Chula Med J Vol. 57 No. 2 March - April 2013

# Effects of playing video game on cognitive function in persons with mild cognitive impairment at King Chulalongkorn Memorial Hospital

Karanee Leelavanichkul*

Solaphat Hemrungrojn**

**Leelavanichkul K, Hemrungrojn S. Effects of playing video game on cognitive function in persons with mild cognitive impairment at King Chulalongkorn Memorial Hospital. Chula Med J 2013 Mar - Apr; 57(2): 187 - 202**

**Background** : *There have been increasing efforts to develop non-pharmacological preventive interventions for cognitive decline experienced by older adults. Cognitive training via playing games especially ones that aim at training concentration and speed processing has been shown to have positive effects on the certain domains of cognition in healthy older adults. Only few studies have directly examined possible cognitive benefits and transfer effects of playing video game in persons with mild cognitive impairment (MCI).*

**Objective** : *To explore the effects of a video game on cognitive functions in older adults with MCI.*

**Design** : *Quasi-experimental study*

**Setting** : *Dementia Clinic, King Chulalongkorn Memorial Hospital*

**Methods** : *Twenty volunteers aged 54-74 years fulfilling the MCI diagnostic criteria were enrolled. The sample was divided into 2 groups (10 members each): the Video game Group, received 6 weeks of speed - attention type video game training and Control Group. Cognitive functions were assessed using the Cambridge Neuropsychological Test Battery (CANTAB) before and after training. Data were analyzed using descriptive statistics and nonparametric Wilcoxon-Mann-Whitney U test.*

* Master of Science in Mental Health Program, Faculty of Medicine, Chulalongkorn University

** Department of Psychiatry, Faculty of Medicine, Chulalongkorn University

**Results** : *At 6 weeks, the Video game Group had significant improvement in executive function in the area of working memory (CANTAB SWM test) compared to Control Group ($p < 0.05$). The significant within group effects of pre- and post training for the Video game group showed improvement in processing speed and executive function test outcomes of problem solving and visual learning tasks (CANTAB OTS and PAL).*

Conclusions : *The result indicated that there is a possibility which the elderly with MCI could improve executive functions in short term training. Although the present study is limited by small sample sizes, nevertheless, the results are promising for the further investigation and development of cognitive-specific video games in larger, more diverse samples.*

**Keywords** : *Video game; mild cognitive impairment; CANTAB.*

Reprint request: Hemrungrojn S. Department of Psychiatry, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

Received for publication. March 10, 2012.

**ฆรณี ลีลาวณิชกุล, โสฬพัทธ์ เหมรัญช์โรจน์. ผลของการเล่นวีดีโอเกมต่อ cognitive function ในกลุ่มคนที่มี mild cognitive impairment ณ โรงพยาบาลจุฬาลงกรณ์. จุฬาลงกรณ์เวชสาร 2556 มี.ค. – เม.ย.; 57(2): 187 – 202**

**บทนำ** : *ในปัจจุบัน นักวิจัยมุ่งสนใจในการหาวิธีป้องกันภาวะสมองเสื่อม โดยวิธีที่ไม่ใช้ยา การฝึก cognitive ผ่านการเล่นวิดีโอเกม โดยเฉพาะแบบที่เน้นเสริมสร้าง สมาธิและความไวในกระบวนการคิด มีการศึกษาพบว่ามีผลด้านบวกในการเสริมสร้าง cognition ในผู้สูงอายุ ยังมีการศึกษาในเรื่องนี้ไม่มาก ในคนที่มี mild cognitive impairment (MCI)*

**วัตถุประสงค์** : *เพื่อสำรวจผลของการเล่นวีดีโอเกมต่อ cognitive function ในกลุ่มคนที่มี MCI*

**รูปแบบการวิจัย** : *การศึกษาแบบกึ่งทดลอง*

**สถานที่ทำการศึกษา** : *คลินิคโรคสมองเสื่อม โรงพยาบาลจุฬาลงกรณ์*

**วิธีการศึกษา** : *อาสาสมัคร 20 คน ที่ผ่านเกณฑ์วินิจฉัย MCI อายุระหว่าง 54 - 74 ปี โดยแบ่งเป็น 2 กลุ่ม คือกลุ่มควบคุมและกลุ่มทดลอง กลุ่มละ 10 คน กลุ่มทดลองจะได้เล่นวิดีโอเกมฝึก cognitive ด้าน speed - attention เป็นระยะเวลา 6 สัปดาห์ หลังจากนั้นทั้ง 2 กลุ่มได้การประเมินด้านต่าง ๆ ของ cognition โดยการใช้เครื่องมือระบบคอมพิวเตอร์ Cambridge Neuropsychological Test Battery (CANTAB) ก่อนและหลังการทดลอง มีการวิเคราะห์ข้อมูลโดยการใช้สถิติเชิงพรรณนา และ สถิติ Wilcoxon-Mann-Whitney U*

