JOURNAL OF INFORMATION AND COMMUNICATION TECHNOLOGY
https://e-journal.uum.edu.my/index.php/jict

How to cite this article:
ChePa, N., Yi, L. L. S., Yusoff, N., Wan Yahaya, W. A. J., & Ishak, R. (2023). A game-based psychotherapy intervention model for memory disorder: Model validation using EEG neurofeedback data. *Journal of Information and Communication Technology, 22*(4), 619-655. https://doi.org/10.32890/jict2023.22.4.4

A Game-based Psychotherapy Intervention Model for Memory Disorder: Model Validation Using EEG Neurofeedback Data

*[1]Noraziah ChePa, [2]Laura Lim Sie-Yi, [3]Nooraini Yusoff,
[4]Wan Ahmad Jaafar Wan Yahaya, [5]Rusdi Ishak
[1&2]Human Centred Research Lab, School of Computing,
Universiti Utara Malaysia, Malaysia
[3]Department of Data Science,
Universiti Malaysia Kelantan, Malaysia
[4]Centre for Instructional Technology and Multimedia,
Universiti Sains Malaysia, Malaysia
[5]Bahagian Kebajikan Produktif & Komuniti,
Jabatan Kebajikan Masyarakat Perlis, Malaysia

*[1]aziah@uum.edu.my
[2]lauralim041@gmail.com
[3]nooraini.y@umk.edu.my
[4]wajwy@usm.my
[5]rusdi@jkm.gov.my
*Corresponding author

Received: 5/10/2022 Revised: 16/10/2023 Accepted: 17/10/2023 Published: 25/10/2023

ABSTRACT

Game-based psychotherapy intervention is a promising alternative to non-pharmacological approaches in treating memory disorders.

Nevertheless, the game-based approach is yet to be included systematically in existing intervention models for treating memory disorders. Hence, this article discusses how a proposed game-based psychotherapy intervention is developed and validated using neurofeedback approach. The proposed model consists of nine exogenous and six instantaneous factors as the main components. To ensure its applicability, a validation procedure has been carried out through a series of psychotherapy experiments involving the elderly with memory disorder symptoms. Electroencephalogram (EEG) data captured from the experiments are thoroughly analysed to validate relationships among factors in the model. Experimental findings have proven that all relationships are successfully validated and supported except for the belief component with the cut-off point of 56.6%. The novelty of this study can be attributed to the integration of digital games and neurofeedback in psychotherapy for memory disorders. The model is believed to be a guideline in planning suitable cognitive training and rehabilitation for people with memory disorders towards improving the quality of the elderly life.

Keywords: EEG neurofeedback, elderly care, game-based intervention, memory disorder.

INTRODUCTION

Memory disorder disease is a major cause of disability and dependency among older people, which can devastate the lives of affected individuals, their caretakers and families, indirectly affecting the financial support of the family (World Health Organization, 2019). Current treatments available for memory disorders include pharmacological treatment and non-pharmacological treatment. Non-pharmacological therapies in dementia and Alzheimer's disease (AD) are often aimed at rehabilitation, while medication administration from pharmacological medicine is widely used to manage the condition (Vigil & Tataryn, 2017). Although effective, pharmaceutical therapies may be very costly and even unsafe (Kavirajan & Schneider, 2007; Zheng et al., 2017).

Cognitive training (CT) in memory disorder-related diseases has received higher interest from the international research community

(Chandler et al., 2016). It is recommended that cognitive-based exercises be included in psychotherapy interventions customised to the local environment, including financial and human resource availability (World Health Organization, 2019). Traditional treatments are nonetheless expensive as regards travel charges to rehabilitation centres, leading to fatigue and the desire for further treatment decreases (Bouchard et al., 2012; Costa et al., 2015). Thus, digital games are offered as an additional tool for psychotherapy interventions since their connection with the patients is straightforward (Benveniste et al., 2010).

Many research depends on evaluations by therapists or by adapting classical tests such as the mini-mental state exam (MMSE) and Montreal Cognitive Assessment (MoCA) for evaluating the cognitive functions performance in their studies (Heitz et al., 2016; Lau & Agius, 2021; Pirovano et al., 2013; Yeo et al., 2018; Young et al., 2019). Most of these researches measure the flow through questionnaires as well as interviews instead of direct cognitive data acquisition. However, these methods are time-consuming, and the result may be influenced by personal motivations and bias (Wilkinson et al., 2018). While psychotherapy intervention is conducted, the advance of neurofeedback as a tool is utilised to measure the functional significance in the brain (White et al., 2014).

In light of neurofeedback's potential to train people to direct neuronal capacity and, in this manner, to change the oscillatory examples of the electroencephalogram (EEG) (Vigil & Tataryn, 2017), EEG-based neurofeedback might be a restorative incentive in dementia. EEG neurofeedback CT is a finer approach that is able to target a particular component in the brain to optimise the cognitive function of that certain area (Yeo et al., 2018). EEG is frequently utilised in clinical assessment and recognition of neurological ailments. In contrast to other non-obtrusive neuroimaging innovations, for example, fMRI, EEG gives an immediate, ongoing estimation of mind action with high fleeting goals (Jatoi & Kamel, 2018). Moreover, EEG recording gadgets can be compact and generally easy, empowering certifiable applications (Jung et al., 2018). Brain-computer interface (BCI) based neurofeedback games have been developed, and most of these games focus on studies related to attention as a control parameter with the implementation of EEG (Thomas et al., 2013).

Experimental neurofeedback allows the analysis of brain activity using both independent and dependent variables, making it an extremely effective technique for determining the functional relevance of brain activity (White et al., 2014). According to Strout et al. (2016), standardised measures of cognition are needed in scientific assessments of psychotherapy therapies so that results may be more easily pooled and compared. The reflective mechanisms of cognitive reserve need to be fully examined comprehensively with suitable neuroimaging facilities in well-designed intervention (Sherman et al., 2017). Taking advantage of the neurofeedback technology, EEG is implemented in this study to provide immediate response from the brain during psychotherapy intervention.

This study introduces a game-based psychotherapy intervention model as an intervention to slow the progression of impacted neurologic disorders. This article focuses on the experimental neurofeedback approach used to evaluate the proposed model for the elderly with memory loss issues. The refined version of the suggested model is delivered as a result of the validation process.

RELATED WORKS

Game-based psychotherapy intervention and neurofeedback are two important approaches that have been integrated in this study. Game-based psychotherapy intervention refers to the use of digital or traditional games as a therapeutic tool in the context of psychotherapy, which integrates the elements of games, such as rules, challenges, and engagement, into the psychotherapeutic process to achieve therapeutic goals. While neurofeedback (also known as EEG biofeedback or neurotherapy), is a therapeutic technique that involves monitoring and providing real-time feedback on brainwave activity with the aim to help individuals learn how to regulate their brain function aiming to improve cognitive, emotional, or behavioral functioning. It is used in various clinical and therapeutic settings to address conditions such as anxiety, Attention-Deficit/Hyperactivity Disorder (ADHD), and certain neurological disorders. To understand both approaches, their previous works have been carefully reviewed.

Game-based Psychotherapy Intervention

Numerous intervention models for health-related issues, particularly for the elderly, have been introduced, such as the intervention reminiscence-based screening (IRBS) model (Tallutondok, 2019) and the elder abuse intervention model (Mosqueda et al., 2016). Nevertheless, these models are not ideal for use in psychotherapy interventions designed to treat memory disorders since they do not fulfil the requirements of the research's scope, which is limited to older adults. Thouzeau and Raymond (2017) offered a game theory model for menopause, considering a decrease in maternal mortality, whereas Goes et al. (2020) proposed a self-care intervention model in accordance with self-care deficits.

However, there are some drawbacks of the existing intervention models that motivated this study. These models do not evaluate the elderly's intrinsic variables at any point, even if a rise in these factors might motivate the intervention. Furthermore, these models are either for screening purposes or unsuitable for game-based intervention. Concrete and solid proof is needed to obtain the most successful ideas and implementations of a digitalised game-based psychotherapy intervention (Zheng et al., 2017).

Game-based psychotherapy intervention such as word games and puzzles has gained attention nowadays (Berg-Weger & Stewart, 2017). Gameplay may improve recovery training. Games require attention in the simplest mechanics to create meaningful play. It will generate a pleasant environment with loads of immediate advantages. Due to the nature of their design, brain workouts are basically monotonous and mechanical (Santen et al., 2018). This appealing design may not be an adequate motivational engine for the patients due to the challenges in mapping hard rehabilitation exercises to enjoyable game dynamics. However, in games, motivation may be created in a number of distinct ways that all contribute to the same result.

From a neurological perspective, it is evident that positive logical stress plays a significant role in enhancing the cognitive capacity of individuals (Aliyari et al., 2022). In this regard, engagement in puzzle game activities elicits activation of the prefrontal cortex, a brain region associated with cognitive processes such as reasoning, attention, and decision-making. Consequently, this cognitive stimulation contributes to enhancements in intelligence, learning aptitude, and decision-making capabilities. Scientific evidence suggests that puzzle games, which fall under the category of intellectual games that stimulate the brain and improve cognitive performance, have been found to decrease the activity of the stress-fear system and the levels of cortisol and alpha-amylase (Szubert & Jaśkowski, 2014, Aliyari et al., 2022) due to the cognitive patterns exhibited by players behaviour.

