paired with an eye tracker. The experimental group received 12 sessions of FIBOD training with three times a week over a period of four weeks with each session lasted for 15 minutes meanwhile no intervention was applied to control group. The pre- and post-test of response accuracy and reaction time from both MST and VST task were analysed between both groups.

RESULTS: The statistical test of repeated measure ANOVA showed that there was no significant difference in response accuracy (F (1,32) = 3.17, p = 0.085, ηp2 = 0.09) and reaction time (F (1,32) = 0.03, p = 0.856, ηp2 = 0.001) of working memory after FIBOD smart balance training. There was also no significant difference in response accuracy (F (1,32) = 3.13, p = 0.087, ηp2 = 0.09) of visual attention however there was a significant difference in reaction time (F (1,32) = 4.52, p = 0.041, ηp2 = 0.12) of visual attention after FIBOD smart balance training thus a planned comparison using paired samples t-tests, revealed that the experimental group showed a significant difference [mean difference = 48.35, 95 % CI = (19.68, 77.03)], p = 0.003 in the reaction time.

CONCLUSION: FIBOD smart balance training can be regarded as an effective balance-based exergame for improving visual attention in healthy young adults.

Keywords: Balance, Exergame, Working Memory, Visual Attention, Eye tracking

CHAPTER 1

INTRODUCTION

Balance is the capacity to preserve control over the body movement such as changing directions, pausing, commencing or maintaining the body's in a specific position (Çetin et al., 2018). It is a convoluted mechanism involving the synchronization and movement of ankle, knee and hip joints followed by integration of multiple human sensory modality such as visual, auditory and kinetic (Ibrahim et al., 2016). Balance skill is important for ones in their life regardless of any population from adolescent to elderly as balance impairment will lead to limitation on one's daily living and active engagement in community. For instances, postural instability can cause complexities in performing one's daily motor activity or tasks due to the deteriorations in the neuromuscular systems (Straudi et al., 2017). Emerging studies had showed that balance training does have positive affect in cognitive function by triggering different metabolic mechanism and brain pathways (Martin-Niedecken & Schättin, 2020; Rogge et al., 2018; Schättin et al., 2016). It was found that the vestibular system is the main sensory system that activated during balance activity. The vestibular system has a significant role in administering information on movement, spatial orientation and body posture to our brain which is crucial for our daily activities (Nam et al., 2016).

There are extensive researches that had been conducted to determine the relationship between balance-based training and cognitive abilities among children, adolescent and older adults (Brouwer et al., 2017; López-Serrano et al., 2021; Rogge et al., 2017) yet, study conducted among young adults is still in its infancy. Henceforth, the current study applied a balance-based training known as Fitness Balance Board (FIBOD) among young adults to determine its effect in improving cognitive function. FIBOD is a combination of the video game "Endless Run" and the exercise equipment "Smart Balance Board," which is also often identified as exergaming. Exergaming are technology-driven and movement-based video games which is comparatively an emerging idea since mid-2006 further seen as a recent rise in popularity and intrigued used for neurorehabilitation in elderly people (Sinclair et al., 2007). In spite of the fact that, most of the profitable exergames were fundamentally created for amusement intent, however recently exergames have been considered beneficial to promote interest in physical training, along with providing compliance towards work out and recovery tasks (Anders et al., 2018). Interestingly, older adults established more advantages in both aspect of cognition and physical through balance-based exergame such as Nintendo Wii-Fit (Martin-Niedecken & Schättin, 2020; Netz, 2019; Schättin et al., 2016). In the current study, the FIBOD provides a video game-based balance training that integrates different physical movement and interactive game elements which is anticipated to consolidate certain cognitive abilities of young adults. Prior literatures had showed that exergames able to provide familiar and attractive training approach at the meantime achieved cognitive, physical and mental outcome in elderly adults (Rogge et al., 2018; Schättin et al., 2016). Therefore, the purpose of this study was to determine whether the cognitive function of working memory and visual attention able to be improve in young adults as both of these cognitive processes are essential for everyday activity and knowledge acquisition.