**ผลการศึกษา** : *พบว่ากลุ่มที่เล่นวิดีโอเกม เมื่อมีการประเมินด้วย CANTAB มีการพัฒนาด้าน executive function ในส่วน working memory (SWM test) สูงกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) และเมื่อวิเคราะห์ภายในกลุ่ม ก่อนและหลังเล่นเกม พบความแตกต่างภายในกลุ่ม โดยกลุ่มเล่นเกมเมื่อประเมินด้วย CANTAB มีการพัฒนาในด้าน processing speed และ executive functions ในส่วน problem-solving และ visual learning (OTS และ PAL tests)*

**สรุป** : *ผลการทดลองนี้สนับสนุนว่าการเล่นวิดีโอเกมในคนที่มี MCI นั้น สามารถพัฒนา cognitive functions ถึงแม้ว่างานวิจัยนี้เป็นงานวิจัยเพื่อศึกษานำร่อง จึงยังมีกลุ่มตัวอย่างจำนวนน้อย แต่พบผลการวิจัยที่น่าพอใจและน่าที่จะมีการศึกษาผลของการเล่นวีดีโอเกมในกลุ่มผู้ที่มี MCI ต่อไปในจำนวนที่มากขึ้น*

**คำสำคัญ** : *วีดีโอเกม, mild cognitive impairment, CANTAB.*

Mild cognitive impairment (MCI) is a prevalent condition in older adults, which significantly affects independent function and incident disability. [1, 2] MCI can also advance to dementia such as Alzheimer's disease (AD), a leading cause of costly long-term care. While all patients who develop some forms of dementia go through a period of MCI, not all patients exhibiting MCI will develop AD. The conversion rate from MCI to AD is 10 - 15% per year while normal aging group is found at 1 - 2%. [2, 3] As a result, there has been increasing attention on the prevention and nonpharmachological treatment of cognitive decline in MCI group.

A number of nonpharmachological approaches have been designed to maintain and strengthen the cognitive capacity of the aging brain. There is evidence suggesting that cognitive training activity helps preserve cognitive functions in normal older adults and participants with MCI, based on longitudinal [4, 5] and experimental studies. [6-8] Cognitive training is a method that aims at improving, or maintaining cognitive functions through the repeated and structured practice of specific cognitive tasks such as visual memory, attention, processing speed, language or executive functions (e.g. planning, problem-solving). A review by Reichman and colleagues reported studies that enlisted individual with MCI into a cognitive training intervention, participants benefited from the treatment not only in cognitive areas but also to domains such as activities of daily living, mood and behavior. The authors concluded a longitudinal studies are required to determine whether interventions prevent or slow the progression to AD. [9]

One of the key concepts on cognitive training research is the transfer effects of the training or restorative effects. The restorative strategies will target a specific cognitive domain such as attention, memory or problem-solving in training in order to improve functional performance on that specific domain, and with a possibility to see a transfer effect to other non-trained cognitive domains. [10, 11] For example, cognitive training in areas other than memory has actually been seen to generalize and transfer to memory systems. [8, 12, 13] Several studies have considered playing video game as a cognitive training that centered on this restorative approaches. [9, 14] To date, a number of available products include web-based cognitive exercise programs, live cognitive training programs, and recreational games played online or hand-held devices have claimed to have this transfer of training effect on their users. Still, very few have scientific evidence to support their effectiveness.

The purpose of this research is to study the effects, at 6 weeks, after the cognitive training (speed-attention typed) via video game playing on cognitive functions in older adults with MCI. We used Cambridge Neuropsychological Test Automated Battery or CANTAB (Cambridge Cognition Ltd, UK) which was developed for use in detecting early cognitive changes and suitable for repeat testing in cognitive research as cognition evaluation tool. In this study, 5 language-independent CANTAB tests were chosen to assess different aspects of cognitive functioning, including: visuospatial functions (in terms of speed and accuracy), attention, memory, and executive functions (working memory, problem-solving and visual learning).

## Methods

All procedures were approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University. All participating subjects gave written, informed consent to take part in the study and for their data to be published anonymously.

### *Subjects*

MCI subjects were identified by the psychiatrists at the Dementia Clinic, using MCI criteria developed by Petersen et al. [1] and neuropsychological paper-based tests: the Thai Mini-Mental State Examination (TMSE) [15] and The Thai version of Montreal Cognitive Assessment (MoCA-Thai).[16] None of the participants meet the current DSM-IV criteria for dementia [2] and TMSE score must be at least 24. Subjects received additional MCI screening by MoCA with a cut-off point of below 25. Subjects with MCI were excluded from the study if they have less than 4 years of education, engage in regular exercise activity ( ≥3 times/ week of 60 min-exercise) or play video games ≥ 3 times /week of >30 min duration). Twenty patients were invited to join the study. At baseline, all subjects were aged between 54 and 74 years (*M* = 64.40, *SD* = 5.15).

