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Development of a computer-based cognitive training game and usage feasibility with Thai stroke patients

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ABSTRACT

Background: Cognitive impairments are common sequelae found in patients after a stroke event, leading them to necessitate long-term care. Currently, there are two common cognitive approaches, namely conventional intervention, and technology-based intervention, with the latter having become extensively used, especially in developed countries. In a developing country like Thailand, there is still a clear lack of usage of computer-based cognitive training and there is still a lack of research focus on investigating the feasibility of its usage with Thai stroke patients.

Objectives: This study aimed to develop a computer-based cognitive training game and investigate its feasibility for being used with Thai stroke patients

Materials and methods: This study was a developmental research design consisting of two phases. Phase one involved the development, content validity, and pilot use of our computer-based cognitive training game. The game contents were examined by three experts, who are occupational therapists with more than 5 years of experience with cognitive rehabilitation for stroke patients, to assure content validity. Phase two instead, involved the process of investigating the feasibility of using the newly developed computer-based cognitive training games with Thai stroke patients. Participants in this study were stroke patients with cognitive impairments identified with the Mental State Examination (MSET10) and who were familiar with the technology. Fourteen participants were asked to rate their overall experience with the newly developed game, the design, the convenience aspects, and the portability of the training material, by using The Test of Satisfaction on Computer-based Cognitive Game. Demographic characteristics and user experiences were analyzed by descriptive statistics.

Results: The newly developed computer-based cognitive training game, called CoWMeG, is a game-like training using simulated real-life activities whose design is based on the Thai ecosystem, and it consists of ten games. The game's contents involve working memory tasks, such as verbal, visuospatial, executive, and process speed skills-related tasks. Each game was designed to have different difficulty levels with each level consisting of three subsequential screen pages (i.e., instruction, playing, and scoring screen pages). Most of the participants rated their user experiences with CoWMeG as very satisfied, corresponding to 84.2 percent of the total answers on satisfaction.

Conclusion: In accordance with the obtained results, the newly developed computer-based cognitive training game, named CoWMeG, may represent a feasible tool to be used with Thai stroke patients who have cognitive impairments.

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Introduction

Stroke is the highest leading cause of morbidity and mortality among non-communicable diseases in Thailand[1] and one of the major causes of death and disability worldwide.[2] Wolfe estimated that by 2023, 30 percent of the world population will be affected for the first time by a stroke, with approximately 65 percent of stroke patients being functional dependent after one year.[3] Adults and elderly people are those in the segment of the population more affected by stroke.[4,5] The study of Yi et al,[5] highlighted a higher number of stroke cases occurring in people aged 40 and above. In addition, considering the segment of the population aged 55 years old and older, the number of stroke cases is currently on the rise, with the number of registered stroke events doubling every 10 years.[4] These previous findings were confirmed also in Thailand where the average age for stroke patients was found to be 65 years old.[6] In general, stroke can cause physical dysfunctions, language communication issues, and cognitive impairments.[7] Cognitive impairments after a stroke had been confirmed happening with a probability that ranges between 20 percent to 70 percent depending on patient status.[8] In addition, research studies have shown cognitive impairments as a significant predictor for occupational limitations.[9,10] In fact, stroke patients usually are required to undergo cognitive rehabilitation and long-term care due to their issues related to the stroke event.[11]

Regarding cognitive rehabilitation, it may be divided into two techniques: conventional and computer-based.[12] Conventional training usually includes manual exercises like paper-pencil tasks whereas computer-based training includes computerized cognitive rehabilitation and game-life programs. In the research field, paper-pencil and table-top tasks are currently the most common cognitive training in Thailand.[13-15] However, in recent years, many research works have employed computer-based training for cognitive rehabilitation, especially in developed countries.1[2,16-18] Prior to the adoption of computer-based intervention, computer -based training was only considered an option for cognitive training, and it was not extensively used.[11,19] The increasing usage of computer-based intervention in the healthcare sector may be explained by the digital transition that is currently happening all around us, including in many professional settings, like the health one. The portability and easiness of interaction with touchscreen devices have opened new doors of opportunity for deploying touch-screen solutions also in the segments of the population usually less tech-savvy, like the older generation. Even though elderly people are less likely to use technology than younger people,[20] they have become more open to accepting it and more familiar with it,[21] also due to the exposure and interaction with relatives and family members more tech-savvy. However, it is important to keep in mind that not every technology-based intervention would be suitable for being used indistinctly, especially with elderly people, due to a wide array of age-related issues.[20] In this regard, the study of Fager and Burnfield offered interesting insights on patients' experience with using technology for their inpatients' rehabilitation.[22] In the specific, the participants in their study stated that using games and mobile technologies motivated and supported them throughout the therapeutic intervention they underwent. In general, it can be said that games are usually related to fun and enjoyable experiences and thus they motivate people in desiring to play, without realizing that they are training.