Working memory defined as a limited storage that can withhold new knowledge temporarily and crucial in inference making further provide guide in making decision (Sala et al., 2001). The knowledge is sustained in working memory by maintaining, upholding or elaborating further undergoes adaptations or alteration to support the task facing where selective processing is applied to promote attention towards the knowledge that's highly compatible and essential (Sala et al., 2001). Meanwhile, visual attention is defined as an attentional state in which the image of retina and the mechanism of ‘sensory' neurons over the visual cortex are held constant in focusing a crucial component of a location or visual scene (Carrasco, 2011). It helps us to fastidiously discriminate huge measure of details by prioritizing few crucial details and ignoring irrelevant information or distraction (Carrasco, 2011). Apart from that, the eye tracking in the present study was used to understand how and why eye movements were made and how information was gathered visually during the cognitive task. The eye tracker can provide possible insight on information processing of the underlying occurrences of encoding phase during mnemonics similarity task (MST) and target detection during visual search task (VST). The eye movement parameter of “Fixation Duration” was analysed from the encoding phase with the response type from detecting target and lures during the recognition phase of Mnemonics Similarity Task (MST), followed by the “Time to First Fixation” to reach target’s area of interest (AOI) in visual search task (VST) to compute the reaction time of visual attention. Therefore, the current study applied the FIBOD smart balance training with “Endless Run” game to study the improvement in working memory and visual attention of healthy young adults with an eye tracker.

1.1 Problem statement

Prior literatures had showed that balance training indeed contributes positive effect to cognitive function such as executive function, sustained attention, spatial cognition and memory through different activation of metabolic mechanism, cortical and sub-cortical pathways (Martin-Niedecken & Schättin, 2020; Rogge et al., 2018; Schättin et al., 2016). However, most of the study have addressed the use of balance exercise in the form of balance ability and rehabilitation for elderly adults due to aging and postural instability (Ibrahim et al., 2016; Nam et al., 2016; Rogge et al., 2017). Eventually, there has been a paucity of research on the effects of balance-based training on cognitive function of young adults as the majority of documented balance training studies use the balanced board for balance training and to contribute to the prevention and rehabilitation of joint injury, postural stabilization, and cognitive function in the population of elderly adults (Martin-Niedecken & Schättin, 2020). Despite the fact that some studies have addressed this topic variable among young adults, yet very different approaches and methodologies had been used (Ciria et al., 2017; Norouzi et al., 2019). It is very important to conduct among young adults especially the memory function that may start to decline in the early adulthood.

Thus, the focus of this study was to assess the cognitive ability of young adults after FIBOD smart balance training. It is important to determine whether it is possible to improve working memory and visual attention with specific training regimes such as balance-based exergame in healthy young adults where in this study is FIBOD smart balance board with “Endless Run” game. This is a balance board that had been tested in accessing balance performance for the population of elder adults in Malaysia (Khor et al., 2018; Xiang et al., 2017). Thus, this study able to utilize the smart balance board in balance training to identify its effect in improving the working memory and visual attention of young adults. Furthermore, it is critical to expand our understanding of the effects of FIBOD smart balance training with “Endless Run” game on cognitive functions such as working memory and visual attention in young adults because both of these cognitive functions play an important role in knowledge acquisition and learning. Hence, the improvement in working memory and visual attention of young adults can demonstrate the generalizability of balance skills to cognitive improvement.

1.2 Study rationale

There had been recent increase in research particularly concerned with the effect of physical activity on cognitive abilities of adults by means of neuro-cognitive tests especially for elderly adults. Prior literature had shown that balance training able to improve the attention and memory of children (Koutsandréou et al., 2016; Haghgoo, 2018) and elderly (Eggenberger et al., 2016; Schättin et al., 2016; Stojan & Voelcker-Rehage, 2019; Zettel-Watson et al., 2017) however not specifically in young adults. Recent to date, there was less studies had compared the perceived response between balance-based exergame training and cognitive ability in the young adults. Therefore, the current study able to address the research gap by applying balance-based exergame training that incorporate the smart balance board and "Endless Run" game towards young adults to study the effect in improving working memory and visual attention further measuring the eye movement during the task.

Furthermore, López-Serrano et al. (2021) suggested that exergames can be transformed into the constructivist teaching initiatives via a well-designed interactive video game to improve cognition. This is due to the fact that the concurrent use of emerging technologies with gamification had showed to significantly raise motivation to learn and acquired knowledge, particularly in children and adolescents (López-Serrano et al., 2021). Henceforth, the findings of present study can be beneficial for academic to integrate balance-based exergaming as an additional tool for optimizing the young adult's cognitive development. Thereupon, FIBOD can be recommended as an innovative tool to promote the enhancement of cognitive function.