Based on the three cognitive patterns proposed by Hong and Liu (2003), namely trial-and-error thinking, heuristic thinking, and analogical thinking, Hong et al. (2012) identified a fourth cognitive pattern known as fixated thinking. One important difference between fixated thinking and the other three types of game strategy is the noticeable difference between the number of visits, which allow the elderly to focus on what is in their hand. Players have the option to try again if they lose, as is customary in many games. The ability to keep trying until a solution is found is a major motivator for perseverance in gaming (Tekinbas & Zimmerman, 2005). However, using the "number of visits" concept can help solve jigsaw puzzles strategically. However, it also shows a problem: the strategy may not be very detailed. Focusing too much on one way of thinking can limit the capacity to explore different patterns, shapes, and connections in the puzzle. Having tunnel vision can make it difficult for players to fully understand and enjoy a puzzle's different aspects and challenges, even if it leads to more events. Qin et al. (2010) suggested that a game with a fixed difficulty level might unintentionally prevent players from adapting and improving. It could limit the potential for a more exciting and intellectually stimulating puzzle-solving experience.

An existing game system introduced by Pirovano et al. (2013) named the IGER system has incorporated the scheduling with therapists. This system allows many exergames with particular sets of features to be implemented. The purpose of this system is to serve the patient to be able to carry out rehabilitation with the provided schedule defined individually by the therapist. However, this system needs to be applied with careful consideration, as claimed by the proponents, since this system is developed specifically for exergames under therapist monitors. Another system for attention training has been proposed by Jirayucharoensak et al. (2014) by incorporating the neurofeedback approach. Raw EEG signals were identified by using an EEG amplifier with a fixed sampling rate before the system read the signals of the attention status of a subject. Beta and Alpha frequency bands were investigated in the measure of power ratio to estimate the attention level. The result of the attention level becomes the guideline to adjust the target on the screen, whereby video game is utilised as the neurofeedback tool to measure the sustainability of the subject's attention level.

An architecture of a conceptual level system has been proposed by Styliadis et al. (2015) to improve the gaming setting with a user-friendly fix for EEG monitoring as well as video recording. The intelligent monitoring screen displays the outcome from the gaming platform that the user interacts with and gives appropriate feedback. This system includes three main components that encounter the unobtrusive gaming environment: the gaming platform triggers the role player, the sensing element monitors the interaction, and the third component records the sessions. However, this study did not examine the relationship between the nature of encouragement and substantive instructions and the user's gaming experience.

A recent study by Lau and Agius (2021) has also proposed an architecture of a game named A-go! for mild cognitive impairment by incorporating activities of daily life (ADLs) games. This system is intended for practicality, with the training games operating with low-cost consumer-grade single-channel EEG headgear, which should make the service more scalable and accessible for broader use, such as at home. However, this game is only intended to be used with supervision from a therapist to assess a player's performance.

Electroencephalogram (EEG) Neurofeedback

The Neurofeedback approach has been proven to be capable of extracting important information from the brain and investigating the cognitive state of individuals with many successful examples. It works directly with individual brains at different paces, which aids in brain wave pattern improvement that is associated with a medical instrument known as EEG. Compared to traditional evaluation methods such as MMSE and MoCA, the EEG neurofeedback method enables us to target the functional significance in the brain with high accuracy (White et al., 2014). The graphical record bands area unit named delta, theta, alpha, beta and gamma per band. All bands are measured in terms of hertz and microvolts. Cerebral neural activity provides extensive information regarding neuronal activity. When neurons are engaged, electric pulses are generated. The brain's electrical activity, EEG, can be measured by putting electrodes on the scalp. In turn, EEG is produced by a particular kind of synchronous activity of neurons known as pyramid neurons, reflected in the electrical output in the skin regions following the electrodes. Various electrical activity patterns, known as brain waves, may be identified by their amplitudes and frequencies. EMOTIV Epoc+ headset consists of 14 EEG channels (AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, and O2) and is usually utilised in neurofeedback studies (Marzbani et al., 2016).

When EEG diagnosis is used to evaluate dementia status, it appears that a viable way of obtaining data on these individuals to check the progress of AD seems to be quiet and that the spread is likely to result in compensatory concealing mechanisms that cannot be identified through MMSE or MoCA. As for neurofeedback training in older brains, the seminal work by Angelakis et al. (2007) applied EEG neurofeedback in the older population and showed improved processing speed and executive functions (EFs). Success has also been reported using EEG-based neurofeedback for attention training in young adults (Egner & Gruzelier, 2001), in post-traumatic stress disorder (Ros et al., 2017), and older dementia patients (Surmeli et al., 2016). The work by Surmeli et al. (2016) provided significant success with EEG neurofeedback, in which a large percentage of patients demonstrate brain atrophy and consequently may abandon medication following therapy and follow-up. Memory impairment (MCI) is characterised by a larger atrophy in the left temporal lobe's medial temporal region, which correlates with the loss of episodic memory, atrophy, and the Mini-Mental State Examination (MMSE). However, neurofeedback has not developed a lateralised protocol on MCI (Chan et al., 2001; Rusinek et al., 2004).

Neurofeedback showed that some individuals still have a good degree of neuroplasticity compared to AD patients. The results are restricted in memory but intriguing in orienting balance and verbal capacity. Most AD success cases have utilised EEG or Z-score neurofeedback with regular sessions. Berman and Frederick (2009) employed a mid-range neurofeedback strengthening procedure, discovering that the existing memory capacity in this individual is really an independent variable correlating with the outcome of the therapy. This indicates that the therapy must adjust to the subject's cognitive state and the results of the treatment.

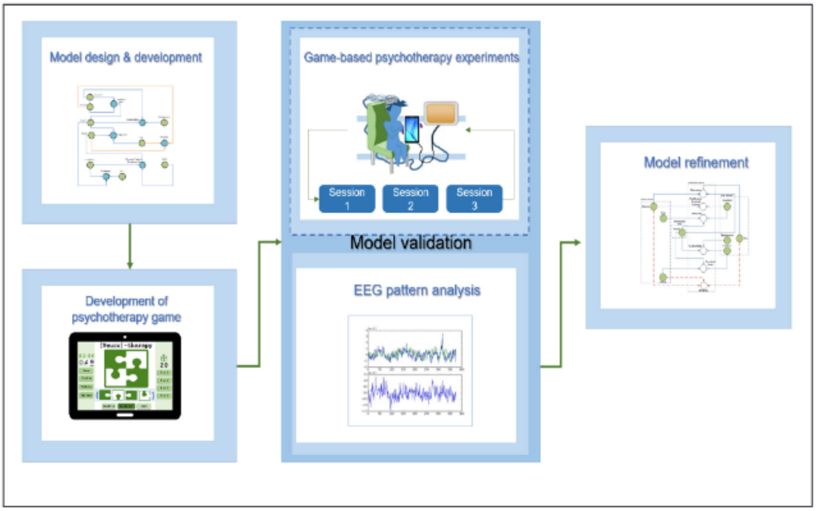
There are popular methods for preparing EEG data, such as frequency domain (Kulkarni & Bairagi, 2017), time domain (John et al., 2018), and time-frequency domain (Bibina et al., 2017). Method using frequency domain is the most common, and one of the most effective and standard approaches as the power spectrum represents the 'frequency value' of the signal or the distribution of signal power over frequency (Dressler et al., 2004) and this method is applied by Kulkarni and Bairagi (2017) in detecting AD. Meanwhile, mathematical functions, physical signals, or economic or environmental data time series are analysed in the time domain. In the study conducted by John et al. (2018), in indicating the EEG signals for Alzheimer patients, the time domain is implemented to measure the Hurst exponent. Nonetheless, the application of this method in this study is used for different lobes (F-frontal, P-parietal, O-occipital and T-temporal) instead of specific brain channels. Bibina et al. (2017) conducted a study on diagnosing AD using time-frequency domain analysis. The time-frequency interpretation retains information about the time and frequency of non-stationary signals. The feature exploited in time-frequency domains includes the sparse oscillatory events taken from EEG signals to diagnose EEG bumps. This technique demonstrates that the signal is across a range of times in each frequency band.

METHODOLOGY

The methodology of this study consists of four main phases: model design and development, development of psychotherapy game, model validation, and model refinement, as illustrated in Figure 1. This article briefly discusses the early two phases and focuses on evaluating the proposed game-based model developed in Phase 1 by emphasising the findings of psychotherapy experiments. The phases involving model architecture design, development, and the creation of the psychotherapy game were executed as distinct components in a prior project. Consequently, the primary emphasis within this article is directed at the model validation process, with particular attention to technical and empirical aspects.

Figure 1

Methodology For Game-based Psychotherapy Intervention Model



Design and Development of a Game-based Intervention Model for Memory Disorder

Major components of the game-based intervention model for memory disorder include exogenous and instantaneous elements. An extensive literature review identifies nine exogenous factors, including the elderly's attributes: attitude, emotion, skill, belief, attractive, fun, reminiscence, complexity, and support from the caregiver. These factors combine three different dimensions of patient characteristics, caregiver environmental support, and game criteria, as illustrated in Figure 2.

Figure 2

Exogenous Factors

The therapeutic change elements in the model are based on the linking effect to interpersonal relationships (ability to focus (perceived focus)), clarification of feelings (enjoyment and boredom), encouragement (motivation), and expectations in therapy relationships (comfortability)). Furthermore, interpersonal skills building (ability to decide (perceived control)) as measures and desired outcomes of the psychotherapy intervention model (England et al., 2015). Thus, the six instantaneous factors identified are perceived focus, enjoyment, motivation, comfortability, perceived control, and boredom. Its relations with exogenous factors are depicted in Table 1.