### *Intervention method*

The sample was divided into 2 groups (10 members each): the Video game Group and Control Group. The Video game Group played XaviX Hot Plus video game system for 50 minutes per session and at least 2 sessions per week for the period of 6 weeks (12 sessions). Twelve games labeled under ‘rehabilitation program’ categorized by Xavix Hot Plus Brochure [17] were selected. These are games that were designed to train cognitive skills in the area of concentration and speed of processing in elderly and dementia patients. The intervention group received video game training according to the experimental schedule. For example, the ‘Touch panel’ games (Figure 1, top) are designed to improve the concentration skills and give seniors a mild level of physical exercise, while the ‘Japanese drums’ and ‘Which is different one?’ games (Figure 1, bottom) are intended to improve reflexes, strengthen muscles, and visuomotor processing activity.

### *Outcome measures*

Cognitive function outcome was assessed by Cambridge Neuropsychological Test Automated Battery (CANTAB). The battery used in this study consisted of 5 selected CANTAB tests and usually lasted 45 minutes. All subjects were administered in 2 sessions within 6 weeks of each other. Descriptions of the tests and selected outcome measures were summarized in Table 1 and sample task screen shots of 5 selected CANTAB test: MTS, OTS, PAL, PRM, and SWM were shown in Figure 2.[18]

### *Statistical analysis*

The quantitative data were described in terms of sample size, mean, standard deviation and range (minimum and maximum). The comparability of the 2 groups was verified on the baseline data. The means were compared using nonparametric Wilcoxon-Mann-Whitney U test. The tests were 2-sided, with significant limit of 5%. The statistical analysis was performed using SPSS® software V17.0.

**Figure 1.** Xavix Hot Plus video game system and sample screen shots.

**Table 1.** Summary of the CANTAB outcome measures.

| CANTAB test & Outcome measure | Function measured |
|---|---|
| 1. Match To Sample Visual Search (MTS)<br>– Percentage correct<br>– Time to correct response | ➤ Speed and accuracy trade-off task, testing the ability to match visual samples and measuring their reaction and movement time |
| 2. One Touch Stockings of Cambridge (OTS)<br>– Mean choices to correct<br>– Time to correct response | ➤ A test of executive function, planning, problem solving and working memory (gives a measure of frontal lobe functioning) |
| 3. Paired Associates Learning (PAL)<br>– Memory score<br>– Total errors | ➤ Assesses visual associative learning and memory, ability to form visuospatial associations |
| 4. Pattern Recognition Memory (PRM)<br>– Percentage correct<br>– Speed response | ➤ Visual pattern recognition memory in a 2-choice forced discrimination paradigm (sensitive to medial lobe) |
| 5. Spatial Working Memory (SWM)<br>– Total errors<br>– Time to complete task | ➤ Measures the ability to retain spatial information and manipulate it in working memory (sensitive of frontal lobe and executive dysfunction) |

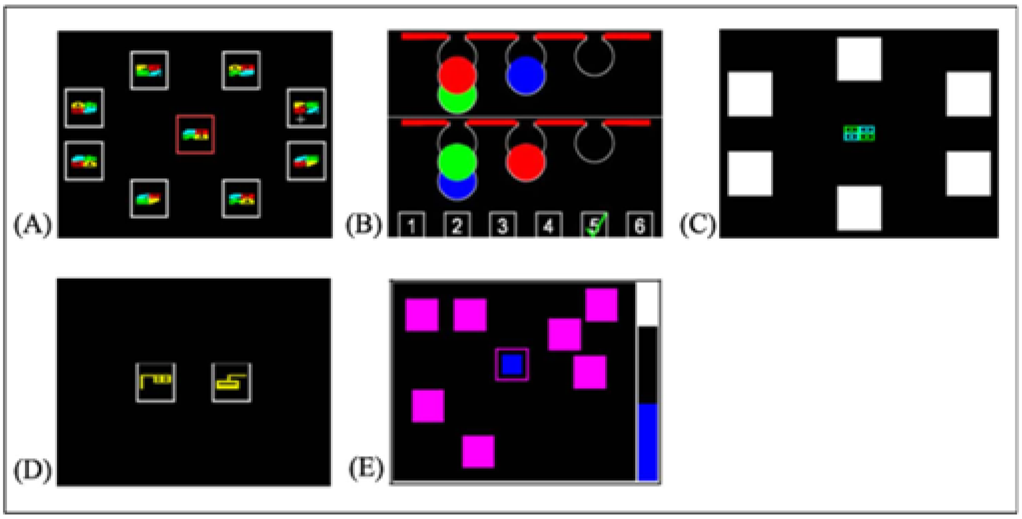


**Figure 2.** Task screens of CANTAB battery test (www.cantab.com). (A) MTS: speed and accuracy, (B) OTS: executive function (planning, problem-solving), (C) PAL: executive function (visual learning and memory) (D) PRM: visual memory, (E) SWM: executive function (working memory).