1.3 Research Question

1.3.1 Research Question 1

Is there a significant difference in working memory after FIBOD smart balance training with “Endless Run” game in young adults?

1.3.2 Research Question 2

Is there a significant difference in visual attention after FIBOD smart balance training with “Endless Run” game in young adults?

1.4 Objective

1.4.1 General Objective

To compare the working memory and visual attention of young adults before and after the FIBOD smart balance training with “Endless Run” game.

1.4.2 Specific Objective

1. To determine the effect of FIBOD smart balance training with “Endless Run” game in improving working memory.
2. To determine the effect of FIBOD smart balance training with “Endless Run” game in improving visual attention.

1.5 Hypothesis

$H1^{0}$ There is no significant difference in response accuracy of working memory after FIBOD smart balance training with “Endless Run” game.

$H1^{a}$ There is a significant difference in response accuracy of working memory after FIBOD smart balance training with “Endless Run” game.

$H2^{0}$ There is no significant difference in reaction time of working memory after FIBOD smart balance training with “Endless Run” game.

$H2^{a}$ There is a significant difference in reaction time of working memory after FIBOD smart balance training with “Endless Run” game.

$H3^{0}$ There is no significant difference in response accuracy of visual attention after FIBOD smart balance training with “Endless Run” game.

$H3^{a}$ There is a significant difference in response accuracy of visual attention after FIBOD smart balance training with “Endless Run” game.

$H4^{0}$ There is no significant difference in reaction time of visual attention after FIBOD smart balance training with “Endless Run” game.

$H4^{a}$ There is a significant difference in reaction time of visual attention after FIBOD smart balance training with “Endless Run” game.

1.6 Operational Definition

Balance

The balance in this study is defined as the total score of error on the BESS score card from the Balance Error Scoring System (BESS) assessment.

Working Memory

The working memory in this study is defined as the mean lure discrimination index (LDI score) as response accuracy and the mean reaction time of correct responses in milliseconds (ms) from mnemonics similarity task (MST).

Visual Attention

The visual attention in this study is defined as the percentage (%) of response accuracy for correct responses and the mean reaction time in milliseconds (ms) for searching target out of distractor in visual search task (VST).

CHAPTER 2

LITERATURE REVIEW

2.1 Balance

Physical activity is beneficial not only in enhancing athletic performance but promoting the life-long ability of the human brain in adapting daily task demands. Physical training was found to improve human cognition through the enhancement of structure and function of human brain (Voss et al., 2013). Consistent physical exercise was found to result in long changes that improve brain integrity and functioning further promote cognitive fitness (Latino et al., 2021). Recently, there had been increasing studies conducted to study the influences of physical activity such as aerobic training, resistance training and motor training on cognitive function. As such, regular aerobic fitness was found to increase sustained attention in young adults (Ciria et al., 2017) and increase in hippocampus capacity of young and elderly adults (Erickson et al., 2011). Apart from aerobic exercise, motor-based exercise that emphasized on stance and postural balance also tend to give rise to brain changes (Rogge et al., 2018). Coordinative exercise such as balance-based training allows the activation of the cerebellum which is responsible for motor control and motor learning further influences variety of higher cognitive functions (Dunsky, 2019; Latino et al., 2021). Most of the past studies had shown that balance training able to positively affect cognitive function by triggering different metabolic mechanism and brain pathways (Liu-Ambrose et al., 2012; Martin-Niedecken & Schättin, 2020; Rogge et al., 2018; Schättin et al., 2016). Therefore, this study aimed to determine the effect of FIBOD smart balance, a balance-based exergame, on the cognitive function of working memory and visual attention of young adults.

Balance is the capacity to preserve control over the body movement such as changing directions, pausing, commencing or maintaining the body's in a specific position (Çetin et al., 2018). On the other hand, balance training is defined as a form of postural control and flexibility exercise that reinforce the muscles in respective stance control to keep ones upright and prevent falls (Rogge et al., 2017). Balance-based training applies the homogenization of sensory modality such as vision, vestibular sense, and motor-associated multisensory cues for information processing further activate the somatosensory system and vestibular system respectively (Rogge et al., 2018). The activation of somatic sensory system is to provide information about the current state of joints and ligaments, such as strain or flexing, along with discomfort in joints, muscle tissues, and connective tissues (Lapier, 1998). A functional near-infrared spectroscopy (fNIRS) study was conducted on 10 healthy adults where the participants were required to perform three blocks of balance based physical activities (Herold et al., 2017). A block composed of three stances such as standing on the floor for 30 seconds (baseline) followed by another 30 seconds repeating the same stance. Then, the participants were required to pace and maintain balance with feet next to each other for 30 seconds on top of the balance board (balance condition) followed by resting period by standing on the floor again for 30 seconds. The finding showed that there were larger BOLD responses in postcentral gyrus (PoG), precentral gyrus (PrG) and supplementary motor area (SMA) during postural and balance control on the balance board (Herold et al., 2017). This confirmed that balance activity is highly related to the activation of sensorimotor cortical areas that responsible for proprioception of body and balance control.