Table 1

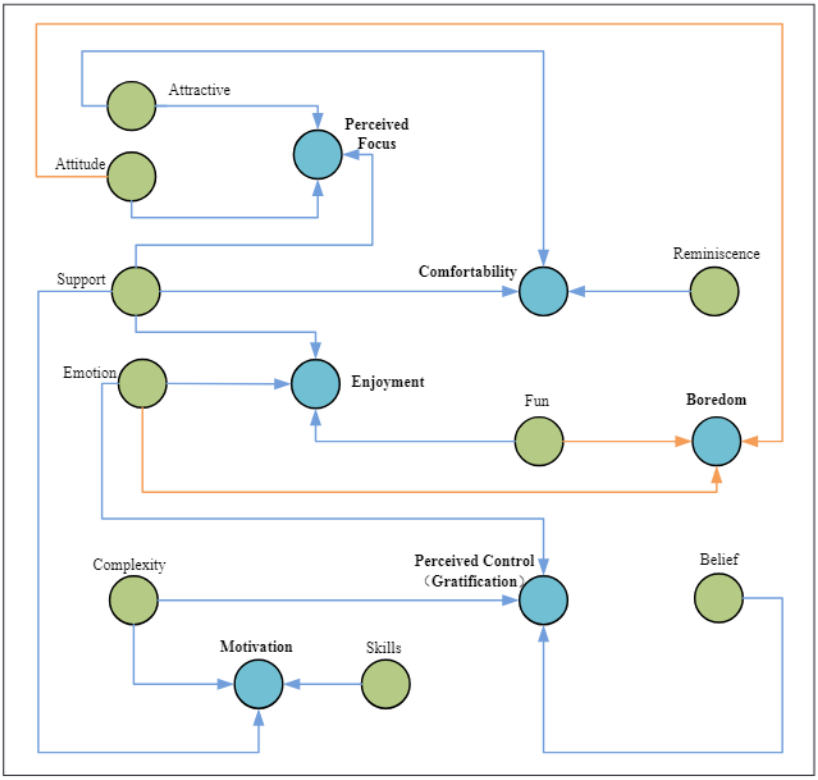
Relations between Instantaneous and Exogenous Factors

No	Instantaneous	Exogenous	References
1.	Perceived Focus	Patients – Attitude Games – Attractive Caregiver – Support	Canvin et al. (2014) Lutz et al. (2008) Panagl et al. (2018)
2.	Enjoyment	Patients – Emotion Caregiver – Support Games – Fun	Ostir et al. (2000) Lopez-Hartmann et al. (2012) Moller et al. (2021)
3.	Motivation	Patients – Skill Caregiver – Support Games – Complexity	Holtforth and Michalak (2012) Kitakoshi et al. (2015) Holtforth and Michalak (2012) Uebelacker et al. (2008)
4.	Comfortability	Games – Attractive Caregiver – Support Games – Reminiscence	Saraiva et al. (2018) Roffe et al. (2005) Satija and Bhatnagar (2017)
5.	Perceived Control	Patients – Belief Patients – Emotion Games – Complexity	Wallston et al. (1987) Town et al. (2019) Dijkstra and Homan (2016) ChePa et al. (2019)
6.	Boredom	Patients – Emotion Patients – Attitude Games – Fun	Perls (1969) Loukidou et al. (2009) Hooft and Hooff (2018)

Attitude of patients, attractive of games or tools, and support of caregivers demonstrate variation in improving perceived focus towards the psychotherapy. Meanwhile, emotion, fun of the game and support from caregiver contribute to enjoyment. On the other hand, complexity of the game, skills of patient and support contribute to motivation. In the meantime, comfortability is contributed by support from caregiver, attractive and reminiscence of the game. Besides, belief, emotions of patients, and task challenges (complexity) are contributing factors that keep an individual engaged in a task as being affected by the perceived control. Last but not least, it is identified that attitude, fun and emotion are contributing negatively to boredom. Based on these relationships between exogenous and instantaneous factors, the proposed game-based psychotherapy intervention model is designed and constructed using the Network Oriented Modelling approach. Figure 3 illustrates the proposed conceptual model with its detailed interconnected nodes.

Figure 3

The Proposed Conceptual Model of Game-based Psychotherapy Intervention for Memory Disorder



Green nodes represent exogenous factors, whilst instantaneous factors are represented by blue nodes. The interaction between these nodes shows both positive and negative features relating to exogenous factors in terms of their impact on instantaneous factors. While orange connections show a negative relationship, blue connections show positive ones. Both validation and verification have been conducted in the model evaluation. The following sections discuss the validation process in detail.

Development of Psychotherapy Game

To validate the proposed model, a game is required as a tool to be utilised in psychotherapy experiments. To achieve this, a puzzle-based game, namely [Neuro]-therapy, has been designed and developed as a proof of concept for game-based psychotherapy intervention (ChePa et al., 2020). The basic idea of the game is based on the proposed guideline comprising 34 criteria. The game features, including the arrangement of buttons, colour combinations, size, and overall layout, are thoughtfully created to accommodate the elderly.

Before proposing the 34 criteria, three sets of criteria were acquired through systematic literature reviews (SLR) and interviews involving 40 elderlies in Changlun, located in the northern part of Kedah, Peninsular Malaysia. Two rounds of reviews have been conducted for SLR by adapting the Preferred Reporting Items Systematic Reviews and Meta-Analysis (PRISMA) approach. Two basic operations performed included selecting the eligible articles to be reviewed and then extracting and analysing the selected articles.

The first set of criteria was acquired from a systematic literature review involving three main databases: Scopus, Web of Science and ACM Digital Library. The search has identified 992 articles altogether, with 69 papers remaining for further selection, while 909 were excluded due to the irrelevancy of the focus. However, only 16 articles are eligible to be included in the review. The second set of criteria was acquired from another round of SLR involving three other main databases: Wiley, ProQuest, and EBSCOhost. The search identified 38, 396, and 240 relevant articles from the databases. However, only 18 articles are purely relevant to be included in this study. Through two rounds of SLR involving six main databases, 17 and 12 criteria have been identified.

The third set of criteria has been acquired through face-to-face interviews with a group of elderly people aged 60 years old and above. Through interviews, six criteria have been identified. These three sets of criteria have been thoroughly analysed, compared, and classified to formulate a guideline. Four main criteria categories are device, game interface, game features, and gameplay elements. Figure 4 shows the interface of [Neuro]-therapy game, which displays the image of the face category with 16 puzzle pieces.

Figure 4

[Neuro]-therapy Game

[Neuro]-therapy has been developed for users to exercise memory therapy. The game comprises a collection of jigsaw puzzles. Users must put together image puzzles in order to construct the whole picture. The puzzles vary in complexity to test memory recall. To further incentivise user participation, two buttons are included: hint (to reveal one puzzle space) and solve it (to reveal n-1 puzzle spaces). In addition, the game's background music contributes to a tranquil and relaxing training atmosphere. The game's activities facilitate memory training to an exceptional degree. They improve memory, problem-solving, logical thinking, and concentration. To facilitate memory and brain exercise, six levels of difficulty are provided in terms of puzzle size ranging from four pieces (2x2), nine pieces (3x3), 16 pieces (4x4), 25 pieces (5x5), 36 pieces (6x6), and 49 pieces (7x7). Since the levels are fixed, future works might consider including customisable levels by players to improve the game's flexibility.

The exercises featured within the game offer significant advantages for memory training. These exercises improve memory recall and bolster problem-solving and logical thinking capabilities while enhancing attention. As an illustration, the game imposes time limits for solving each puzzle, encouraging quick mental calculations. The aim is to complete the jigsaw puzzle in less time, signifying improvements in memory and recall abilities.

Model Validation

Validation of the proposed model was conducted through game-based psychotherapy experiments. The purpose of conducting model validation is to check the workability of the proposed game-based psychotherapy intervention model (Ebener & Hasselhorn, 2019). For this purpose, a series of psychotherapy experiments have been conducted at RSK Bedong and Changlun, Kedah, involving a group of elderly showing symptoms of memory impairment.

1) Sampling

A non-probability sampling method is used in identifying the targeted participants for psychotherapy experiments (Vehovar et al., 2016). The selection of RSK Bedong is based on convenience sampling, non-probability sampling in which people are sampled, whilst judgement sampling is used to determine the final participants in the experiment (Lavrakas, 2008). Based on the suggestions and recommendations from the therapist at an elderly care centre, 13 elderlies fit the inclusion criteria and were selected to participate in the experiments together with another two subjects from the nearby area. The criteria for selecting the subjects include age of more than 60 (Koris et al., 2017), showing early symptoms of memory disorder, having regular or corrected-to-standard vision and hearing, and being able to obey test directions (Ciasca et al., 2018). For experimental research with tight experimental controls, successful research is possible with samples as small as 10 to 20 in size (Sekaran & Bougie, 2003).

2) Instrument

Prior to the psychotherapy sessions, the developed [Neuro]-therapy was pre-installed in mobile testing units, which is friendly to their physical conditions. This game has been provided as the instrument for the elderly throughout the psychotherapy experiments for 14 weeks. In psychotherapy sessions, the brain activities of subjects have been monitored and recorded using EEG sensors while playing with the game as soon as the subjects can play [Neuro]-therapy on their own during the process, the EMOTIV device known as Epoc+ headset is placed on subject's head and the subjects are required to play [Neuro]-therapy for three-level from the easiest level (2x2 puzzle) to the hardest level (4x4 puzzle). Figure 5 illustrates how game-based psychotherapy experiments are conducted.

