Original Article

Effects of Applications on Computer Tablet for Cognitive Training in Stroke Patients

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ABSTRACT

Objectives: To study the effects of a computer tablet applications for cognitive training on cognitive functions in stroke patients.
Study design: A quasi-experimental, one group, pretest-posttest design.
Setting: Occupational Therapy Unit of Thammasat University Hospital
Subjects: Fifteen patients with first stroke and cognitive impairment, aged between 35-70 years, and duration of stroke less than a year, who received occupational therapy service from December 2018 to June 2019
Methods: Participants were selected by purposive sampling. The mini-mental state examination (MMSE)-Thai 2002 was used to screen for cognitive impairments. Participants received a tablet computer-based cognitive training under supervision of an occupational therapist 3 times per week for 6 consecutive weeks. They underwent the Digit Span Test, the Thai Cognitive-Perceptual Test (Thai-CPT) and the Dynamic Loewenstein Occupational Therapy Cognitive Assessment (DLOTCA) before and after the training period. Descriptive statistics and non-parametric Wilcoxon Signed Ranks Test were used to analyze data.
Results: The average age (SD) of the participants was 58 (11.39) year old. The male:female ratio was 1.1:1. The improvement of attention, memory and executive functions reached statistical significance ($p < 0.05$).
Conclusion: The tablet applications for cognitive training which were used in this study improved attention, memory and executive functions in stroke patients.

Keywords: cognition, perception, computer tablet, stroke rehabilitation, occupational therapy

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Introduction

Stroke is a significant health problem world-wide. The World Health Organization (WHO) reported global death rate from stroke as 17.9 million per year, which is 77% in 100,000 people especially in those who were 70 years old and over. It is the second cause of death to coronary disease.[1] In Thailand the current stroke situation reported by the public health statistics shows 47.15% death rate in 100,000 people and is the number one cause of death in non-communicable diseases (NCDs), and there are 30,837 patients diagnosed per year, and the number may increase if correct prevention is not established.[2] One in three stroke patients are permanently disabled and 20% needed long-term care in rehabilitation clinics. The residual disability affects their quality of life, self-image and their families' economy.[3] Stroke patients have impairments in the motor and sensory systems which cause difficulties in body movements. In addition, many stroke survivors have cognitive impairments from lesions in different areas of the brain, which become barriers to being independent. They must depend on their families and the society which leads to social disadvantages.[4] Cognitive impairments after stroke is prevalent and affects 72% of all stroke patients in the first 1-3 months.[5] The most commonly impaired domains are the followings: attention, memory, language, orientation, and executive functions.[6] Generally, maximal recovery is within 12-18 months and 30% of the patients who still have cognitive impairments after one year develop post-stroke dementia.[7] Cognitive rehabilitation models commonly used in stroke patients in Occupational Therapy clinics are 1) remedial or restorative approach which stimulates neuroplasticity using table top or computer-based activities with other specific techniques by professionals, and 2) adaptive or compensatory approach which improves patients ability to engage in occupations under their limitations and compensate for loss abilities through activities analysis and synthesis, cognitive strategies, and environment modifications and adaptations.[8]

Recently, several computer-based cognitive trainings have become available for use in clinical practice such as computerized software, tablets, gaming consoles and virtual reality systems. Prior oversea studies on the effects of computer-based cognitive training varied in program formats, measurement of results, and research methodologies.[9] Several studies in stroke patients showed that a computer assisted cognitive training can improve working memory, delayed

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memory, attention span, visual and auditory learning, verbal fluency, and depressive symptoms.[10,11] It was suggested that supervision by a qualified therapist who could modify level of task difficulty to suit individual patient at their respective stage of recovery, is another very important factor.[12,13]

Even though studies about computer-based cognitive trainings from oversea are numerous. However, the number of studies from Thailand is still limited. Cultural bias is a potential factor which limits the validity of adopting training software which were developed abroad. Recently in Thailand, a CogTA-Tab for cognitive training has been developed and designed based on Thai contexts.[14] Researchers chose to use a tablet as therapy media because modern tablets are so portable, easy to operate, have fast and powerful computing power and yet do not cost a fortune. Stroke patients, who typically experience weakness on one side of the body could without much difficulty could carry the tablet around and operate them with little assistance. The goal of this research was to study the effect of cognitive training using this software on tablet computer by measuring changes of attention, memory, and executive functions after a course of tablet-based training with the CogTA-Tab in a group of stroke patients.