On the other hand, the vestibular system is activated during balance activity to cater the brain on the sense of movement, spatial orientation and body posture (Nam et al., 2016). This system is located extremely within the inner ear and adjacent to thick temporal bones (Moossavi & Jafari, 2019; Rogge et al., 2018). The mid-posterior fundus of the Sylvian fissure in the neural network is also considered the center of cortical processing for neurosensory cues, with two vestibular areas located here; the posterior insular cortex (PIC) and parietoinsular vestibular cortex (PIVC) (Frank et al., 2016). The vestibular system plays an important role in providing information on self-movement, stabilization of our head, adjustment of eyes further preserve our body balance and movement adaptation via the processing of sensory inputs (Moossavi & Jafari, 2019). The information transmitted from the vestibular system tends to integrate with other sensory system by apportion throughout the different subcortical regions such as basal ganglia, brain stem, hippocampus, cerebellum and cerebrum that correlated with cognitive function (Moossavi & Jafari, 2019). Most of the vestibular stimulus in the cerebrum are transmitted via three channels; to the brain stem nuclei of raphe nucleus and locus coeruleus, to cerebrum areas of vision and cerebellum further to the sub-cortical areas that related to cognition such as parabrachial nucleus (PBN), the hippocampus, prefrontal cortex through thalamus (Lopez, 2013).

In the present study, balance-based intervention is chosen as prior studies had proven that balance training is favourable for continuation and development of postural stability followed by the neural adaptions on cortical and subcortical cortex (Mouthon & Taube, 2019; Rogge et al., 2018). It was suggested that balance exercises not only can activate sensorial organs for instances the somatic sensory system, vestibular system, and vision processing but also the centre nerve system which are effectual for brain aptitude and enhancement of cognitive function (Nam et al., 2016). A study conducted on memory and spatial cognition of 40 normal adults aged from 19 to 65 years old underwent two different types of training; balance training and relaxation training found that balance training able to improve the cognitive abilities notably associative memory and spatial cognition correspond with improved balance performance compare to the relaxation training (Rogge et al., 2017). This suggested that improvement in balance performance arise from the vestibular system eventually evoke higher cortical processing and neural network that moderate memory and spatial cognition (Rogge et al., 2017). In fact, Rogge et al. (2018) conducted another study on morphological brain changes after balance training through high resolution of MRI T1-weighted images on healthy adults. It was found that balance training induces changes particularly in the left temporal lobes and the circular insular sulcus that engaged in the processing of voluntary movement (Rogge et al., 2018). Henceforth, the result suggested that balance training able to evoke neuro-adaption in cortical areas that connected with vision and vestibular voluntary movement perception that responsible for spatial orienting and memory enhancement.

2.2 Exergame

Within the past, physical exercise such as motor training, fitness training and sport activities showed up to actuate physical and metabolism changes that in turn encourage specific cognition functioning through structural and functional augmentation (Monteiro-Junior et al., 2016; Ramírez-Granizo et al., 2020). At the meantime, cognitive training, such as brain games, appeared to accelerate the trained cognitive capacities almost entirely with a very limited transfer effect to inferior or untrained domains of cognition (Monteiro-Junior et al., 2016). As a result, the influence of both physically and cognitively training vary widely in their effects on cognition and brain progression, contributing to the emergence of exergames, a new approach of combined intervention to ensure maximum training proficiency and cognitive benefits (Ramírez-Granizo et al., 2020). Researchers and instructional designers are increasingly using this new technology to create exergaming that included cognitive training platforms such as video games with cognitive element or gamification to investigate its effect on cognitive processing, neuroplasticity and age-related differences (Ramírez-Granizo et al., 2020). NintendoWii, Dance Revolution or Xbox Kinect together with the implementation of video games are some example of commercial exergames that had already demonstrated robust positive effect on cognition and physical training (Stojan & Voelcker-Rehage, 2019). Exergames is also refer as movement-based video games that often generated from the kinesthetics movement with high neuromuscular energy compared to conventional simplify postural control motor activities (Netz, 2019). The likely advantages of the exergames compared to conservative balance-based intervention are motivation increment thereupon rigid adherence, offer dual task training with synergistic effect (combine physical and cognitive exercise), various forms of feedback in terms of visual, auditory or even tactile (vibration) and provide individual progress through transformation and adjustment of the training intensity based on level of the player (Willaert et al., 2020).