## Results

### *Sample Characteristics*

Table 2 compared Video game Group and Control Group's characteristics in terms of age, gender, years of education, and baseline neuropsychological test scores of TMSE and MoCA. The Video game Group and the Control Group did not differ with regard to age, gender, or years of education ($p > 0.05$). The 20 participants had a mean age of 64.40 (*SD* = 5.15, max/min = 54/74, $p = 0.74$). The group comprised 6 males (30%) and 14 females (70%) with average of 11.15 years of education (*SD* = 4.54, max/min = 4/16, $p = 0.74$). There was also no significant difference in the performance of the 2 groups on TMSE or MoCA scores ($p > 0.05$). The average mean TMSE and MoCA scores were 27.55 (*SD* = 1.32, max/min = 25/30, $p = 0.97$) and 23.25 (SD = 1.25, max/min = 20/24, p = 0.91), respectively.

CANTAB cognitive outcome analyses at baseline ($T_1$) were summarized in Table 3 with significant level set at 5% presented from nonparametric Wilcoxon-Mann-Whitney U test, comparing between groups (Video game and Control Groups) in all instances. There were no significant differences between the 2 groups at baseline (Table 3) in all test outcomes from the 5 selected CANTAB tests ($p > 0.05$). Thus, the statistical results in Table 2 and 3 exclude the possibility that any pre-existing difference of measure between groups affected the result of each measure after 6 weeks period ($T_2$).

### *Effects of video game on cognitive functions*

The mean change in score (pre-training score minus post-training score, $\Delta M$) in all measures of cognitive functions scores by CANTAB were calculated (see Table 4). Nonparametric Wilcoxon-Mann-Whitney U test were conducted to compare between the Video game and Control Groups for the mean change in scores ($\Delta M$) in each cognitive tests. The level of significance was set at $p < 0.05$.

**Table 2.** Characteristics of participants at baseline assessment ($T_1$).

| | Video game Group (n =10) | Control Group (n = 10) | All (n = 20) | *p*-value |
|---|---|---|---|---|
| Gender, n (%) | | | | |
| Male | 2 (10%) | 4 (20%) | 6 (30%) | 0.33 |
| Female | 8 (40%) | 6 (30%) | 14 (70%) | |
| Age (years) | | | | |
| Mean ± SD | 64.70 ± 5.70 | 64.10 ± 4.84 | 64.40 ± 5.15 | 0.74 |
| Ranges (min/max) | (54/74) | (55/71) | (54/74) | |
| Education (years) | | | | |
| Mean ± SD | 11.50 ± 4.88 | 10.80 ± 4.42 | 11.15 ± 4.54 | 0.74 |
| Ranges (min/max) | (4/16) | (4/16) | (4/16) | |
| TMSE | | | | |
| Mean ± SD | 27.50 ± 1.27 | 27.60 ± 1.43 | 27.55 ± 1.32 | 0.94 |
| Ranges (min/max) | (25/29) | (25/30) | (25/30) | |
| MoCA | | | | |
| Mean ± SD | 23.20 ± 1.32 | 23.30 ±1.25 | 23.25 ± 1.25 | 0.86 |
| Ranges (min/max) | (21/24) | (20/24) | (20/24) | |

**Table 3.** CANTAB means and standard deviation for the Video Game and Control Group at baseline ($T_1$).

| CANTAB Test | Test outcome | Video game Group (*n* = 10) Mean ± *SD* | Control Group (*n* = 10) Mean ± *SD* | *p*-value |
|---|---|---|---|---|
| MTS | Percentage correct | 92.65 ± 8.31 | 92.71 ± 8.39 | 0.97 |
| | Time to correct response (s) | 15.54 ± 5.13 | 15.40 ± 3.19 | 0.91 |
| PRM | Percentage correct | 85.00 ± 9.46 | 80.00 ± 8.52 | 0.22 |
| | Speed response (s) | 2.64 ± 0.44 | 2.89 ± 0.24 | 0.07 |
| OTS | Mean choices to correct | 1.35 ± 0.16 | 1.40 ± 0.27 | 0.76 |
| | Time to correct response (s) | 109.46 ± 39.96 | 108.94 ± 32.71 | 0.71 |
| PAL | Stage score (max 11) | 5.90 ± 2.23 | 4.30 ± 2.16 | 0.10 |
| | Total errors | 6.50 ± 4.12 | 7.60 ± 4.14 | 0.47 |
| SWM | Total errors | 25.80 ± 7.69 | 20.50 ± 6.50 | 0.14 |
| | Time to complete (s) | 121.88 ± 23.42 | 118.21 ± 19.73 | 0.76 |