Considering Thailand, based on our literature review, there is only one prior research study related to the occupational therapy field currently present in the body of literature,[23] where the researchers adopted technology-driven solutions to create computer-based cognitive training for stroke patients: CogTA-Tab. This application focused on the training of different cognition spheres such as attention, memory, and executive functions. CogTA-Tab consists of a total of fifteen cognitive games with different difficulty levels. In the aforementioned study, fifteen stroke patients underwent a CogTA-Tab training for 6 consecutive weeks, 3 times per week. The results of the study showed a significant improvement in cognitive functions (p<0.05). However, regarding its design, even though the researchers tried to introduce sensory information such as sounds, pictures, numbers, and symbols into the training application, few elements such as score or sound feedback represent an area of improvement for CogTA-Tab. Specifically, sensory information like feedback represents an important factor in a game-like activity. According to the definition of a game by Juul,[24] games usually require players to put in their efforts for earning an outcome like a score, which represents feedback of performance. Using feedback, such as a visual score and verbal feedback may help improve a person's self-awareness, functional task completion, and fulfill individual satisfaction on performance, as stated in Schmidt et al.[25] Thus, aiming to fill the gap in previous research work,[23] we designed a computer-based cognitive training game by adding some elements of gamification such as verbal and score feedback and by creating three subsequential screen pages for each level (e.g., instruction, playing, and outcome pages). Additionally, we designed a computer-based cognitive game tailored specifically around the Thai ecosystem (i.e., Thai language, culture, and common activities in Thailand) capable to be user-friendly also for elderly people. In summary, the aims of this research study were to develop a computer-based cognitive training game for stroke patients with cognitive impairments and to investigate its usage feasibility with Thai patients.

Materials and methods

This research adopted a developmental research design and it consists of two phases: development and pilot use phase, and user experience phase. In the development and pilot use phase, we adopted the modified development process guideline of Benson and Clark.[26] In the user experience phase, we investigated the feasibility of our computer-based cognitive training game for being used with Thai stroke patients with cognitive impairments. More details on each phase can be found following.

Phase 1: Development of computer-based cognitive training game and pilot use

The objective of this phase was to develop the computer-based cognitive training game following specific steps, namely planning, construction, and quantitative evaluation. In addition, during the development and pilot use phase, we also adopted a co-design approach, an approach that encourages to add in the process stakeholders who could offer holistic perspectives.[27, 28] In our case, the group of stakeholders involved in the study included the research team, occupational therapists, academics staff, one information technology engineer, a team of game developers, and stroke patients.

Planning step: In this step, we reviewed the related research studies, theories, and frameworks. This research study adopted the Dynamic Interaction Model for framing dimensions related to the cognition sphere (i.e., person, environment, and activities) and the Model of Human Occupation (MOHO) as a framework for understanding the desire of a person in engaging in activities.[29, 30] We decided to focus on the working memory sphere because it is commonly affected by stroke events and, additionally, there are many research works currently present in literature that highlighted the effectiveness of working memory training.[11, 18, 31-33] The game contents of the computer-based cognitive training game were identified based on the previous research work and theory and included verbal tasks, visuospatial tasks, executive tasks, and processing speed tasks.[34-38] Finally, we identified a set of simulated real-life activities related to the Thai culture, language, and in general, the Thai ecosystem. The deliverable of this step was the game contents of the computer-based cognitive training game created by using simulated real-life activities tailored to the Thai ecosystem.

Construction step: In this step, three experts examined the game contents included in the computer-based cognitive training games. These three experts are occupational therapists with more than 5 years of experience with cognitive rehabilitation for stroke patients, both in the practical field (2 experts) and in the academic field (1 expert). The Index of Item-Objective Congruence (IOC) from the content validity was equal to 0.67-1.00, which indicated that the game contents were well-congruent with its objectives.[39] Next, we revised the game contents following the experts' advice. Before developing the computer-based cognitive training game into its application, the different stakeholders, including the research team, information technology engineer, and game developers, met for providing their perspectives and offering their suggestions regarding the user interface design. At the end of this step, we had the computer-based cognitive training game application. We developed the game for being used on an Android Samsung Galaxy Tab S6 Lite tablet (screen-wide 10.4 inches). We opted for a tablet as a therapy tool due to its portability, touch screen solution, relatively low cost, and large availability on the Thai market. These characteristics made a tablet solution suitable for this research work's goals. For developing the computer-based training game application, the cross-platform game engine 'Unity' (version 2020.1.0) was used. Unity is a well-known engine for game development.[40]

Quantitative evaluation step: In this step, we conducted a pilot use of the computer-based cognitive training game application on a tablet with five stroke patients who were familiar or had previous related experience with using technology tools (e.g., laptop, tablet, and smartphone). Participants were recruited from Buriram Hospital, Thailand, during the month of December 2020. Participants were first-time stroke patients and had cognitive impairments identified by the MSET10, with cut-off scores at ≤14 for no education; at ≤17 for primary school level; and at ≤22 for a higher level of education. Additionally, participants with visual and communication impairments were not included. Five stroke participants, who had cognitive MSET10 scores ranging between 12 and 22, were asked to play the computer-based cognitive training game 3 times, 30-45 minutes for 1 week. After finishing to play in each level of each game, participants were asked to rate the difficulty of every level in terms of time countdown, gameplay, and overall graphic interface including clarity of objects adopted in the levels. The questions were presented in the form of a Likert scale ranging from 1 (very easy) to 5 (very hard). During the playing sessions observation phase, notes and comments were recorded as guidelines for the final minor revision of the computer-based cognitive training game. The deliverable of this step was the fully developed computer-based cognitive game (CoWMeG). The flowchart of phase 1 can be seen in Figure 1.