Recent researches had reported that merging physical exercise and cognitively challenging tasks such as interactive video game that resemble the body and brain integration for balance training were found to be more effective in consolidate certain cognitive abilities and enhances neuroplasticity compared to traditional or conventional training approaches (Bense et al., 2001; Martin-Niedecken & Schättin, 2020). A study was conducted by Schättin et al. (2016) on older adults to compare an exergame over a normal balance training in relation with electroencephalographic (EEG) waves over the Prefrontal Cortex (PFC), executive function (EF), and gait performance. All the older adults underwent 24 training sessions of three times a week with 30 minutes per session and found that the exergame training and balance training contribute different proportion of neuroplasticity in prefrontal cortex. It was found that all four-executive function (EF); divided attention, working memory, set shifting and No-go relatively improved within the participants in exergame meanwhile in the balance group only one executive function was improved which is set shifting (Schättin et al., 2016). Eventually, this indicates that video game-based physical exercise is more effective in improving cognitive abilities compared to conventional balance training. In the present study, FIBOD is a balance-based exergames where the primary aspects of the training are facilitated by an electronic equipment; FIBOD smart balance board and an interactive video game named “Endless Run” with the input as balance of players as well as the feedback of the balance board displays via human-computer interfaces. Therefore, the present study aimed to determine the effect of FIBOD smart balance training with ‘Endless Run” game in improving the working memory and visual attention of heathy young adults with an eye tracker.

2.3 Working Memory

Emerging work suggests that coordinative and postural control activity positively associated with various cognitive-related variables especially on memory function (Rogge et al., 2017, 2018). It was found that balance exercise is corresponded to an increased volume of hippocampus for memory formation and retrieval of new memories followed by the basal ganglia, parietal brain areas and frontal cortex for memory enhancement via the pathways of Vestibulo-thalamo-cortical (Moossavi & Jafari, 2019). Prior literatures had found that executive function such as working memory is relatively one of human cognition that reduce along with age progression from young adults to elderly (Brockmole & Logie, 2013; Klencklen et al., 2017;

Bullock et al., 2018). Thus, this study concentrated on cognitive function of working memory as research examining working memory specifically in young adults with balance-based exercise is limited, even though working memory had been found to decline at the early adult stage. Besides, working memory is one of the utmost features of cognition in daily living particularly important to permit us for interim storage and alteration of knowledge during learning (Wadha, 2018).

Working memory is refer to the information processing mechanism which function to store dynamic information for short-term periods and undergoes manipulation through three basic processes of embedding, maintenance, and retrieval (Sala et al., 2001). However, the information processing that occurs in working memory can be overwhelmed by various factor such as individual's differences, intellectual capability or mental effort in perceptual load (Sala et al., 2001). Baddeley and Hitch designed a comprehensive model of working memory in which the retrieved knowledge is expected to be stored in two domain-specific subsystems manifested by the central executive: the phonological loop and the visuo-spatial sketchpad. The phonological loop in charge for interim prolongation of linguistic and acoustic items meanwhile the visuo-spatial sketchpad responsible for items encoded via visual or spatial (Sala et al., 2001). Henceforth, working memory had been defined as a short term memory that require temporarily storing and manipulation of different information to commence an actions (Sala et al., 2001). Besides, the main distinctions between long-term memory (LTM) and short-term memory (STM) are duration and capacity, with STM used for holding sensory events, movement, and cognitive information, such as digits, words, or items, for a brief period of 18-30 seconds with a capacity of approximately four chunks or pieces of information, whereas LTM may last for months, years, or even decades with an unlimited capacity (Cowan, 2008).

However, even while working memory and STM considerably overlap, the distinction that is typically made is that working memory involves the storage, processing, and remembering of memory over a period of time, whereas STM refers to the temporary storage of information in memory hence working memory tasks have been suggested to be more difficult in terms of attention control compared to STM tasks (Cowan et al., 2005; Chai et al., 2008).