Figure 5

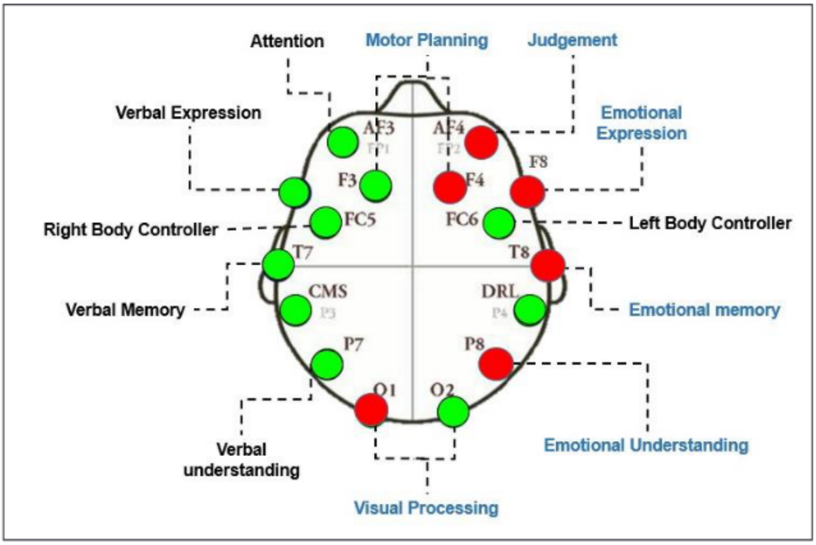
Validation Procedure Via Game-based Psychotherapy Experiments

3) Procedure

EEG data are recorded from six channels of the Emotiv headset reader associated with each exogenous factor (spatial filtering), and the power bands associated with the instantaneous factors have also been identified (spectral filtering). In order to measure the relationships between exogenous and instantaneous factors, the selected channels are mapped to the assigned power band based on the relationships between exogenous and instantaneous factors in the model. Each relationship is represented by a set of data based on the channel and power band. Based on the functions adapted from Boucha et al. (2017) and Holman and Adebesin (2019), each exogenous factor (Patients: Attitude, Emotion, Skill, Belief; Caregiver: Support, Games: Attractive, Fun, Reminiscence, Complexity) that have been identified in the proposed model is matched and represented with the suitable channel to be analysed for the purpose of model validation. Figure 6 shows the representative EEG channel for each exogenous factor.

Figure 6

Exogenous Factors and Its Respective Channels



The factors of *emotion*, and *fun* are exhibited in channel F8, which performs emotional expression, either happy or angry. Since our definition of the *attitude* factor is the acceptance towards the treatment, it is also represented by channel F8. Channel F4 represents the skill factor, as its function is related to motor planning in handling the activities during the psychotherapy experiments. Meanwhile, the factors of *belief* and *support* from the caretaker are represented by channel P8, where the function is related to *emotion* in terms of understanding and motivation. The understanding of the treatment affects the *belief* in patients, and the *support* from the caretaker may boost the patient's motivation during the treatment. Either channel O1 or O2 matches the factor of attractive with the function of visual processing, and thereby, it can be detected whether the patients are attracted or not. In our case, channel O1 is selected. As for *the reminiscence factor, it is most suitable to be represented by channel T8, which* is the emotional memory. Last but not least, the *complexity* factor is matched with channel AF4 as the judgement towards the level of difficulties can be detected from these channels.

4) EEG Pattern Analysis

Prior to pattern analysis, the recorded EEG data were pre-processed, involving four sub-processes: spatial filtering, spectral filtering, temporal filtering, and amplitude normalisation, which aimed to handle the imbalanced data (Jamaluddin & Mahat, 2021). The EEG data analysis is based on the improvement from experiment session one to session three, where the EEG data for selected channels and power bands were pre-processed to form time-frequency domain graphs. The analysis is based on the pattern from the graph to determine the improvement based on the mean value from each session (Krauss et al., 2018; Yuvaraj et al., 2014; Zimmerman, 2011). Elevation in the graph indicates improvement, and the decline of the graph indicates deterioration in the function of the specific channel.

The common practice in methodological recommendations for psychological intervention experiments and trials is quantifying the number of participants who achieve positive reactions based on specific cut-off rating scales after a pharmacological or psychotherapeutic trial (Guidi et al., 2018). Thus, this study considers the Montreal Cognitive (MoCA) test with a cut-off point equal to or more than 17 out of 30 (Trzepacz et al., 2015), which is 56.5%.

Model Refinement

In this phase, the proposed model's structure and content are enhanced and improved based on the experiments' outcome and the expert review feedback. The content in terms of the relationships between factors (connections between nodes) of the proposed model was refined in this phase. Analysis from model validation is used to refine the proposed model, which corresponds to the result of EEG data acquired during the psychotherapy experiments. The data collected are analysed to validate the relationships in the model based on the brainwave patterns throughout three sessions of psychotherapy experiments. The improved brainwave patterns indicate that the relationships in the model are proven workable and vice versa. A refined game-based psychotherapy intervention model is produced at the end of this phase.

RESULT AND DISCUSSIONS

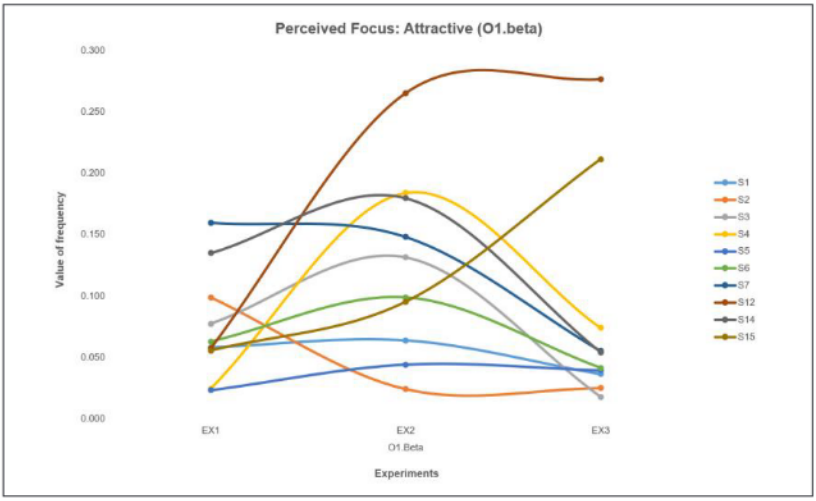
This section discusses how all relations reflected in instantaneous factors, as proposed in Figure 3, were validated through EEG data analysis recorded during game-based psychotherapy sessions. To validate the relations, this study considers the Montreal Cognitive (MoCA) test with a cut-off point equal to or more than 56.5% (17 out of 30) (Trzepacz et al., 2015). EEG data recorded from six channels for three sessions were labelled Ex1, Ex2, and Ex3, indicating the first, second, and third experiments, respectively. S_1, S_2, S_3,… S_n represents the subjects involved in experiments, which refer to the elderly.

Perceived Focus

Three exogenous factors that contribute to *perceived focus* are *attractive, attitude* and *support*. Data recorded for a beta band of channel O1 describes the attractive factor from the first experiment (EX1) to the third experiment (EX_3) for ten subjects. Eight subjects showed positive improvement during the psychotherapy experiments (80%), proving that *attractive* has a positive effect towards perceived focus. *The beta band of Channel F8 represents attitude*. S_7 and S_{12} showed good improvement of attitude from EX_1 to EX_3 progressively as the frequency band demonstrated increment. S_1, S_2, S_3, S_5 and S_6 showed an elevation in the frequency band from EX_1 to EX_2; however, $S_{2\text{ and}}$ S_3 stayed constant during $EX_{3,}$ whereas S_1, S_5 and S_6 showed decrement during the last experiment session. In contrast, S_4, S_{14} and S_{15} showed negatively progressed *attitude* as their graph depletes from EX_1 to EX_3. These indicate that the subjects were more likely to have less agreement on the game used in the psychotherapy intervention because they thought the game was too simple. In spite of that, 7 out of 10 subjects showed improvement towards the psychotherapy intervention (70%); thus, the relationship between the factor of *attitude* and *perceived focus* factor is also supported, as shown in Figure 7.