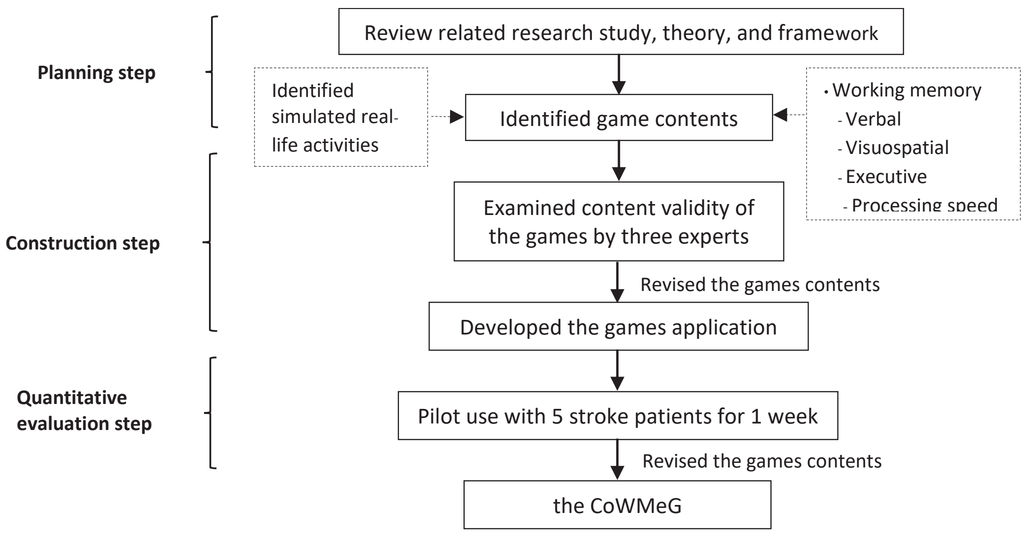


Figure 1. *Flow chart of the development process of the computer-based cognitive training game (CoWMeG).*

Phase 2: Investigation of user experience

This phase aimed to investigate the usage feasibility of CoWMeG with Thai stroke patients. The chosen sample size of this phase was based on the previous research work of Muskens et al,[41] where the authors developed an entertainment application for elderly people with physical and cognitive impairments. The fourteen participants were recruited from Buriram Hospital, Thailand, between February and April 2021. The selection criteria of the participants were the same as in the pilot use process. The participants were asked to play CoWMeG 3 times per week, 30-45 minutes, for 2 weeks following the guidelines for using CoWMeG. Then, the participants were asked to rate their user experience with playing CoWMeG by using the Test of Satisfaction on Computer-based Cognitive Game which was developed by the authors.

Instruments

There were two assessment instruments used in this study; the Mental State Examination (MSET10) and the Test of Satisfaction on Computer-based Cognitive Game. The MSET10 was used to screen patients who had cognitive impairments. It consists of 10 questions whose scores range from 0 to 29 which the lower the score indicates the higher cognitive impairments. The cut-off scores depend on the level of education: at ≤14 with no education, at ≤17 in the education level of primary school, and ≤22 in the education level of higher than primary school. The psychometric properties of the MSET10 showed high sensitivity and specificity.[42]

The Test of Satisfaction on Computer-based Cognitive Game was used to investigate the user experience with the computer-based cognitive training game. The test was developed and modified based on previous research works.[15] The test includes questions related to 4 different aspects: 1) overall experience: including enjoyment, quality, and satisfaction; 2) design of the games: including satisfaction with score and verbal feedback, clarity of pictures, clarity of sounds, and clarity of text; 3) portability of training material: including size, shape, weight, and durability of the tool used (tablet); and 4) convenience aspects: including setting up, laying aside, and maintenance. The questions were provided in the form of a Likert scale ranging from 1 (very unsatisfied) to 5 (very satisfied).

Statistical analysis

Demographic characteristics and user experience of participants were analyzed using descriptive statistics. Demographic characteristics of participants included gender, age, education, diagnosis, affected side, stroke onset, and the MSET10 scores. These characteristics were analyzed to obtain quantities such as frequency, percentage, mean, standard deviation, and maximum and minimum. The user experience was reported as a percentage.

Results

In this section, we present the results of the computer-based cognitive training game and user experience. Further details can be found following.