The underpinning functional brain system wherein exergaming may have an impact on executive function of working memory, vary largely across studies, and are still poorly understood in the population of young adults. Prior studies on the effect of exergames or motor-demanding intervention such as balance exercise had shown positive transfer effects on working memory especially among children (Koutsandréou et al., 2016) and older adults (Stojan & Voelcker-Rehage, 2019; Zettel-Watson et al., 2017). In study conducted by Koutsandréou et al. (2016), the children were involved in 10 weeks of an additional afterschool balance exercise regimen that befall for 45 minutes with training frequency of per week three times. The result showed that children who underwent motor training had significantly improved in letter digit span working memory task after the intervention period compared to cardiovascular training (Koutsandréou et al., 2016). It was explained that motor training involves activation of sensory and higher-order cognitive processes that are needed for motion as well as functional aspects of motor stability. Eventually, this study suggested that motor-dominant training can be a potential approach to improve working memory in preadolescent children (Koutsandréou et al., 2016).

The similar effect in working memory was also found in balance-based intervention studies that conducted with older adults. The review on past studies that conducted with older adults aged from 60 to 85 years old in relation with exergames intervention were found to applied varying training period of more than four weeks (e.g. 8 weeks, 12 weeks and 16 weeks) with different training durations (e.g. 30 to 45 minutes) (Stojan & Voelcker-Rehage, 2019). Yet, there were only two studies that used exergames interventions for 8 weeks on healthy older adults to determine the effect on working memory (Eggenberger et al., 2016; Schättin et al., 2016). Both of the study found to have positive effect on participants' working memory and suggested that exergaming would influence frontal brain regions network which has a direct impact on executive functions of working memory (Eggenberger et al., 2016; Schättin et al., 2016). Apart from that, study from Zettel-Watson et al. (2017) had suggested that better dynamic balance and aerobic tolerance able to enhance perceptual speed, inhibitory, and working memory of elderly. It was found that the balance scale and a 6-minute walk were explicitly connected to information processing, inhibitory, and working memory, demonstrating that good physiological capability resulted in higher cognition task scores (Zettel-Watson et al., 2017). This was also supported by the findings of a study conducted by Norouzi et al. (2019) on older adults who received 12 sessions of 60-to-80-minute motor-cognitive dual task training over four weeks. It was discovered that dual-task interventions with combine motor and cognition training found to impact and promote working memory of older adults correspond with improvement in balance performance throughout three time points; baseline, post-intervention and finally during follow-up (Norouzi et al., 2019). As a result, dual-task training, such as exergaming with motor-cognitive training that recruits bodily-postural control, is not only composed of voluntary motor tasks to facilitate motor functions but is also capable of favouring cortical and sub-cortical working memory networks in the brain.

Since most of past study had been conducted on the population of children and older adults, it is still unclear whether the similar effect can be found in young adults on improving working memory. As far concern, there are indeed few studies that had been conducted on young adults for example Wadhwa (2018) conducted a study to portray the proficiency of exergames; Nintendo WII brain training and NintendoWII exergame in favouring the improvement of cognitive abilities; processing speed, working memory and visuospatial among 48 young adults who underwent one whole month of training with every session duration of 30 to 45 minutes per day. The study discovered that Nintendo WII brain training games, which integrate cognitive paradigm and fine motor skills, were far more helpful in enhancing young adults' spatial cognition, visual processing, and working memory compared to Nintendo WII exergames that composed of only motor training (Wadhwa, 2018).

Followed by, another exergames-based study conducted revealed that young adults who played physically active video games (AVG) for 30 minutes performed better on computerised working memory tasks, with higher accuracy, lower encoding and retrieval latency times (Hwang & Lu, 2018). Findings from Hwang and Lu’s study suggested that playing physically active video games can act as a prime factor for executive function augmentation mainly in working memory (2018). This corresponds with study conducted by Clemenson and Stark (2018) that showed daily playing 30 minutes of 3D video game for two weeks; able to improve visual working memory. It was suggested that 3D video games have a high level of spatial information that is vividly realistic, presumably resulting real-time strategies that impact hippocampus to create a "map" or “route” presentation of the video game environment for wayfinding throughout the gaming interface subsequently support memory development (Clemenson & Stark, 2015). This in line with West et al.’s

(2018) randomised longitudinal training study with young adults which found that the hippocampus of action video game (AVG) player has reduction in grey matter using non-spatial memory strategies meanwhile applied spatial strategies showed increase in grey matter of hippocampus for action video game (AVG) player after training. The findings showed that the design of action video games for cognitive training might benefit the hippocampal system for memory improvement.