Figure 7

Model Validation Results for Perceived Focus



Enjoyment

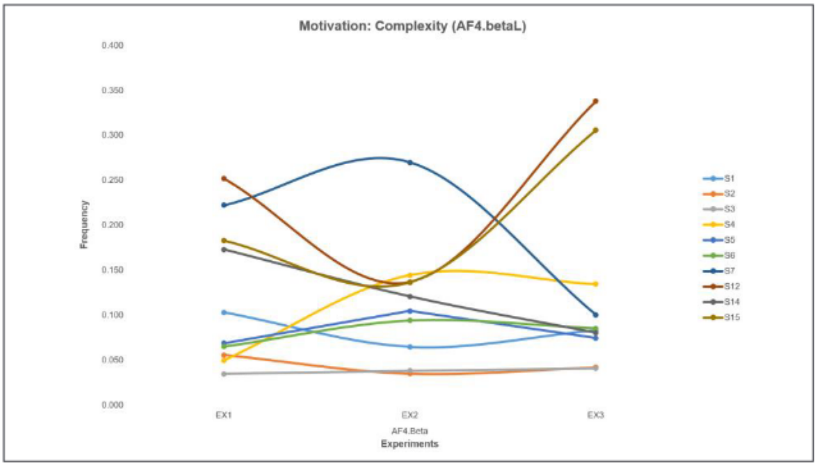
Enjoyment is contributed by three exogenous factors: *emotion, fun,* and *support.* Data recorded for theta band for Channel F8 represents the factor of *emotion* and *fun*. From the data, two subjects, namely S_1 and $S_{15,}$ showed constant elevation from EX_1 until $EX_{3,}$ while S_2, S_3, S_5, and S_{12} showed an increment in the frequency band from EX_1 to EX_2 but slightly dropped during EX_3. Vice versa, S_7 showed a decrement in results from EX_1 to EX_2; however, S_7 showed great improvement during EX_3. These results indicate the positive development in this particular band channel. On the other hand, three subjects, S_4, S_6 and S_{14} showed deteriorating development throughout the psychotherapy experiments. This uncertainty could be due to the environment and pressure during the sessions due to the tight emotive device on their head. Seven out of ten subjects appeared to have affirmative growth in the graph (70%). Concurrently, both factors of *emotion* and *fun* share the same characteristic in Channel F8; thus, the relationships of both factors with *enjoyment* are validated and supported. For *support*, 60% of subjects emerged to have acknowledged growth contributing towards *enjoyment* supported by experimental data. Therefore, *emotion*, *fun* and *support* positively contributed to *enjoyment* factor, as shown in Figure 8.

Motivation

Motivation is contributed by three exogenous factors: *skills, support* and *complexity.* For S*kills*, eight subjects showed positive results (80%), indicating that the skill positively affects one's *motivation* during psychotherapy intervention. For *support*, all subjects showed a positive trend from EX_1 to EX_3 with a 100% improvement score. Therefore, a relationship of *support* and *motivation* is supported by experimental data. Most subjects showed positive results for complexity with a 90% improvement score. For S_3 and $S_{6,}$ both subjects showed an increment of the beta band from EX_1 to EX_2 and stayed constant during EX_3. S_4, S_5, and S_7 also showed an increment of the beta band from EX_1 to $EX_{2;}$ however, the results dropped during EX_3. Meanwhile, S_7 showed the most significant drop during $EX_{3,}$ as the subject only completed the first two easiest levels without a problem. It can be concluded that *skill*, *support* and *complexity* contribute positively towards *motivation* as shown in Figure 9 (a).

Figure 9

Model Validation Results for Motivation



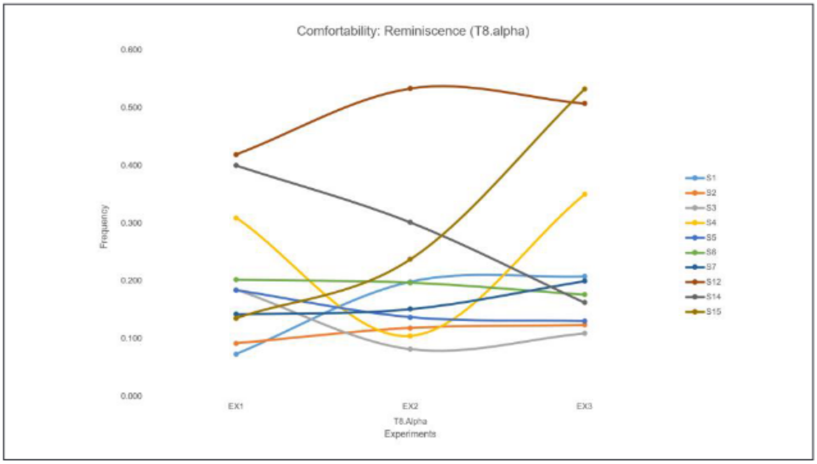
Comfortability

Three exogenous factors contributed to *comfortability* are *support*, *attractive* and *reminiscence.* EEG data for *support* recorded through *the* alpha band in Channel P8 shows that five subjects, S_1, S_4, S_6, S_{12}

and $S_{15,}$ exhibited increment in the beta band from EX_1 to EX_2. During EX_3, S_1 and S_{15} continued to escalate, especially $S_{15,}$ which had a significant boost, while S_4, S_6 and S_{12} exhibited slight depletion in this session. Vice versa, S_2, S_3, S_5 and S_7 initially showed decrement, and their result improved during the last experiment. Nine subjects showed positive results of 90%. *Attractive* is represented by the alpha band in Channel O1. S_3, S_4, S_5, S_6, S_7 and S_{12} showed increment in frequency band from EX_1 to EX_2. However, S_3, S_6, S_7 and S_{12} dropped at the same image during the experiments. Besides, S_1, S_2 and S_{15} showed a declining trend in the alpha band of Channel O1 from EX_1 to EX_2 but improve significantly during $EX_{3,}$ especially S_{15}. The overall results justify the relationship between *attractive* factors and *comfortability* supported by experimental analysis. While for reminiscence, a 70% improvement score is obtained. Hence, the experimental results supported and testified to the eligibility of the relationship between *reminiscence* and *comfortability.* The analysis of the alpha band for Channel F8 proves that the *support, attractive,* and *reminiscence* factors indeed complied with the relationship towards *comfortability* as shown in Figure 10.

Figure 10

Model Validation Results for Comfortability

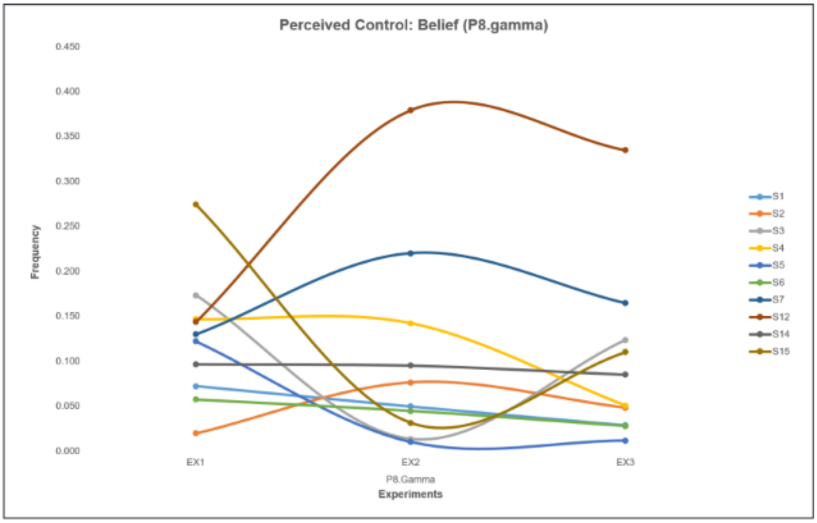


Perceived Control (Gratification)

Emotion, belief, and complexity are three exogenous factors that contribute to perceived control. EEG data for *emotion* is recorded via gamma band for Channel F8. From the data, S_{14} showed improvement from EX_1 to EX_3 while S_1, S_3, S_4, S_5, S_6 and S_7 showed a decrement in the graph at first, and then five of the subjects hit a peak during EX_3 except for S_6, which shows constant result during EX_3 with the result of 90%. *Belief* is another factor in which data were recorded via the gamma band for channel P8. From the data, S_2 and S_{12} exhibited elevation in the frequency band from EX_1 to EX_2; however, the performance declined during EX_3.

Figure 11

Model Validation Results for Perceived Control



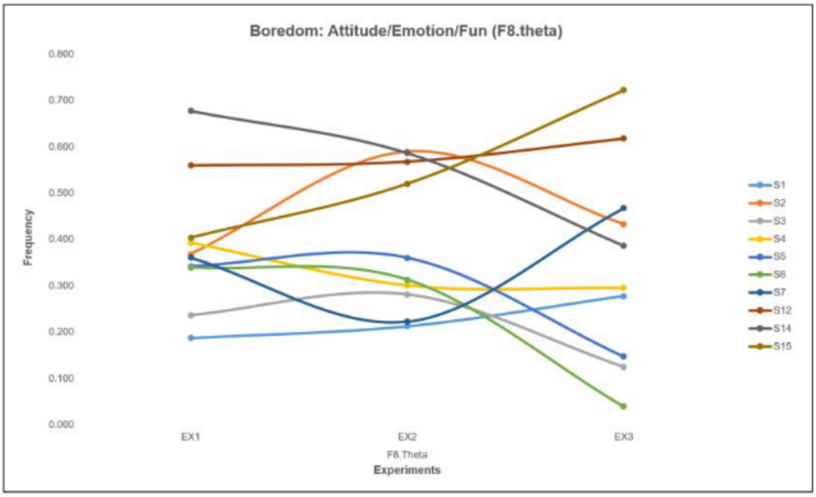
Meanwhile, S_3, S_7 and S_{15} showed a decrement in a graph from EX_1 to EX_2 while slightly improved during EX_3. S_{14} showed a constant graph from EX_1 to EX_2, then slightly plummeted during EX_3. In the meantime, the lines for S_1, S_4, S_5 and S_6 decreased throughout the experiment. Only five subjects showed an improvement of 50%, which is less than 56.6%; thus, the relationship between *belief* and *perceived control* was not supported by experimental results and was rejected. EEG data for *complexity* was recorded via the gamma band of Channel AF4. In the frequency band, S1, S3, S4 and S14 continued rising from EX1 to EX3. Meanwhile, S_5, S_6 and S_7 showed an increment from EX_1 to EX_2; however, during EX_3, three exhibited decrement due to the familiarity towards the game with the improvement of 90. It can be concluded that *perceived control*, *emotion* and *complexity* contribute positively towards *perceived control* while *belief* is not supported and rejected, as shown in Figure 11.