*$p < 0.05$, N,n – numbers, SD – standard deviation, s – second

Table 4. At 6-week post training, change in cognitive outcome scores ($\Delta M$), median and interquartile range (IQR) for selected CANTAB tests

| CANTAB Test | Outcome measure | Video game ($N$ = 10) $\Delta M$ ($SD$) | Control ($N$ = 10) $\Delta M$ ($SD$) | $p$-value |
|---|---|---|---|---|
| MTS | Percentage correct † | -3.65 (7.03) | -3.08 (7.49) | 0.62 |
| | Time to correct response (s) | 3.24 (3.90) | 2.12 (3.98) | 0.65 |
| PRM | Percentage correct † | -0.42 (6.93) | 1.67 (11.82) | 0.97 |
| | Speed response (s) | 0.33 (0.39) | 0.11 (0.47) | 0.36 |
| OTS | Mean choices to correct | 0.14 (0.16) | 0.04 (0.28) | 0.34 |
| | Time to correct response (s) | 24.04 (28.01) | 10.43 (26.89) | 0.26 |
| PAL | Stage score † (max 11) | -1.30 (1.34) | -0.50 (1.96) | 0.26 |
| | Total errors | 2.70 (3.06) | 0.40 (3.50) | 0.14 |
| SWM | Total errors | 3.40 (5.59) | -4.90 (7.02) | 0.01* |
| | Time to complete (s) | 18.71 (21.69) | -10.32 (32.85) | 0.05* |

† Cognitive improvements are shown in the negative direction

* $p$ < 0.05, s - second

After 6-week training, the Video game Group reported significantly better for performance on working memory by making fewer errors and using less time to complete the CANTAB SWM test than the control group. The observe differences ($\Delta M$) were statistically significant for the SWM test outcome on error and time factors ($p$ = 0.01 and $p$ = 0.05). In the other 4 tests (MTS, OTS, PAL and PRM), no significant differences in the measured outcomes were found after 6 weeks ($p$ > 0.05) (Table 4).

Means and standard deviations scores of CANTAB tests and significance on the pre- and post score were also compared for each group separately. Wilcoxon Signed Ranks tests were performed to determine whether cognitive test scores changed within intervention or control groups. Change in scores were calculated by subtractive post- from pre-intervention scores ($T_1$-$T_2$). As shown in Table 5 and Figure 3 - 5, the Video game Group showed some trends towards improvement in processing speed (the time response part of the test outcome) and the executive functions in the areas of planning and problem solving and visual learning (reduction of errors). Although the differences in performance ($\Delta M$) did not reach statistical significance level, but PAL and OTS tests outcomes within the Video group shows significant level of improvement ($p$ = 0.02 for both). Seventy percent of 10 members in this group performed better at problem-solving by making fewer choices to get correct response and fewer errors in visual learning task. Also within the Video group, the processing speeds of the 4 tests: MTS, OTS, PRM and SWM were all better at significant level (p <0.05).

**Table 5.** Pre- and post-data: Video game group (Wilcoxon signed rank test).

| CANTAB Test | Test outcome | Mean (SD) at $T_1$ | Mean (SD) at $T_2$ | *p*-value |
|---|---|---|---|---|
| MTS | Percentage correct † | 92.65 (8.31) | 96.30 (5.78) | 0.12 |
| | Time to correct response (s) | 15.54 (5.13) | 12.30 (3.08) | 0.04* |
| OTS | Mean choices to correct | 1.35 (0.16) | 1.21 (0.20) | 0.02* |
| | Time to correct response (s) | 109.46 (39.96) | 85.42 (33.76) | 0.04* |
| PAL | Stage score (max 11) † | 5.90 (2.23) | 7.20 (1.87) | 0.02* |
| | Total errors | 6.50 (4.12) | 3.80 (1.87) | 0.02* |
| PRM | Percentage correct † | 85.00 (9.46) | 85.42 (7.92) | 0.96 |
| | Speed response (s) | 2.64 (0.44) | 2.31 (0.40) | 0.01* |
| SWM | Total errors | 25.80 (7.69) | 22.40 (7.93) | 0.12 |
| | Time to complete (s) | 121.88 (23.42) | 103.17 (13.04) | 0.04* |

*p < 0.05

† Cognitive improvements are shown in the negative direction

Table 6 summarized the within group score comparison for the controls. None of the outcomes was substantially difference between the pre- ($T_1$) and post- 6-week ($T_2$), except in the SWM test. A worsening in working memory scores (increase in number of errors) during the test was detected in seven members of the control group (Table 6).

**Table 6.** Pre- and post-data: Control group (Wilcoxon signed rank test).

| CANTAB Test | Test outcome | Mean (SD) at $T_1$ | Mean (SD) at $T_2$ | *p*-value |
|---|---|---|---|---|
| MTS | Percentage correct † | 92.71 (8.39) | 95.79 (5.76) | 0.27 |
| | Time to correct response (s) | 15.40 (3.19) | 13.29 (3.60) | 0.11 |
| OTS | Mean choices to correct | 1.40 (0.27) | 1.36 (0.24) | 0.67 |
| | Time to correct response (s) | 108.94 (32.71) | 98.51 (29.23) | 0.17 |
| PAL | Stage score (max 11) † | 4.30 (2.16) | 4.80 (1.87) | 0.40 |
| | Total errors | 7.60 (4.14) | 7.20 (2.86) | 0.91 |
| PRM | Percentage correct † | 80.00 (8.52) | 78.33 (13.86) | 0.68 |
| | Speed response (s) | 2.89 (0.24) | 2.78 (0.43) | 0.29 |
| SWM | Total errors | 20.50 (6.50) | 25.40 (7.41) | 0.05* |
| | Time to complete (s) | 118.21 (19.73) | 128.53 (22.73) | 0.24 |