The computer-based cognitive training games: CoWMeG

CoWMeG is a computer-based intervention that consists of a total of ten working memory games involving verbal, visuospatial, executive, and processing speed tasks. Each game may involve more than one task. For example, in game 10, the gameplay involves both visuospatial and processing speed tasks (see Table 1). In addition, each game contains different difficulty levels, ranging from easy to hard, with an increasing number of stimuli (to remember) according to a higher difficulty level. CoWMeG is considered as a game-like training, created on the definition of the game from Juul,[24] where players need to put their efforts into earning an outcome like a score. In addition, CoWMeG adopts simulated real-life activity games, where the type of activities or stimuli included in the games were chosen based on Thai culture, language, and environment. Specifically, each of the games was created relying on common real-life activities, such as cooking, using a phone, or interacting with a home-like environment. Each activity was created recalling elements commonly found in Thailand, such as typical Thai foods and ingredients, animals common in Southeast Asia, in addition to using Thai language and alphabet across the game. These choices aimed to offer a virtual experience that could resemble a Thai user's familiar environments.

Table 1 Ten games of the computer-based cognitive training game and its representative working memory skills.

The computer-based cognitive training games: CoWMeG	Number of levels	Working memory skills			
		Verbal	Visuospatial	Executive	Processing Speed
Game 1 Shopping	5		/		/
Game 2 Measure your speed	3				/
Game 3 Making omelet with pork menu	3	/			
Game 4 Making fried rice menu	4	/			
Game 5 Making clear soup with tofu, glass noodle, and minced pork menu	3	/			
Game 6 Remembering the objects in a bedroom scene	3		/		
Game 7 Catching animals	3			/	/
Game 8 Remembering by eyes and listening by ears	3	/	/		/
Game 9 Telephone	3		/		
Game 10 Selling food by customer's order	3		/		/

Regarding working memory tasks of the CoWMeG (i.e., visuospatial, verbal, executive, and processing speed tasks), participants were asked to engage in different tasks, described following.

Working memory tasks:

Visuospatial tasks involve visual memorization. For example, in game 6, the player was asked to remember some bedroom-related objects (e.g., bed, curtain, clock, frame) that were shown in a specific sequence and in a specific position in the presented bedroom scene. After this initial phase, the player was presented with the same scene, filled with many objects, included those previously visualized. Thus, the player had to select only the previously presented objects, following the correct order, touching them on the screen accordingly.

Verbal tasks involve verbal memorization. For example, in game 3, the player was asked to remember some ingredients (e.g., oil, eggs, sauce), listed verbally, for preparing a specific meal. Sequentially, the player had to select, following the right order, each ingredient shown as an icon on a table in the center of the screen presented together with other ingredients, for then dragging them into a cooking pan (visualized on the screen).

Executive tasks, like in game 7, require a player to select only the animals (e.g., fish, shell, octopus) belonging to the group of those living in the ecosystem represented with the background scene (e.g., underwater scene).

Processing speed tasks require participants to complete a specific task within a specific time. For example, in game 2, the player was presented with a scene (e.g., sky, jungle, or nature scene). The player was then required to memorize a specific sequence of two or more items (e.g., star-moon-star-moon) that appeared in the same scene (e.g., many stars and many moons). During the selection, the player was required to select all the items (disappearing on touch) on the screen following the right sequence previously presented, and within a specific time, until all the items (e.g., moons and stars) disappeared from the scene. Once the countdown reached zero, all the items collectively disappeared from the scene, indicating the end of the game.

User interface design:

Regarding the user interface design of the CoWMeG, it consists of three pages: the main page, the level page, and the subsequential screen page (see Figure2). On the main page, the player can choose the game to play (between game 1 and game 10). On the level page, the player can choose the levels of difficulty of each game. The subsequential screen page consists of the instruction page, the playing page, and the scoring page. The first screen page presents the instructions (for each level) presented to the player. Additionally, on this screen page, the stimuli, presented on the screen after a vocal instruction, need to be remembered by the player. The second screen page represents the actual playing phase, where the player needs to play and thus perform the level-required task. The last screen page refers to the outcome part, where the score of the player's performance on the task is shown. In addition to the visual score, sound feedback is provided, in the form of a sound such as 'well done', 'almost got the highest score', or 'please try again'. This overall user interface design of CoWMeG was based on the research team's needs and on the information technology engineer and game developers' suggestions. An example of the level page and the subsequential screen page can be seen in Figure 3.