Boredom

Boredom comprises three exogenous factors: attitude, emotion and fun, represented by the Channel F8 frequency band of theta. S_4, S_6 and S_{14} showed declination throughout the experiments. Overall, seven out of ten subjects showed negative influence in the theta band for Channel F8 with a 70% improvement score in which *attitude, emotion* and *fun* have negative relationships towards *boredom.* Thus, all exogenous factors for boredom are accepted with support from experimental data, as shown in Figure 12.

Figure 12

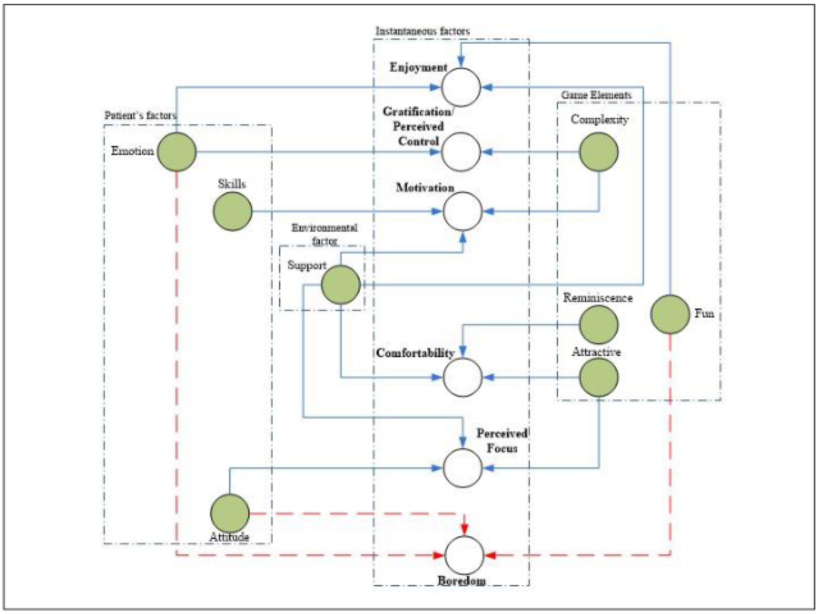
Model Validation Results for Boredom



Based on the analysis, only belief is not supported and rejected. It indicates that only the patient's emotion and game's complexity play a significant role in perceiving control in game-based intervention. While the patient's belief plays no significant impact on perceived control. Therefore, it is excluded from the proposed model. The proposed model is amended, and the validated model is produced, as shown in Figure 13.

Figure 13

A validated Game-based Psychotherapy Intervention for Memory Disorder



The validated model provides valuable insights for conducting psychotherapy interventions by effectively incorporating suitable digital games. This contribution connects the fields of health informatics in e-healthcare for the elderly with digital game technology. It considers the interaction among tools, user behaviours, emotions, and caregivers within the digital game, using a neurofeedback approach to gain a deeper understanding of real human behaviour during psychotherapy interventions.

This study's importance lies in its creation of an integrated model for psychotherapy interventions that incorporates games and neurofeedback while explaining crucial relationships among related factors. The proposed model is able to support professionals in conducting and facilitating psychotherapy intervention by describing necessary elements: criteria of digital psychotherapy games, related behaviours, and emotions. These elements can assist professionals in facilitating psychotherapy about the knowledge to promote effective and functional intervention for memory disorder.

CONCLUSION

A game-based psychotherapy intervention model has been successfully designed, developed, and validated. The applicability of the proposed model is measured through analysis of EEG data acquired via a series of game-based psychotherapy experiments. The proposed model has been validated and amended accordingly. Based on the analysed results, it is concluded that all the relationships in the model are supported with an improvement of more than the cut-off point of 56.6%. Findings show that the experimental data support all relations except for the *belief* component, hence the exclusion of it in the refined model.

The proposed model can give benefits to many parties. Psychologists or cognitive scientists can utilise it to get deeper insights into other related domains, such as traumatic brain injuries (TBI). Care centres and hospitals may also benefit from implementing game-based psychotherapy to abide by the model as a guide in their memory-related rehabilitation. The model can also be practised for in-house intervention assisted by family members as well. By understanding the relationships within psychotherapy intervention for a higher successful rate of intervention, family members can conduct activities with the elderly under their care who experience memory disorders such as AD and dementia. Likewise, this model can be practised in the intervention of domains other than memory disorder, as the implementation is feasible for multiple intervention programs.

Potential future works can be the incorporation of other related theories to strengthen the model, such as reminiscence and flow theories. The improved model is significant in providing a guideline for game-based intervention in other related domains. The proposed model is believed to be effective in improving cognition among the elderly; the interesting and positive findings can be attributed to integrating digital games and psychotherapy for the elderly, particularly those with memory disorder symptoms.

ACKNOWLEDGMENT

We acknowledge financial support by the Ministry of Higher Education Malaysia under the Fundamental Research Grant Scheme

(FRGS/1/2019/ICT02/UUM/02/4) and support by the partnering institutions: Universiti Utara Malaysia (UUM), Universiti Malaysia Kelantan (UMK), Universiti Sains Malaysia (USM), and Jabatan Kebajikan Masyarakat (JKM). The team also greatly valued the participation of respondents of Rumah Seri Kenangan Bedong, Kedah, in psychotherapy intervention experiments.

REFERENCES

Aliyari, H., Golabi, S., Sahraei, H., Minaei-Bidgoli, B., Tadayyoni, H., & Kazemi, M. (2022). Evaluation of stress and cognition indicators in a puzzle game: Neuropsychological, biochemical and electrophysiological approaches. Archives of Razi Institute, *77*(4), 1397.

Angelakis, E., Stathopoulou, S., Frymiare, J. L., Green, D. L., Lubar, J. F., & Kounios, J. (2007). EEG neurofeedback: A brief overview and an example of peak alpha frequency training for cognitive enhancement in the elderly. *Clinical Neuropsychologist, 21*(1), 110–129. https://doi.org/10.1080/13854040600744839

Benveniste, S., Jouvelot, P., & Péquignot, R. (2010). The MINWii project: Renarcissization of patients suffering from Alzheimer's disease through video game-based music therapy. *Entertainment Computing*, *3*(4), 111-120. https://doi.org/10.1016/j.entcom.2011.12.004

Berg-Weger, M., & Stewart, D. B. (2017). Non-Pharmacologic interventions for persons with dementia. *Missouri Medicine, 114*(2), 116–119. http://www.ncbi.nlm.nih.gov/pubmed/30228557%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6140014

Berman, M. H., & Frederick, J. A. (2009). Efficacy of neurofeedback for executive and memory function in dementia. *Alzheimer's & Dementia*, *5*(4S_Part_17), e8-e8.

Bibina, V. C., Chakraborty, U., Lourde, M. R., & Kumar, A. (2017). Time-frequency methods for diagnosing Alzheimer's disease using EEG – A technical review. *ACM International Conference Proceeding Series, Part F1309*, 49–54. https://doi.org/10.1145/3121138.3121183

Boucha, D., Amiri, A., & Chogueur, D. (2017). Controlling electronic devices remotely by voice and brain waves. *Proceedings of the 2017 International Conference on Mathematics and Information Technology, ICMIT 2017*, 2018-January, 38–42. https://doi.org/10.1109/MATHIT.2017.8259693

Bouchard, B., Imbeault, F., Bouzouane, A., & Menelas, B.-A. J. (2012). Developing serious games specifically adapted to people suffering from Alzheimer. In *Serious Games Development and Applications: Third International Conference, SGDA 2012, Bremen, Germany, September 26-29, 2012. Proceedings 3* (pp. 243-254). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-40790-1

Canvin, K., Rugkåsa, J., Sinclair, J., & Burns, T. (2014). Patient, psychiatrist and family carer experiences of community treatment orders: Qualitative study. *Social Psychiatry and Psychiatric Epidemiology, 49(12)*, 1873–1882. https://doi.org/10.1007/s00127-014-0906-0

Chan, D., Crum, W. R., Rossor, A. M., Rossor, M. N., Stevens, J. M., Scahill, R. I., Leschziner, G., Fox, N. C., Whitwell, J. L., & Cipolotti, L. (2001). Patterns of temporal lobe atrophy in semantic dementia and Alzheimer's disease. *Annals of Neurology, 49*(4), 433-442. https://doi.org/10.1002/ana.92

Chandler, M. J., Parks, A. C., Marsiske, M., Rotblatt, L. J., & Smith, G. E. (2016). Everyday impact of cognitive interventions in mild cognitive impairment: A systematic review and meta-analysis. *Neuropsychology Review, 26*(3), 225–251. https://doi.org/10.1007/s11065-016-9330-4

ChePa, N., Bakar, N. A. A., Hussain, A., & Hibadullah, C. F. (2019). The influence of rewards on games flow, challenge, and its effects towards the engagement of Malaysian digital traditional games. *Baghdad Science Journal, 16*(2), 534–542. https://doi.org/10.21123/bsj.2019.16.2(SI)0534

ChePa, N., Yusoff, N., Wan Yahaya, W. A. J., Ishak, R., Sie-Yi, L. L., & Adetunmbi, S. (2020). A mobile psychotherapy game for elderly with memory disorder issues. *International Journal for Studies on Children, Women, Elderly And Disabled, 11*(11), 76–84.