Besides, the current study determines the effect of working memory correspond to lure discrimination mediated by hippocampus whereby higher working memory capacity was associated with low false recognition (Stark et al., 2019). A review by Stark (2019) reported that implementation of interventions such as 3D video games and acute physical activity tend to demonstrate better mnemonics discrimination and improved response accuracy ultimately implies that physical exercise able to enhance neural plasticity particularly in the dentate gyrus (DG) of the hippocampus. However, mixed effect was found in the study of Bullock et al (2018) that conducted to examine the effect of age-related differences with different level of aerobic fitness on memory using mnemonics similarity task. In the study, two groups of participants; 95 young adults and 81 older adults were recruited with their aerobics fitness level measured. It was found that the LDI scores in young adults were not associated with aerobics fitness meanwhile older adults tend to show better performances in the LDI score with high aerobics fitness (Bullock et al., 2018). Eventually, it was suggested that the low rate of aerobic endurance applied resulted in a non-significant effect on positive transfer of young adult memory. Since brain development varies with age, a review on the cognitive benefit and neurophysiological effects of exergames on healthy older adults aged 60 to 85 years discovered that older adults' cognition benefits from few training sessions with relatively low physical-cognitive demand due to their lower performance measures (Stojan & Voelcker-Rehage, 2019). Meanwhile, physically and cognitively healthy young adults may require more training sessions and higher physical-cognitive demands to improve cognitive performance due to potential ceiling effects and less decreased brain functions (Stojan & Voelcker-Rehage, 2019). Besides, the young adults 'brain appears to retain many of the abilities of adolescent while also acquiring some new ones which persists into middle life, whereby the adult brain appears to be capable of rewiring itself, absorbing decades of events and habits (Phillips, 2011). Hence, this highlights the importance of the age-related dose-response association between intervention period of adults towards the cognition of memory improvement.

While there had been much research on behavioural measure of working memory, few researchers have taken into consideration of the use of eye tracking. Eye-related behaviour reflect a vital information of automated neurological processes from the intake of a visual scene to visual processing in brain region for further formation of memory (Danilov et al., 2019). Previous researches had demonstrated the occurrences of false memory can be reduced with actively remembering study items during the encoding phase to create different presentations in memory that are identifiable from similar lures (Danilov et al., 2019; Krotkova et al., 2018). Recent to date, there was only one eye tracking study conducted on mnemonics similarity task by Moliter et al. (2014) pertaining to fixation to reveal the source of false alarm. The finding was associated with "poor encoding" which claimed that lure false alarm occurred from fewer fixations compared to correctly rejected lures (Moliter et al., 2014). The study showed that lower fixation during encoding phase lead to lure false alarms compared to other response types further claimed that the encoding phase plays an important roles in behavioural response of lures. Hence, eye movements during the encoding phase can aid in the formation of memories to support memory judgement. It was suggested that attention serves as a limited resource to maintain information temporarily (memory encoding) in Baddeley's working memory model (Sala et al., 2001) whereby paying attention to a visual regions able to facilitates the visual processing of respective objects or scene in those regions and enhance the transformation and maintenance of the visual representation into working memory (Roebers et al., 2010).

Memory encoding is a multi-stage process that includes image identification, which is heavily reliant on foveal processing, as well as consolidation into working memory, which cannot be seen through visual processing (Lange et al., 2018). This correlated with study conducted by Danilov et al. (2019) proposed that the chance of making a false error also can be depended on the way of paying attention to certain important details in an image. In the eye tracking study, it was found that the ability to distinguish between a similar object and the original one related to larger fixation duration and fixation count on unique and relevant parts of the original object during the encoding phase (Danilov et al., 2019). It was also explained that the longer the fixation duration, the higher the probability to be remembered. Thus, this showed that the fixations characteristics from the encoding phase play significant roles in determining the success in the recognition phase. Therefore, by taking into consideration the findings of aforementioned studies, the current study investigates the performance of working memory using eye-tracking measures of "fixation duration" to study the initial encoding of an item with its subsequent response in recognition phase.