*p < 0.05

† Cognitive improvements are shown in the negative direction

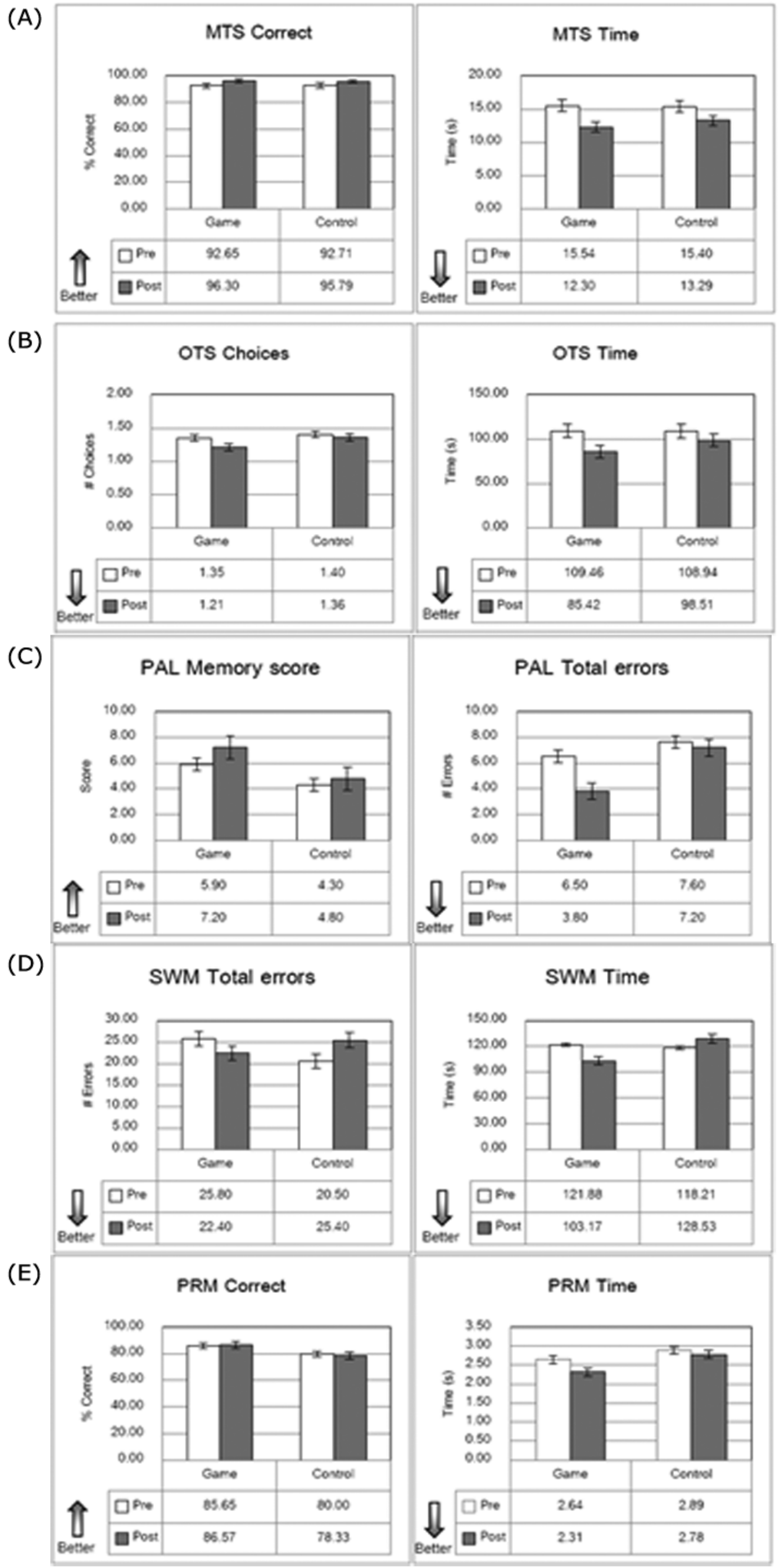


**Figure 3.** CANTAB scores at time pre- and post-intervention. Error bars indicate standard errors across all samples. The direction of the arrow shows what considered as improvement (better) in each task: (A) the attention (in terms of speed and accuracy) was measured by MTS test, (B-D) the executive functions (planning and problem-solving, visual memory and learning, working memory) were measure by OTS, PAL, and SWM tests, respectively, and (E) the visual memory was measured by PRM test.