Ciasca, E. C., Ferreira, R. C., Santana, C. L. A., Forlenza, O. V., Dos Santos, G. D., Brum, P. S., & Nunes, P. V. (2018). Art therapy as an adjuvant treatment for depression in elderly women: A randomised controlled trial. *Revista Brasileira de Psiquiatria, 40*(3), 256–263. https://doi.org/10.1590/1516-4446-2017-2250

Costa, Soares, N. M., Reis, W. A., & Bublitz, F. M. (2015). A systematic review on the usage of games for healthcare. *5th IEEE International Conference on Consumer Electronics - Berlin, ICCE-Berlin 2015,* 480–484. https://doi.org/10.1109/ICCE-Berlin.2015.7391316

Dijkstra, M. T. M., & Homan, A. C. (2016). Engaging in rather than disengaging from stress: Effective coping and perceived control. *Frontiers in Psychology*, *7*(Sept), 1–12. https://doi.org/10.3389/fpsyg.2016.01415

Dressler, O., Schneider, G., Stockmanns, G., & Kochs, E. F. (2004). Awareness and the EEG power spectrum: Analysis of frequencies. *British Journal of Anaesthesia, 93*(6), 806–809. https://doi.org/10.1093/bja/aeh270

Ebener, M., & Hasselhorn, H. M. (2019). Validation of short measures of work ability for research and employee surveys. *International Journal of Environmental Research and Public Health*, *16*(18), 3386. https://doi.org/10.3390/ijerph16183386

Egner, T., & Gruzelier, J. H. (2001). Learned self-regulation of EEG frequency components affects attention and event-related brain potentials in humans. *NeuroReport, 12*(18), 4155–4159. https://doi.org/10.1097/00001756-200112210-00058

England, M. J., Vutler, A. S., & Gonzalez, M. L. (2015). Psychosocial Interventions for Mental and Substance Use Disorders: A Framework for Establishing Evidence-Based Standards. In M. J. England, A. S. Vutler, & M. L. Gonzalez (Eds.), Psychosocial Interventions for Mental and Substance Use Disorders: A Framework for Establishing Evidence-Based Standards. *The National Academic Press.*

Goes, M., Lopes, M. J., Oliveira, H., Fonseca, C., & Marôco, J. (2020). A nursing care intervention model for elderly people to ascertain general profiles of functionality and self care needs. *Scientific Reports*, *10*(1), 1770. https://doi.org/10.1038/s41598-020-58596-1

Guidi, J., Brakemeier, E., Bockting, L. H., & Cosci, F. (2018). Methodological recommendations for trials of psychological interventions. *Psychotherapy and Psychosomatics*, *87*(5), 276-284. https://doi.org/10.1159/000490574

Heitz, C., Noblet, V., Phillipps, C., Cretin, B., Vogt, N., Philippi, N., Kemp, J., De Petigny, X., Bilger, M., Demuynck, C., Martin-Hunyadi, C., Armspach, J. P., & Blanc, F. (2016). Cognitive and affective theory of mind in dementia with Lewy bodies and Alzheimer's disease. *Alzheimer's Research and Therapy, 8*(1), 1–15. https://doi.org/10.1186/s13195-016-0179-9

Holman, M., & Adebesin, F. (2019). Taking the subjectivity out of UX evaluation with emotiv EPOC+. *ACM International Conference Proceeding Series,* 16–18. https://doi.org/10.1145/3351108.3351139

Holtforth, M. G., & Michalak, J. (2012). Motivation in Psychotherapy. *In The Oxford Handbook of Human Motivation* (Issue November 2018). https://doi.org/10.1093/oxfordhb/9780195399820.013.0025

Hong, J. C., & Liu, M. C. (2003). A study on thinking strategy between experts and novices of computer games. *Computers in Human Behavior, 19*(2), 245-258. https://doi.org/10.1016/S0747-5632(02)00013-4

Hong, J. C., Hwang, M. Y., Tam, K. P., Lai, Y. H., & Liu, L. C. (2012). Effects of cognitive style on digital jigsaw puzzle performance: A GridWare analysis. *Computers in Human Behavior, 28*(3), 920-928. https://doi.org/10.1016/j.chb.2011.12.012

Hooft, E. A. J. van, & Hooff, M. L. M. van. (2018). The state of boredom: Frustrating or depressing? *Motivation and Emotion, 42*(6), 931–946. https://doi.org/10.1007/s11031-018-9710-6

Jamaluddin, A. H., & Mahat, N. I. (2021). Validation assessments on resampling method in imbalanced binary classification for linear discriminant analysis. *Journal of Information and Communication Technology, 20*(1), 83–102.

Jatoi, M. A., & Kamel, N. (2018). Brain source localisation using reduced EEG sensors. *Signal, Image and Video Processing, 12*(8), 1447–1454. https://doi.org/10.1007/s11760-018-1298-5

Jirayucharoensak, S., Israsena, P., Pan-Ngum, S., & Hemrungrojn, S. (2014). A game-based neurofeedback training system for cognitive rehabilitation in the elderly. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare* (pp. 278-281). https://doi.org/10.4108/icst.pervasivehealth.2014.255448

John, T. N., Puthankattil, S. D., & Menon, R. (2018). Analysis of long range dependence in the EEG signals of Alzheimer patients. *Cognitive Neurodynamics, 12*(2), 183–199. https://doi.org/10.1007/s11571-017-9467-8

Jung, Hsu, S.-H., Lan, X., Zhou, Y., Wen, D., & Li, G. (2018). The study of evaluation and rehabilitation of patients with different cognitive impairment phases based on virtual reality and EEG. *Frontiers in Aging Neuroscience, 10*(April), 1–6. https://doi.org/10.3389/fnagi.2018.00088

Kavirajan, H., & Schneider, L. S. (2007). Efficacy and adverse effects of cholinesterase inhibitors and memantine in vascular dementia: a meta-analysis of randomised controlled trials. *Lancet Neurology, 6*(9), 782–792. https://doi.org/10.1016/S1474-4422(07)70195-3

Kitakoshi, D., Hanada, R., Iwata, K., & Suzuki, M. (2015). Cognitive training system for dementia prevention using memory game based on the concept of human-agent interaction. *Journal of Advanced Computational Intelligence and Intelligent Informatics, 19*(6), 727–737. https://doi.org/10.20965/jaciii.2015.p0727

Koris, R., Nor, N. M., Haron, S. A., Ismail, N. W., Junid, S. M. A. S., Nur, A. M., Shafie, A. A., Yusoff, S., & Maimaiti, N. (2017). Socio-demographic, cognitive status and comorbidity determinants of catastrophic health expenditure among elderly in Malaysia. *International Journal of Economics and Management, 11*(3 Special Issue), 673–690.

Krauss, P., Schilling, A., Bauer, J., Tziridis, K., Metzner, C., Schulze, H., & Traxdorf, M. (2018). Analysis of multichannel EEG patterns during human sleep: A novel approach. *Frontiers in Human Neuroscience, 12*(March), 1–8. https://doi.org/10.3389/fnhum.2018.00121

Kulkarni, N. N., & Bairagi, V. K. (2017). Extracting salient features for EEG-based diagnosis of Alzheimer's disease using support vector machine classifier. *IETE Journal of Research, 63*(1), 11–22. https://doi.org/10.1080/03772063.2016.1241164

Lau, S. Y. J., & Agius, H. (2021). A framework and immersive serious game for mild cognitive impairment. *Multimedia Tools and Applications*, *80*(20), 31183-31237. https://doi.org/10.1007/s11042-021-11042-4

Lavrakas, P. J. (2008). Encyclopedia of survey research methods. SAGE Publications.

Lopez-Hartmann, M., Wens, J., Verhoeven, V., & Remmen, R. (2012). The effect of caregiver support interventions for informal caregivers of community-dwelling frail elderly: A systematic review. *International Journal of Integrated Care, 12*(July-September 20). https://doi.org/10.5334/ijic.845

Loukidou, L., Loan-Clarke, J., & Daniels, K. (2009). Boredom in the workplace: More than monotonous tasks. *International Journal of Management Reviews, 11*(4), 381–405. https://doi.org/10.1111/j.1468-2370.2009.00267.x

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences*, *12*(4), 163-169. https://doi.org/10.1016/j.tics.2008.01.005

Marzbani, H., Marateb, H. R., & Mansourian, M. (2016). Neurofeedback: A comprehensive review on system design, methodology and clinical applications. *Basic and Clinical Neuroscience, 7*(2), 143–158. https://doi.org/10.15412/J.BCN.03070208

Moller, A. M., Baumgartner, S. E., Ku, R., & Peter, J. (2021). Sharing the fun? How social information affects viewers' video enjoyment and video evaluations. *Human Communication Research*, *47*(1), 25-48. https://doi.org/10.1093/hcr/hqaa013

Mosqueda, L., Burnight, K., Gironda, M. W., Moore, A. A., Robinson, J., & Olsen, B. (2016). The abuse intervention model: A pragmatic approach to intervention for elder mistreatment. *Journal of the American Geriatrics Society, 64*(9), 1879–1883. https://doi.org/10.1111/jgs.14266

Nelson, R. A., & Strachan, I. (2009). Action and puzzle video games prime different speed/accuracy tradeoffs. *Perception, 38*(11), 1678-1687.

Ostir, G. V., Markides, K. S., Black, S. A., & Goodwin, J. S. (2000). Emotional well-being predicts subsequent functional independence and survival. *Journal of the American Geriatrics Society, 48*(5), 473–478. https://doi.org/10.1111/j.1532-5415.2000.tb04991.x

Panagl, M., Paletta, L., Steiner, J., Kemp, C., Fellner, M., Künstner, M., Pittino, L., Pszeida, M., & Lerch, A. (2018). Playful multimodal training for persons with dementia with executive function based decision support. In *Proceedings of the 11th PErvasive Technologies Related to Assistive Environments Conference* (pp. 237-240). https://doi.org/10.1145/3197768.3197789

Perls, F. S. (1969). *Gestalt therapy verbatim.* Real People Press.