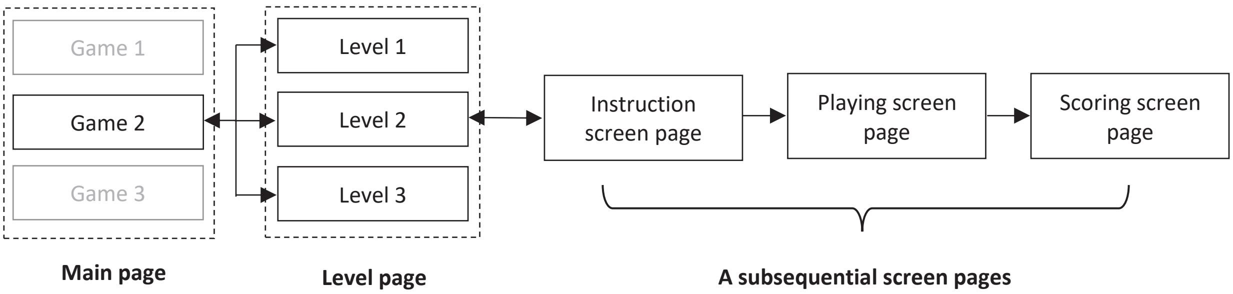
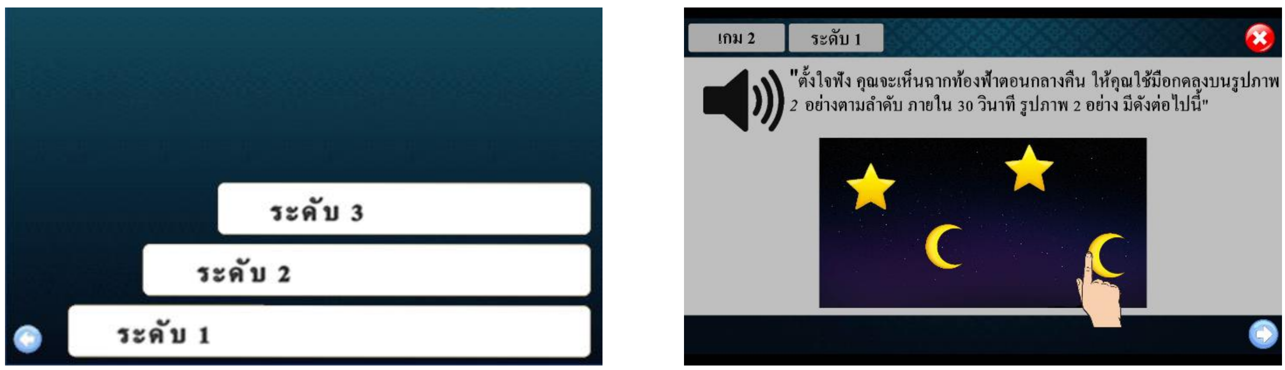
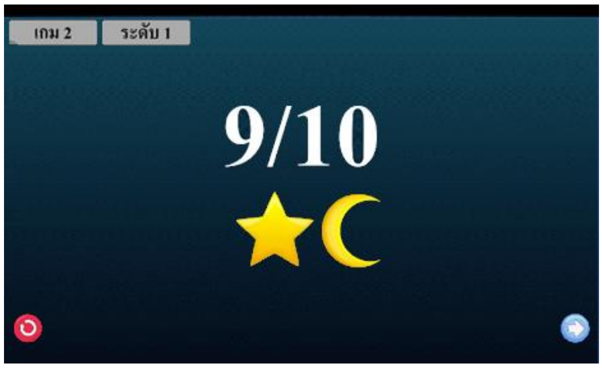


***Figure 2**. User interface design of the computer-based cognitive training game (CoWMeG).*



A B

C



D

Figure 3*. Example of sequential screen appearance for CoWMeG games. A: different difficulty levels page, B: Instruction page, C: Playing page, and D: Scoring page.*

User experience with CoWMeG

For the user experience phase, we included fourteen first stroke patients. Most of the participants were male. The age of participants ranged from 44 to 70 years old, with a mean of 60.57. The majority of the participants reported to have elementary school education (50%, n=7), 5 participants (35.7%) reported a secondary school education level, and 2 participants (14.3%) a high school one. The participants had a cognitive MSET10 score ranging between 13 to 22. Further information can be seen in Table 2.

Table 2 Demographic characteristics of participants in user experience phase.

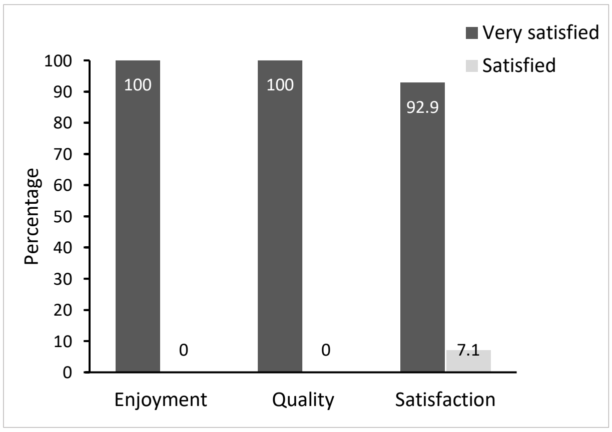
Demographics		The samples (n=14)			
		n	%	(Mean±SD)	Min-Max
Gender:	Male	10	71.4		
	Female	4	28.6		
Age:				60.57 (±8.30)	44-70
	35-49 years old	2	14.3		
	50-60 years old	4	28.6		
	61-70 years old	8	57.1		
Diagnosis:	Ischemic stroke	9	64.3		
	Hemorrhage stroke	5	35.7		
Affected side:	Right hemisphere	7	50		
	Left hemisphere	7	50		
Stroke onset (month)				4.71 (±1.73)	3-8
The scores of MSET10				17.29 (±3.29)	13-22

Note*: MSET10: the Mental State Examination, Max: Maximum, Min: Minimum, SD: Standard deviation*