**Discussion**

The aim of the present study was to explore the effect, after 6 weeks or 12-session of a 50-minute bi-weekly training via cognitive-specific video game, on the cognitive performance in older adult with MCI. We assessed a broad range of cognitive functions using a computerized battery test, CANTAB. The cognition measurements by CANTAB can be assigned into 4 main categories: 1) attention, 2) processing speed, 3) visual memory, and 4) executive processes such as planning, visual learning and spatial working memory.

The most significant result obtained with respect to intervention effect at 6 week post training is the improvement in performance on executive function in working memory task in the Video game group compare to the control group (Table 4, SWM test, $p < 0.05$). Within group analysis post intervention (group effect), improvements were seen in the Video game group in 2 domains: speed and executive functions (planning and visual learning). Approximately 80% of the intervention group showed improvement in processing speed outcome measurements (MTS, OTS, PRM and SWM tests, $p < 0.05$). Better performance on executive functions in the areas of problem solving and visual learning tasks were achieved in 70% and 75% of the Video game Group, respectively.

Most training games in XaviX Hot Plus focus on visual search skills and the ability to identify and locate visual information quickly in a divided-attention format. By the concept of cognitive training, it was then expected that compared with those who did not receive training, the Video game Group would improve in visual attention domain, by performing better on the MTS test. Our finding has yet detected any effect in the outcome in this area at 6 week post-training. This can be explained by the training term of our study, that it may not be enough time to see the effect. It can also be due to most of our subjects were not yet impaired in the domain of our training. Both group performed equally well at the baseline outcomes on the MTS test with approximately 92% accuracy and 15 seconds response time. Researchers have shown that visual search was greater for the patients with AD than the patients with MCI. [19, 20] McLaughlin and colleagues has found similar results in visual attention performance in MCI group and suggested that MCI is not associated with declines in visual search efficacy. [20]

We also examined the transfer of training effect onto the non-trained tasks. MCI is typically characterized by impairment in memory and now with growing evidence, a reduction in executive functions. [21] Thus, transfer of training was selectively evaluated on the visual memory task (PRM test) and executive function domains: problem solving (OTS test), visual learning and memory (PAL test) and working memory (SWM test). Following the 6-week cognitive training, the Video Group showed a trend in improvement in the executive functions (making fewer errors), especially in the working memory task where the effect was highly significant compared to the Control Group ($p < 0.05$). This result is desirable because transfer of the training experience to other cognitive domains is one of the keys in the research of cognitive training intervention.

The transfer effect observed is likely due to the result of the control processes that are involved in similar brain regions. [10] In our study, to play speed-attention typed video game, the prefrontal regions should be recruited in order to successfully complete the visual search processes. The executive functions by CANTAB OTS, PAL, and SWM tests are also known to be mainly supported by the prefrontal cortex.[18] Thus, we can predict the transfer tasks such as working memory, visual learning and problem solving, which involved in the prefrontal cortex, are to be affected. The training transfer was not observed on the visual memory task of PRM test. This might be due to the nature of CANTAB PRM test which is designed to detect change in medial temporal lobe function in which, the process overlap with the training task for this measure was less than that of executive functions.

Our study suggests that there is a possibility which the older adults with MCI could improve cognitive functions in short-term video game training. Importantly, while memory is the primary impairment in MCI, the executive functions, which include working memory (system that stores and manages information to do tasks such as reasoning, and comprehension), new learning, problem-solving and planning, are parts of the core cognitive impairments in those MCI persons converting to AD.[2, 22] Thus, playing video games, as a form of treatment, may have clinical implications for MCI population by improving the executive functions components that are subject to decline in the early stage of AD and are associated with difficulties in every day task. As mentioned, cognitive function in older adults is related to independent living and need for care. Training elderly in the cognition abilities could increase the length of time they are able to remain independent and decrease burdens on caregivers.

The limitation of this study includes relatively small sample size, based in only one center and inability to prolong intervention duration longer than 6 weeks due to time constraints. Also, the lack of random assignment in the quasi-experimental design method may allow studies to be more feasible, but this also poses many challenges for the investigator in terms of internal validity. In addition, it is likely that our study sample included primarily highly motivated subjects and it is unclear whether our results would generalized to less motivated subjects. Also, it was difficult to track or control the variety of extraneous and confounding variables that exist in a social environment (e.g. change in their leisure life style). Lastly, future research should assess not only whether cognitive training via video games improves performance on cognitions, but whether the training improves performance on everyday functions such as ability to use the phone, keep the appointment, preparing a meal, shopping or driving.

**Acknowledgement**

We thank all the volunteers who participated in this study, the staffs at the Dementia clinic for their assistance in patient recruitment, and Mr. Napakawat Buathong for checking statistical analysis on this manuscript. We also thank Mr. Sittisak Thongvatanavanich at Out of the BLUE box Co.Ltd. for his generosity in lending XaviX Hot Plus video game system to Chulalongkorn Hospital.