Methods

This research was approved by the Research Ethics Committee of the Faculty of Associated Medical Sciences, Chiang Mai University No. AMSEC–61EX-021 and the Human Ethic Sub-committee of Thammasat University, No. 3 (Faculty of Health Science and Science and Technology), the project No. 197/2561. This research was supported and funded by the Faculty of Associated Medical Sciences, Chiang Mai University, through 2018 annual research funds. This research was a quasi-experimental, one group, pretest-posttest design.

Participants

Stroke patients who received occupational therapy at Thammasat University Hospital from December 2018 to June 2019.

Inclusion Criteria

- First-time stroke patients, during post-acute phase with less than one year after onset.
- Age between 35-70 years old.
- Having cognitive impairments screened with the Mini-Mental State Examination Thai Version–2002 (MMSE–Thai 2002). Score cut point was ≤ 14 for those who did not enter schools or were unable to read, at 17 for those who passed primary school, and ≤ 22 for those who had higher education.[15]
- Able to read and write in Thai
- Being familiar with using a computer, a tablet or a smartphone.

Exclusion Criteria

- Having visual impairment or communication limitation, dementia or other mental disorders.

Withdrawal criteria

- Receiving less than 80% of the training sessions.
- Taking medications affecting cognitive abilities during the training.

Sample size calculation

Based on data from a previous study,[16] sample size calculation was made with a computer software G*power 3.1. Sample size of 13 were needed when the following parameters were defined: effect size 1.01 with .05 deviation and .08 Power of Test. To prevent drop outs, the researchers added 2 more participants, therefore this research sample size was a total of 15 participants.

Outcome measurement

1. The Forward and Backward Digit Span Test were used to assess attention in this research.[17]
2. Memory was assessed with the “Recall” and “Recognition” subtest of the Thai Cognitive-Perceptual Test (the Thai-CPT).[18]
3. For executive functions, the Matching and Categorization, and the Problem-Solving subtest of the Thai-CPT were used to assess executive functions. An assessor received a formal training in order to use and score this tool accurately.[18] In addition, four topics from two subtests: 1) Visuomotor Construction: Plain Block Design and Puzzle, and 2) Thinking Operation: Pictorial Sequence A & B to assess executive functions, from the Dynamic Lowenstein Occupational Therapy Cognitive Assessment for Adult (the DLOTCA) were also used.[19]

Intervention

Application on Tablet for Cognitive Skills Training in Stroke Patients

“The CogTA-Tab” is a computer program developed by Munkhetvit et al. under cognitive rehabilitation models commonly used in occupational therapy practice.[14] It focuses on training 3 domains of cognitive skills affected by stroke: attention, memory and executive functions. Its application was developed with the software development tool “Unity3D” Version 2018. It can be installed on smartphones or PC tablet which operates on Android operating system Version 5.0 and up. The hardware used in this study was a Huawei Media Pad T5 with 10 inches screen. The CogTA-Tab consists of 15 cognitive training games as follows: 1) Attention training games, in which a visual target randomly appears various locations on screen, then patients respond by touching the screen where the targets are until they have collected the set number of targets. These games require visual attention and orientation in order to search for the targets. Example of the activities are maze game, savings coins, finding different numbers, finding animals, fishing game, provincial explorer, and calm touching game (shown in Figure 1 and 2) Memory training games that feed sensory information including