Pirovano, M., Lanzi, P. L., Mainetti, R., & Borghese, N. A. (2013). The design of a comprehensive game engine for rehabilitation. *IEEE Consumer Electronics Society's International Games Innovations Conference, IGIC, February 2016*, 209–215. https://doi.org/10.1109/IGIC.2013.6659160

Qin, H., Rau, P. L. P., & Salvendy, G. (2010). Effects of different scenarios of game difficulty on player immersion. *Interacting With Computers*, *22*(3), 230-239.

Roffe, L., Schmidt, K., & Ernst, E. (2005). A systematic review of guided imagery as an adjuvant cancer therapy. *Psycho-Oncology, 14*(8), 607–617. https://doi.org/10.1002/pon.889

Ros, T., Frewen, P., Théberge, J., Michela, A., Kluetsch, R., Mueller, A., Candrian, G., Jetly, R., Vuilleumier, P., & Lanius, R. A. (2017). Neurofeedback tunes scale-free dynamics in spontaneous brain activity. *Cerebral Cortex, 27*(10), 4911–4922. https://doi.org/10.1093/cercor/bhw285

Rusinek, H., Endo, Y., De Santi, S., Frid, D., Tsui, W. H., Segal, S., Convit, A., & De Leon, M. J. (2004). Atrophy rate in medial temporal lobe during progression of Alzheimer disease. *Neurology, 63*(12), 2354–2359. https://doi.org/10.1212/01.WNL.0000148602.30175.AC

Santen, J. Van, Dröes, R.-M., Holstege, M., Henkemans, O. B., Rijn, A. van, Vries, R. de, Straten, A. van, & Meiland, F. (2018). Effects of exergaming in people with dementia: Results of a systematic literature review. *Journal of Alzheimer's Disease, 63*(2), 741–760. https://doi.org/10.3233/JAD-170667

Saraiva, A. A., Barros, M. P., Nogueira, A. T., Fonseca Ferreira, N. M., & Valente, A. (2018). Virtual interactive environment for low-cost treatment of mechanical strabismus and amblyopia. *Information (Switzerland), 9*(7), 1–16. https://doi.org/10.3390/info9070175

Satija, A., & Bhatnagar, S. (2017). Complementary therapies for symptom management in cancer patients. *Indian Journal of Palliative Care*, *23*(4), 468. https://doi.org/10.4103/IJPC.IJPC

Sekaran, U., & Bougie, R. (2003). Research methods for business: A Skill-Building Approach, 6th Edition.

Sherman, D. S., Mauser, J., Nuno, M., & Sherzai, D. (2017). The efficacy of cognitive intervention in mild cognitive impairment (MCI): A meta-analysis of outcomes on neuropsychological measures. *Neuropsychology Review, 27*(4), 440–484. https://doi.org/10.1007/s11065-017-9363-3

Strout, K. A., David, D. J., Dyer, E. J., Gray, R. C., Robnett, R. H., & Howard, E. P. (2016). Behavioral interventions in six dimensions of wellness that protect the cognitive health of community-dwelling older adults: A systematic review. *Journal of the American Geriatrics Society, 64*(5), 944–958. https://doi.org/10.1111/jgs.14129

Styliadis, C., Konstantinidis, E., Billis, A., & Bamidis, P. (2015). Employing affection in elderly healthcare serious games interventions. In *Proceedings of the 7th International Conference on Pervasive Technologies Related to Assistive Environments* (pp. 1-4). https://doi.org/10.1145/2674396.2674456

Sun, Y., Lo, F. P.-W., & Lo, B. (2019). EEG-based user identification system using 1D-convolutional long short-term memory neural networks. *Expert Systems with Applications, 125*, 259-267. https://doi.org/10.1016/j.eswa.2019.01.080

Surmeli, T., Eralp, E., Mustafazade, I., Kos, H., Özer, G. E., & Surmeli, O. H. (2016). Quantitative EEG neurometric analysis–guided neurofeedback treatment in dementia. *Clinical EEG and Neuroscience, 47*(2), 118–133. https://doi.org/10.1177/1550059415590750

Szubert, M., & Jaśkowski, W. (2014). Temporal difference learning of n-tuple networks for the game 2048. *In 2014 IEEE Conference on Computational Intelligence and Games* (pp. 1-8). IEEE.

Tallutondok, E. B. (2019). Childhood activities adults utilising for the Intervention Reminiscence- Based Screening Childhood activities adults utilising for the Intervention Reminiscence-Based Screening. https://doi.org/10.1088/1757-899X/523/1/012044

Tekinbas, K. S., & Zimmerman, E. (2005). The game design reader: A rules of play anthology. MIT Press.

Thomas, K. P., Vinod, A. P., & Guan, C. (2013). Enhancement of attention and cognitive skills using EEG based neurofeedback game. *International IEEE/EMBS Conference on Neural Engineering, NER*, 21–24. https://doi.org/10.1109/NER.2013.6695861

Thompson, O., Barrett, S., Patterson, C., & Craig, D. (2012). Examining the neurocognitive validity of commercially available, smartphone-based puzzle games. *Psychology, 3*(7), 525.

Thouzeau, V., & Raymond, M. (2017). Emergence and maintenance of menopause in humans: A game theory model. *Journal of Theoretical Biology, 430,* 229–236. https://doi.org/10.1016/j.jtbi.2017.07.019

Town, J. M., Lomax, V., Abbass, A. A., & Hardy, G. (2019). The role of emotion in psychotherapeutic change for medically unexplained symptoms. *Psychotherapy Research, 29*(1), 86–98. https://doi.org/10.1080/10503307.2017.1300353

Trzepacz, P. T., Hochstetler, H., Wang, S., Walker, B., & Saykin, A. J. (2015). Relationship between the Montreal cognitive assessment and mini-mental state examination for assessment of mild cognitive impairment in older adults. *BMC Geriatrics, 15*(1), 1–9. https://doi.org/10.1186/s12877-015-0103-3

Uebelacker, L. A., Battle, C. L., Friedman, M. A., Cardemil, E. V., Beevers, C. G., & Miller, I. W. (2008). The importance of interpersonal treatment goals for depressed inpatients. *Journal of Nervous and Mental Disease, 196*(3), 217–222. https://doi.org/10.1097/NMD.0b013e3181663520

Vehovar, V., Toepoel, V., & Steinmetz, S. (2016). Non-probability sampling. *The Sage Handbook of Survey Methods*, 329–345.

Wallston, K. A., Wallston, B. S., Smith, S., & Dobbins, C. J. (1987). Perceived control and health. *Current Psychology, 6*(1), 5–25. https://doi.org/10.1007/BF02686633

White, D., Congedo, M., & Ciorciari, J. (2014). Source-based neurofeedback methods using EEG recordings: Training altered brain activity in a functional brain source derived from blind source separation. *Frontiers in Behavioral Neuroscience, 8*(Oct), 1–9. https://doi.org/10.3389/fnbeh.2014.00373

Wilkinson, A., Tong, T., Zare, A., Kanik, M., & Chignell, M. (2018). Monitoring health status in long term care through the use of ambient technologies and serious games. IEEE *Journal of Biomedical and Health Informatics, 22*(6), 1807–1813. https://doi.org/10.1109/JBHI.2018.2864686

World Health Organization. (2019). Risk reduction of cognitive decline and dementia: WHO guidelines. https://www.who.int/mental_health/neurology/dementia/risk_reduction_gdg_meeting/en/

Yeo, S. N., Lee, T. S., Sng, W. T., Heo, M. Q., Bautista, D., Cheung, Y. B., Zhang, H. H., Wang, C., Chin, Z. Y., Feng, L., Zhou, J., Chong, M. S., Ng, T. P., Krishnan, K. R., & Guan, C. (2018). Effectiveness of a personalised brain-computer interface system for cognitive training in healthy elderly: A randomized controlled trial. *Journal of Alzheimer's Disease : JAD, 66*(1), 127–138. https://doi.org/10.3233/JAD-180450

Young, D. K. wan, Ng, P. Y. nam, Kwok, T., Ho, F., Cheng, D., Mak, V., & Lau, A. (2019). The effects of an expanded cognitive stimulation therapy model on the improvement of cognitive ability of elderly with mild stage Dementia living in a community — A randomised waitlist controlled trial. *Aging and Mental Health, 23*(7), 855–862. https://doi.org/10.1080/13607863.2018.1471586

Yuvaraj, R., Murugappan, M., Ibrahim, N. M., Omar, M. I., Sundaraj, K., Mohamad, K., Palaniappan, R., Mesquita, E., & Satiya, M. (2014). On the analysis of EEG power, frequency and asymmetry in Parkinson's disease during emotion processing. *Behavioral and Brain Functions 10*(1), 1-19. https://doi.org/10.3389/neuro.09.061.2009

Zheng, J., Chen, X., & Yu, P. (2017). Game-based interventions and their impact on dementia: a narrative review. Australasian *Psychiatry, 25*(6), 562–565. https://doi.org/10.1177/1039856217726686

Zimmerman, M. E. (2011). Encyclopedia of Clinical Neuropsychology. In *Encyclopedia of Clinical Neuropsychology*. https://doi.org/10.1007/978-0-387-79948-3