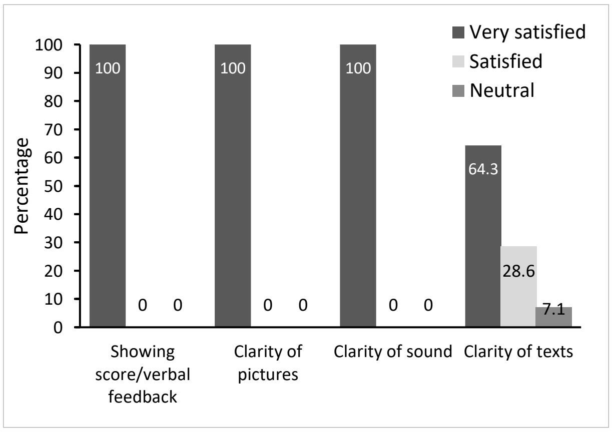
After playing with CoWMeG for 2 weeks, fourteen participants were asked to rate their user experience in four different areas. According to the results, most participants rated their total experience in the four different areas equal to ‘very satisfied’, corresponding to 84.2 percent of the total answers. The results for some of the questions in the areas of overall experience and design of CoWMeG received a 100 percent ‘very satisfied’ rate (in the question of enjoyment, quality, showing score/verbal feedback, clarity of pictures, and clarity of sound), as can be seen in Graph 1 and 2.

Most of the participants rated their experience on the convenience aspect as ‘very satisfied’ with the same percentage (85.7%) in all three questions (see Graph 3). The results in the area of portability of training material depict slightly different rates, with most of the participants rating their experience equal to ‘very satisfied’, ranging from 42.9 to 85.7 percent (of the total answers for each question within the portability category) depending on the question (see Graph 4). However, it is important to highlight the fact that all participants rated their experience with CoWMeG as ranging from neutral to positive experience (represented as 3 to 5 in the Likert scale) and no participant rated their experience as negative (represented as 1 to 2 in the Likert scale).

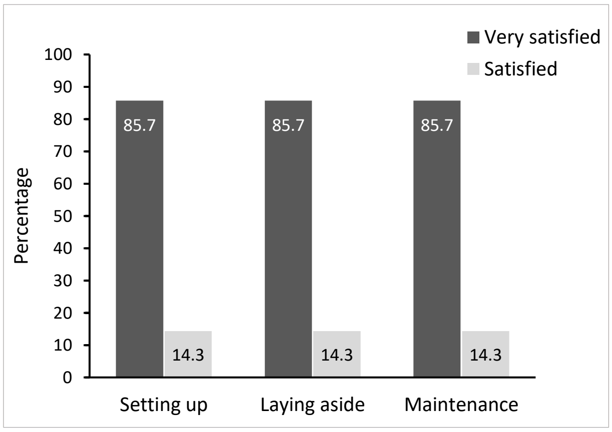
Graph 1 The percentage of user experience on overall experience with CoWMeG



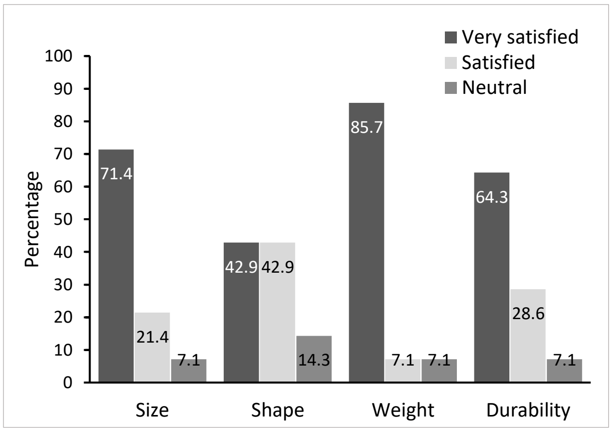
Graph 2 The percentage of user experience on the design of CoWMeG



Graph 3 The percentage of user experience on convenience aspect with CoWMeG



Graph 4 The percentage of user experience on a portable training material (tablet) with CoWMeG



Discussion

In the discussion section, we are discussing two parts: the computer-based cognitive training game and the user experience with the computer-based cognitive training game (CoWMeG).

The computer-based cognitive training game

Computer-based interventions for cognitive impairments have become popular in recent years, and they have been extensively used for cognitive rehabilitation, especially in developed countries.[12, 16-18] The increase in popularity of these computer-based interventions may present several advantages compared to conventional interventions like paper-pencil tasks or table-top tasks. Specifically, in the first place, a computer-based solution offers flexibility and adaptability in terms of task difficulty. In this regard, in fact, a specific task can automatically increase its difficulty level, ranging from easy to hard, and thus adapting to the user's individual cognitive abilities level. This approach of adaptability in the level of difficulty is also commonly found in commercial computer-based cognitive training such as PSSCogRehab software, CoTras program, Parrot software, and Cogmed QM.[32, 43-45] Secondly, a computer-based solution supports easy implementation of game-like functionalities like a countdown timer or processing speed during training. In general, in fact, working memory training is characterized by a storage time equal to 1 minute or less, with an input speed of stimuli of 20 bits per second, requiring the player who trains with it to memorize or to respond to the stimuli within a specific time.46 Due to this characteristic of working memory training and its requirement of countdown timer features, processing speed training may be less convenient to implement in a paper-pencil task or a table-top task.