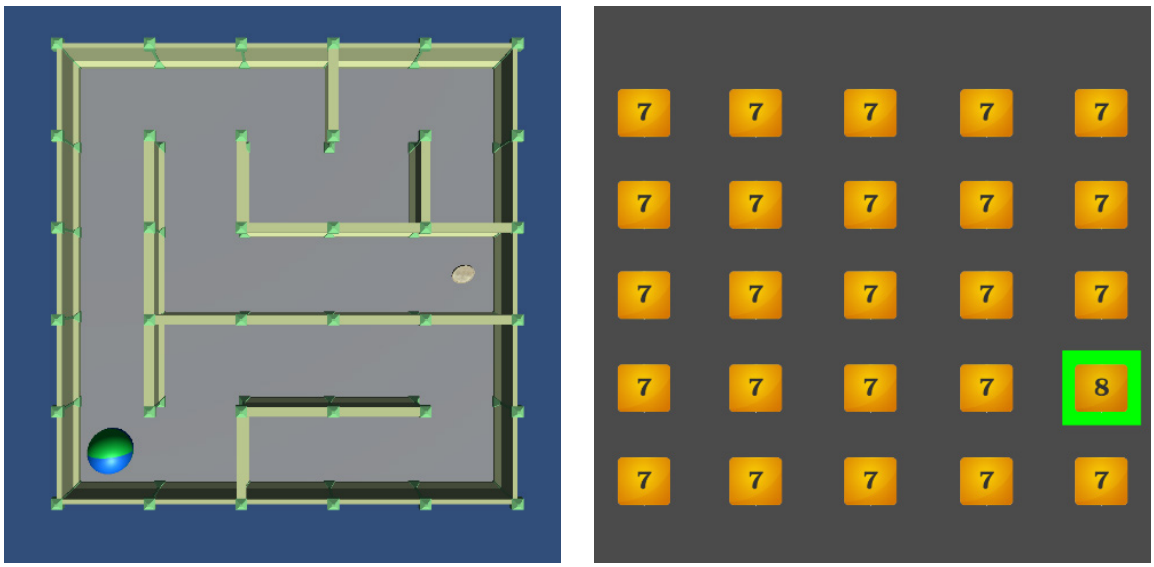

Figure 1. A) Sustained attention training in games maze, B) Focused attention training in find the different number games

Figure 2. Recall memory training on tablet

sounds, pictures, numbers and symbols to stimulate patients to process the information from hearing and seeing senses, then respond by collecting short-term memory and recall memory. Example of the activities are number echo, count lyrics words, can you remember? and listen carefully game. (shown in Figure 2 and 3) Executive functions training games which stimulate patients to use executive functions through pictures, words, and numbers. The patients must try to organize, sort, plan ahead, show flexible thinking and abstract thinking, and stimulate patients to complete the targeted activity. The activities are the train, don't be confused, picture mystery game, and matching pictures game. Within each type of games, there are 3-4 levels of difficulties. Each patient will start at the easiest level (Level 1), then the level of difficulty will gradually increase in each training. In one session, the patients receive training of all these 3 cognitive skills. Moreover, before the training program, the participants and their caregivers received education about stroke and cognitive impairments following stroke. During each 45-minute sessions individualized training were delivered under direct supervision by the researcher. During the 6 consecutive weeks, each patient received 18 treatments in addition to their conventional occupational therapy rehabilitation program at Thammasat University Hospital.

Steps of the study

1. After receiving human research approval from the three Research Ethics Committees mentioned-above, the researchers started collecting 15 participants via specific sampling, explained the research objectives, intervention and protection rights, and asked them to sign an informed consent form.
2. The trained assessor used the Digit Span Test, the Thai CPT, and the DLOTCA to assessed the participants' cognitive functions before the training program (pre-test).
3. Each participant received cognitive skills training using tablet application for 45 minutes per session, 3 sessions per week for 6 consecutive weeks, in combination with a conventional occupational therapy program at Thammasat University Hospital.
4. After completing the cognitive training program, the same assessor reassessed all participants by using the same tools.
5. Data were analyzed and interpreted.

Statistical analysis

Statistical analysis was done by computer program SPSS version 22.0. Demographic data were described as number, percentage, mean and standard deviation (SD). The cognitive functions scores before and after the intervention were analyzed using non-parametric statistics, Wilcoxon Signed Ranks Test where statistical significance was determined at $p < 0.05$.