2.4 Visual Attention

Apart from that, prior research had discovered that motor-demanding training can provoke neuroplasticity in brain regions concerned for visual stimulation via visual-vestibular pathways, such that the area associated with visual processing in the superior transverse occipital sulcus was associated with larger grey matter changes after balance training (Rogge et al., 2018). Balance control and postural coordination required high neuromuscular demands and relatively low metabolic activation due to high attention demand on perceptual load involved in the processing of the body movement through activation of vestibular system (Netz, 2019). Recent research had proven that activation of vestibular system from proprioception and balance control had positive transfer effect on executive function of attention (Bigelow & Agrawal, 2015). The cognitive function such as visual attention is affected by changes in the vestibular inputs as the vestibular system is found to have strong reciprocal inhibition association with the visual processing system (Bense et al., 2001). Besides, the brain processing found to prioritized attentional resources first compare to other cognitive function due a strong connection between balance and visual processing during balance-based intervention (Bigelow & Agrawal, 2015; Rogge et al., 2017). However, study conducted related to exergame or balance intervention in relation to visual attention among young adults is still in its infancy, as most of the past study had been focused on the effect of aerobics fitness and resistance training on attention (Ciria et al., 2017). Therefore, the current study able to fill this void by determining the effect of FIBOD smart balance training on visual attention among young adults.

Visual attention can be defined as an attention mechanism derives from the eye movements where some items are selected for further processing while others are left unnoticed (Hubert-Wallander et al., 2011). It is crucial to visually perceive the relevant surrounding information and integrate the visual information via central vestibular processing through the vestibular nuclei of the brain stem in order to commence motor reactions (Alghamdi, 2018). A study was conducted by Haghgoo (2018) to determine the vestibular therapy effect on motor execution, balance and attention in attention deficit hyperactivity disorders (ADHD) children. The study found that vestibular therapy improved motor skills, response control, auditory, visual attention, and motor planning for the children in the experimental group when compared to control that did not receive vestibular therapy (Haghgoo, 2018). Therefore, it was claimed that vestibular stimulation able to modulate the consciousness level which benefit one's visual attention orientation to the environmental stimuli.

Furthermore, physical exercise with video games appears to be stimulating and facilitating the neural and cognitive processing in the prefrontal cortex and the frontal parietal region as part of an attentional control with the frontal eye field that regulate visual attention further controls gaze behaviour that are vital during action video games play (Almeida et al., 2011). Qiu et al. (2018) carried out a study to determine the neuroplasticity of visual selective attention associated with a one-hour Action Video Game (AVG) session using electrophysiological (EEG) and behavioural measures of response time. The participants included both AVG experts and non-experts who had to complete a pre- and post-assessment of Useful Field of View (UFOV) tasks. During the pre- and post-test sessions, EEG data were collected while the participants played the game. The study discovered improvement in response time (RT) of both experts and non-experts in relation to neuroplasticity as shown through EEG amplitude (Qiu et al., 2018). Thus, the findings showed that AVG experience regardless of experts or non-experts was connected to utmost improvement in visual attention through video game training. Apart from that, an exploratory study conducted on traumatic brain injury patient that further separated into two different training groups; video games therapy (VGT) with balance component and balance platform therapy (BPT) to explore on the attention and balance (Straudi et al., 2017). It was found that patient in VGT showed positive improvement in balance and attention compared to BPT group. The study explained that the increment in depth perception, visual acuity or sensitivity of contrast during VGT eventually enhance top-down selective attention to select on relevant stimuli and inhibit distractor or irrelevant information (Straudi et al., 2017). Henceforth, the aforementioned study showed that video games alone further incorporate with postural control activities such as balance able to ameliorate visual attention in addition with the motor function.

The human visual system plays important roles in visual attention by extracting light from the outer environment and transform it into a representable image in visual cortex (Almeida et al., 2011). Most of the eye tracking study suggested that the eyes tend to go through a filtering process by selecting different aspects of details to retrieve in a visual scene (Danilov et al., 2019; Piras et al., 2010). This can be related as visual attention can help to extract more task-relevant information which benefits ones to knows “where” and “what” to look at during information processing as the capacity of human information processing is limited when there is huge quantity of information occupy an individual’s senses (Almeida et al., 2011; Piras et al., 2010). When two tasks are performed at the same time, there is a limited attention capacity available, so they compete for resources, especially in dual-task conditions (Abuin-Porras et al., 2018). Besides, according to the perceptual load theory, the measure of perceptual load for instances the quantity of stimuli (target or distractor) within a task dictate the competence of attention processing (Murphy &