In addition to the aforementioned convenient aspects of using computer-based interventions for cognitive training, there are some additional advantages that we would like to further discuss. Specifically, a computer-based solution allows a training task to provide automatic feedback. For example, in CoWMeG, we used immediate feedback such as auditory and visual feedback on the player's actions as in game 2, where the beeping sound accompanies the disappearance of the visual stimulus after the player touches it on the screen. Additionally, verbal feedback and score assignments can be easily supported by a computer-based solution, which is also capable to guarantee an error-free and consistent environment over time, typical characteristics of digital solutions. Moreover, Schmidt et al.,[25] stated that the usage of feedback may help to improve a patient's self-awareness, functional task completion, and fulfill an individual's satisfaction with their performance. An additional potential advantage of computer-based training consists in its ability to enhance the accessibility to the training. Specifically, patients or players can easily install an application on their own technology devices, thus being offered the ability to train and play by themselves in any convenient setting, besides the healthcare ecosystem (like in a clinic, or in a hospital). However, we need to remind the reader that CoWMeG is not yet appropriate for being played by a player alone unless they are already familiar with its user interface design. It is also important to highlight the fact that computer-based cognitive interventions have been shown to have better effects on cognitive functions compared to conventional interventions.[47-49] The reasons for this have not yet been fully investigated, but a partial explanation could reside in the advantages offered by computer-based solutions, such as increased motivation and engagement through the use of game elements or gamification (e.g., number of levels, sound, leader board, scores).[50, 51] Factors like immediate feedback and gamification may motivate players to put more effort into repetitive training tasks with the goal of reaching better outcomes (scores) or rewards, and thus, paving the path for their own improvement.

Furthermore, the development of computer-based cognitive training created to be appropriate for a specific target group needs to keep in consideration an important factor such as the user interface. For instance, the interface design may results very important during the development of computer-based solutions tailored for elderly people, who may be less likely to be tech-savvy, and affected by common related-age issues like dexterity impairments and sensory impairments (e.g., blurred eyesight, color vision loss, hearing impairment).[20, 41] Regarding the user interface, Muskens et al.[41] stated that elderly people prefer a lower deep hierarchy, few icons, large buttons or objects, and immediate feedback. In accordance with these suggestions, the user interface of CoWMeG has been designed with only three deep hierarchies (i.e., main page, level page, and a subsequential screen page), and with few icons for each page (e.g., next-back, try again, and close icons) - see in figure 2 and 3. Another element to keep in consideration is the button size. In this regard, the recommended minimum size of a button is 11.43 mm where 17 mm is considered a large size.[52, 53] In alignment with these recommendations, the size of the adopted buttons in CoWMeG ranges from 12 to 60 mm, dimensions that can be considered large and appropriate for elderly people and could address their common problems, such as hand dexterity. Additionally, we used clear pictures and clear sound/texts within a color-contrasting background in order to overcome vision and hearing issues .[20, 54] Thus, we believe that the user interface design of CoWMeG accounts for possible age-related characteristics of the average stroke patient-user, and thus it might be said to be characterized by an 'elderly-friendly' design.

User experience

In our research work, we demonstrated that the newly developed computer-based cognitive training games (CoWMeG) may be feasible to use for training with Thai stroke patients. Regarding this, the majority of the participants in this study expressed their positive user experience with CoWMeG, rating their total overall satisfaction as 'very satisfied' (84.2 percent) and no participants expressed a negative user experience. Specifically, CoWMeG may be identified as an elderly-friendly training game, characterized by user-friendly features like the absence of deep hierarchy, few icons adoption, and large buttons.[41, 52, 53] We also included sensory-information input (i.e., immediate auditory and visual effects, score feedback, and using simulated real-life activities) to maximize the overall understanding, enhance motivation and engagement with the games.[25, 51, 55] Thus, we believe that these characteristics of CoWMeG positively contribute to the user experience outcome. This statement could be also confirmed in Graph 2, where it can be seen that all the participants were very satisfied with the usage of features such as showing the score and verbal feedback, clarity of pictures, and sound. Regarding the clarity of texts (i.e., instruction texts), the 'very satisfied' level recorded a figure of 64.3 percent, lower compared to the 100 percent figures in the other categories of Graph 2. Yet, it is important to stress the fact that even within the clarity of texts category, all the respondents reported a positive experience with CoWMeG, since all the users rated their experience in the range of 3-5 in the Likert scale, thus, positive overall. Finally, we would also like to highlight the fact that game instructions for each level were not offered only in the textual format, but they were additionally presented to the player in alternative ways such as auditory instructions, to facilitate and maximize the overall understanding of the tasks and to support also those players who may be not proficient or even not understand the Thai alphabet.