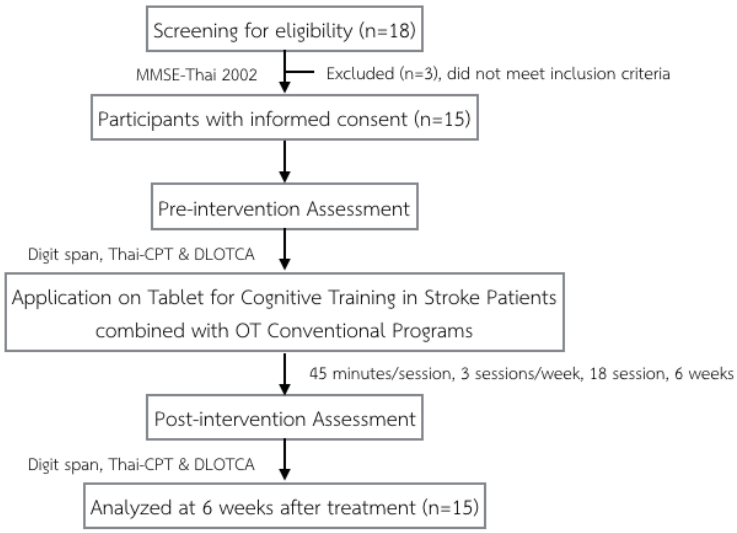

Figure 3. Flow of the study

Results

Fifteen participants were recruited: eight were males (53.3%), average age was 58.73 (SD 11.39; range 35-70) years, 86.7% received education higher than primary level; average duration of stroke was 4.53 months, 80% had ischemic stroke, and 53.3% experienced right-side weakness; and 66.7% were right-handed. Using the MMSE-Thai 2002, the participants' cognitive screening results had an average score of 19.80 (as shown in Table 1).

As demonstrated in Table 2, majority of the participants had improved cognitive test scores (positive rank) in all three cognitive skills. There was no participant with lower test scores after training (negative rank), and there were only small number of participants with same scores despite of training (Ties). Statistical analysis comparing before and after training cognitive measurements with Wilcoxon Signed Ranks Test confirmed significant improvement in attention, memory and executive functions at $p < 0.05$, except for recognition memory. The mean rank of each test score both before and after training, including number of participants with negative ranks, positive ranks and tie, as well as the corresponding statistic significant level can be seen in Table 2

We also observed that stroke patients who had weakness in their dominant arm and hand had difficulties getting used to functioning with their non-dominant hand to respond on the tablet screen. This was common in the initial phase of training using tablet application. Another common problem for older age stroke patients was difficulty using their fingertips to touch the screen due to skin dryness. The use of touch screen stylus could overcome this problem.

Discussion

This research found that the cognitive training program using the CogTA-Tab application on a tablet improved cognitive functions in stroke patients significantly ($p < 0.05$) which proved the research hypothesis that this tablet application would help improve attention, memory and executive functions in all participants after receiving the training. This research shows positive effects of cognitive training programs conforming to the research by Zucchella et al. which combined multi-domain computer-based cognitive rehabilitation program and metacognition strategies training as an early intervention for patients with stroke during subacute phase.[20] The study done by Zucchella et al. used a retraining approach in the belief that repetitive method of skills training or computer-based exercises help to improve cognitive functions in stroke patients, and showed that patients have improved skills in visual attention and verbal memory after 4 weeks of training and suggested that logical-executive functions and the patients' quality of life may take longer

Table 1. Demographic and clinical characteristics of the study participants (n=15)

Demographic data	
Gender[1]	
Male	8 (53.3%)
Female	7 (46.7%)
Age (years)[2], min=35 years, maximum=70 years	58.73 (11.39)
Education level[1]	
Primary school and lower	2 (13.3%)
Higher than secondary school	13 (86.7%)
Duration of stroke (month)[2]	4.53 (2.94)
Types of stroke[1]	
Ischemic	12 (80%)
Hemorrhagic	3 (20%)
Affected side[1]	
Right hemiparesis	8 (53.3%)
Left hemiparesis	7 (46.7%)
MMSE – Thai 2002 score[2]	19.80 (1.69)

[1]Number (%), [2]mean (SD)
*MMSE-Thai 2002, Mini-Mental State Examination-Thai Version 2002

Table 2. Mean rank, z-score, p value between pre-test and post-test scores

Cognitive skills	Negative ranks (post < pre)		Positive rank (post > pre)		Ties (post = pre)	z	*p*-value
	n=15	Mean rank	n=15	Mean rank			
Attention							
Forward digit span	0	0.00	12	6.50	3	-3.089[a]	0.002*
Backward digit span	0	0.00	14	7.50	1	-3.359[a]	0.001*
Total	0	0.00	14	7.50	1	-3.329[a]	0.001*
Memory							
Recall	0	0.00	13	7.00	2	-3.192[a]	0.001*
Recognition	0	0.00	3	2.00	12	-1.604[a]	0.109
Total	0	0.00	14	7.50	1	-3.314[a]	0.001*
Executive functions							
Matching & categorization	0	0.00	8	4.50	7	-2.640[a]	0.008*
Problem solving	0	0.00	14	7.50	1	-3.346[a]	0.001*
Visuomotor construction &thinking operation	0	0.00	14	7.50	1	-3.318[a]	0.001*
Total		0.00	15	8.00	0	-3.415[a]	0.001*

*Statistically significant difference in means ($p < 0.05$), a based on negative ranks

to restore to show more apparent change.[20] Similar to the study by Westerberg et al., memory training using a personal computer at home in combination with daily online follow-up by therapist could improve working memory and attention in stroke patients, and the program should provide graded activities from easy to hard levels to suit each patient's ability, as well as to provide follow-up or feedback from therapist to maintain a continuity of training and patients' adherence to training at home.[21] Moreover, the study by Prokopenko et al. used computer correction in cognitive training by repetitive of correction to help stimulate perception, restoration, and processing of information in the brain. It was found that stroke patients had increased skills in attention, visual and spatial memory after the training.[22]

The CogTA-Tab application used in this study consisted of large variety training activities which may promote active engagement of participants during training. Uses of pictures, sounds, colors and contents related to Thai context might also be another factor that supports the effectiveness of this particular software. In addition, a direct personal supervision during the training allowed an immediate positive feedback which further motivated the participants and retained consistently high patient effort level during training. Furthermore, it allowed for negative feedback, which increased the challenge and motivated the participants to develop their capacity. The positive relationship between the trainer and the participants leaded to relaxed atmosphere during the training which could facilitate higher cognitive performance. It is well known that cognitive strategies training using internal and external strategies, errorless learning technique and cueing or prompting techniques by therapist, could promote development of executive functions, as well as generalization of the new to other activities.[23,24] During this research, the use of the application on tablet for specific cognitive skills training were carried out according to the principles of cognitive restorative approach and applied graded activity, tailored to individual pretraining ability level.

We believe that such improvements might come from the fact that the brain structures and functionals change after received the training program. Lin et al. studied the recovery mechanism of brain functions in stroke patients who received computer-based cognitive training programs to restore executive functions and memory, and found significant structural changes in the brain function networks especially in the hippocampal, the frontal and the left parietal lobe areas, which relate to memory and executive functions.[25] In a study by Yang et al. found that after integrated computerized cognitive training program, the stroke patients showed increased of the hippocampal functional connectivity mainly located in the prefrontal gyrus and medial temporal areas which are related to improved memory and change in brain structures during default mode network (DMN) controlled by the parietal lobe of the brain in posterior cingulate, ventral medial prefrontal, and dorsal medial prefrontal cortex, which are associated of cognitive functions.[26] Meanwhile, Yeh et al. studied cognitive skills training with aerobic activity using computer program and believed that it might speed up the process of recovery in neural and brain cells in affected and nearby areas, help increase axons for synaptic connectivity which affected the brain functionals as seen in fMRI, and the changes are more obvious during 3-6 months after regular training.[27] According to the study of Zhang et al., the effects of a computerized multi-domain cognitive training run on a tablet device on improving skills in reasoning, memory, visuospatial skill, language, calculation, and attention were changes in the brain's gray matter volume in the right angular gyrus and parietal area, near the intra-parietal sulcus, in patients with amnestic mild cognitive impairment.[28]

Our study showed significant changes in the participants' cognitive skills in attention, executive functions and recall memory after completing the training program. However, there was no significant difference in recognition memory between pre- and post-test intervention. We assumed that this is the phenomenon called ceiling effect resulting from the very high to full pre-test score in recognition memory. It is in accordance with the study by Chaiwong et al. finding no difference in recognition memory between pre- and post-test in elderly with mild cognitive impairment.[29] This may also be due to the level of difficulty of the assessment tool, which gives the high pre-test scores. Thus, after the intervention, those whose the pre-test scores were high, shows no difference. Bastin et al. explained a hypothesis that patients whose hippocampal area of the brain was damaged will lose the ability to recall or recollection memory.[30] However, the patients will still have the ability of recognition depending on the autonomic familiarity and personal experiences. Thus, this research found no difference in recognition as the most patients remaining abilities.

The limitations of this research were a small sample size and only one sample group. Some activities in the CogTA-Tab application are similar to some test items from the assessment tools, and could result in more or less practice effects. Further study can be designed to overcome these by including a control group with adequate number of subjects, as well as choosing outcome measurements that did not overlap with the training methods.

In conclusion, using the CogTA-Tab application developed by Thai researchers for 6 weeks of cognitive training could improve cognitive functions in stroke patients during post-acute phase.

Disclosure

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

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