Furthermore, positive ratings for enjoyment, quality, and satisfaction with CoWMeG were reported as very high, with all participants agreeing that CoWMeG offered them a feeling of enjoyment accompanied by a perception of quality. In this regard, there was only one participant who rated their satisfaction as 'satisfied' (4 out of 5 on the Likert scale) with the rest of the participants who reported a 'very satisfied' level of experience (5 on the Likert scale - refer to Graph1). These positive user experiences could be related to the use of a computer-based solution with game-like training, where tasks are usually designed to be fun and engaging. Specifically, video games have been proven to support engagement and motivation,[56, 57] and besides being useful tools for the training of cognitive processes, numerous studies have demonstrated the ability of video games to offer a variety of positive emotion-triggering situations with positive effects on individuals well-being, and with a specific focus on cognitive and emotive enhancement.[51, 58] Moreover, video games, and gamification in activities, 'produce an emotional state induced by several factors, most important of which is fun',[56] supporting both engagement and motivation. Motivation is that driving force that makes people want to invest all their efforts into whatever they do and it is an essential element for having the player engaged with the game-like activities.[59] In general, it can be said that motivation is a fundamental element necessary for every activity someone is involved in.[60] Additionally, Ryan, Rigby, and Przybylski,[61] showed that the need for satisfaction during playing a game leads to short-term improvements in well-being, and in general, playing videogames has positive effects on the cognitive, motivational, emotional, and social aspects of well-being.[62]

Furthermore, our choice to develop CoWMeG for tablets appears to be a feasible solution for being adopted by Thai stroke patients. This could be confirmed in Graphs 3 and 4, where most of the participants perceived this solution as convenient (i.e., setting up, laying aside, and maintenance) expressing a high level of satisfaction (very satisfied) with the physical characteristics of the used tablet (i.e., size, shape, weight, and durability). In fact, a tablet is usually characterized by a wider screen compared to smartphones, thus providing more space for action and wider vision while playing games. Additionally, a touch-screen solution allows players to directly act on the objects with a simple movement and touch of their fingers, thus removing the need to pass through pointing devices, like a mouse, or cumbersome interactions with a keyboard, common requirements found in laptop or table-desktop solutions. Importantly, a tablet solution enhances accessibility, allowing a player to engage with the game-like training anytime and anywhere, due to its portability nature. Moreover, computer-based cognitive training games like CoWMeG may be a solution for supporting occupational therapists in their professional activities with Thai stroke patients, especially in a clinical setting, where there may be a lack of dedicated performing areas.

Finally, it should be acknowledged that the participants in this study were stroke patients who have cognitive MSET10 scores between 13 and 22. Thus, using CoWMeG with stroke patients who have cognitive MSET10 scores lower than 13 may show different results on user experience because the game tasks might be too hard for the players' cognitive abilities. Investigation of CoWMeG for being used with those who have cognitive MSET10 lower than 13 may be needed. However, we assume that CoWMeG may be feasible to use also with those patients who have MSET 10 scores lower than 13 due to the fact that our game was designed based on a number of stimuli (that needs to be remembered by the players) ranging between a minimum of 1 and a maximum of 7±2.[63] Additionally, we do believe that cognitive abilities are not the only element to account, but therapists should also keep in consideration the user's previous technology-related experience, especially during the first time playing. However, Kueider et al.,[64] stated that most computer-based cognitive training does not require tech-savviness for completing the tasks. This might also be seen in CoWMeG where the player needs to perform relatively simple actions like touching, moving, or dragging target objects on the screen in accordance with the game instructions. On the last note, it is important to remind that skin dryness (commonly found in elderly people) could lead to unresponsiveness when touching the screen. This problem could be easily overcome with the usage of a tablet pen.

Limitation and future research

The computer-based cognitive training game (CoWMeG) developed in this study was used with Thai stroke patients who were familiar or had previous related experience with using technology tools (e.g., laptop, tablet, and smartphone), and had cognitive MSET scores between 13 and 22. Different results may be obtained with users who are not familiar with technology, and with stroke patients who have cognitive MSET10 scores lower than 13. Future research could focus on testing the usage of CoWMeG with patients with different cognitive function impairments, and different technology-based experience backgrounds. In addition, future investigation on the effectiveness of CoWMeG is needed mainly on its effects on working memory and occupational performance.

Conclusion

In this research work, we focused on the development of a computer-based cognitive training game and on measuring its feasibility for being used with Thai stroke patients who have cognitive impairments. The newly computer-based cognitive training game, named CoWMeG, consists of a total of ten working memory games. Each game has different difficulty levels with each level consisting of three subsequential screen pages (e.g., instruction, playing, and scoring screen pages). CoWMeG is considered as a game-like training that uses simulated real-life activities whose design is based on the Thai ecosystems (e.g., language and activities). The results on the user experience indicate that CoWMeG may be feasible for being used with Thai stroke patients who have cognitive impairments.

Conflict of interest

All authors declare no personal or professional conflicts of interest relating to any aspect of this study.

Ethic approval

This research project was approved by the Research Ethics Committee of Faculty of Associated Medical Science at Chiang Mai University, Thailand with study code: AMSEC-63EX-041, ethic clearance number:371/2020, and by the Human Ethics Committee of Buriram Hospital, with ethic clearance number 6/2563.

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