**References**

1. Petersen RC, Doody R, Kurz A, Mohs RC, Morris JC, Rabins PV, Ritchie K, Rossor M, Thal L, Winblad B. Current concepts in mild cognitive

impairment. Arch Neurol 2001 Dec; 58(12): 1985-92

2. Petersen RC, Smith GE, Waring SC, Ivnik RJ, Tangalos EG, Kokmen E. Mild cognitive impairment: clinical characterization and outcome. Arch Neurol 1999 Mar; 56(3): 303-8

3. Geslani DM, Tierney MC, Herrmann N, Szalai JP. Mild cognitive impairment: an operational definition and its conversion rate to Alzheimer's disease. Dement Geriatr Cogn Disord 2005;19(5-6):383-9

4. Ball K, Berch DB, Helmers KF, Jobe JB, Leveck MD, Marsiske M, Morris JN, Rebok GW, Smith DM, Tennstedt SL, et al. Effects of cognitive training interventions with older adults: a randomized controlled trial. JAMA 2002 Nov; 288(18): 2271-81

5. Wilson RS, Bennett DA, Bienias JL, Aggarwal NT, Mendes De Leon CF, Morris MC, Schneider JA, Evans DA. Cognitive activity and incident AD in a population-based sample of older persons. Neurology 2002 Dec; 59(12): 1910-4

6. Belleville S, Gilbert B, Fontaine F, Gagnon L, Menard E, Gauthier S. Improvement of episodic memory in persons with mild cognitive impairment and healthy older adults: evidence from a cognitive intervention program. Dement Geriatr Cogn Disord 2006; 22(5-6): 486-99

7. Rapp S, Brenes G, Marsh AP. Memory enhancement training for older adults with mild cognitive impairment: a preliminary study. Aging Ment Health 2002 Feb;6(1):5-11

8. Londos E, Boschian K, Linden A, Persson C, Minthon L, Lexell J. Effects of a goal-oriented rehabilitation program in mild cognitive impairment: a pilot study. Am J Alzheimers Dis Other Demen 2008 Apr;23(2):177-83

9. Reichman WE, Fiocco AJ, Rose NS. Exercising the brain to avoid cognitive decline: examining the evidence. Aging Health 2010; 6(5):565-84

10. Nouchi R, Taki Y, Takeuchi H, Hashizume H, Akitsuki Y, Shigemune Y, Sekiguchi A, Kotozaki Y, Tsukiura T, Yomogida Y, et al. Brain training game improves executive functions and processing speed in the elderly: a randomized controlled trial. PLoS One 2012;7(1):e29676

11. Willis SL, Tennstedt SL, Marsiske M, Ball K, Elias J, Koepke KM, Morris JN, Rebok GW, Unverzagt FW, Stoddard AM, et al. Long-term effects of cognitive training on everyday functional outcomes in older adults. JAMA 2006 Dec;296(23):2805-14

12. Ball K, Edwards JD, Ross LA. The impact of speed of processing training on cognitive and everyday functions. J Gerontol B Psychol Sci Soc Sci 2007 Jun; 62 Spec No 1: 19-31

13. Mahncke HW, Connor BB, Appelman J, Ahsanuddin ON, Hardy JL, Wood RA, Joyce NM, Boniske T, Atkins SM, Merzenich MM. Memory enhancement in healthy older adults using a brain plasticity-based training program: a randomized, controlled study. Proc Natl Acad Sci U S A 2006 Aug; 103(33): 12523-8

14. Green CS, Bavelier D. Exercising your brain: a review of human brain plasticity and training-induced learning. Psychol Aging 2008 Dec; 23(4): 692-701

15. Train the Brain Forum Committee. Thai Mental State Examination (TMSE). Siriraj Hosp Gaz 1993 Jun; 45(6): 359-74

16. The Montreal Cognitive Assessment [online]. 2012 [cited 2012 Apr 30]. Available from: http://www.mocatest.org

17. SSD Company. XaviX Hot Plus Brochure [online]. 2007 [cited 2012 Apr 30]. Available from: http://www.hotplus.jp

18. Cambridge Neuropsychological Test Automated Battery (CANTAB) [online]. 2012 [cited 2012 Apr 30]. Available from: http://www.cantab.com

19. Tales A, Haworth J, Nelson S, Snowden RJ, Wilcock G. Abnormal visual search in mild cognitive impairment and Alzheimer's disease. Neurocase 2005 Feb;11(1):80-4

20. McLaughlin PM, Borrie MJ, Murtha SJ. Shifting efficacy, distribution of attention and controlled processing in two subtypes of mild cognitive impairment: response time performance and intraindividual variability on a visual search task. Neurocase 2010 Oct; 16(5): 408-17

21. Marshall GA, Rentz DM, Frey MT, Locascio JJ, Johnson KA, Sperling RA. Executive function and instrumental activities of daily living in mild cognitive impairment and Alzheimer's disease. Alzheimers Dement 2011 May; 7(3): 300-8

22. O'Donnell J, Pietrzak RH, Ellis KC, Snyder PJ, Maruff P. Understanding failure of visual paired associate learning in amnestic mild cognitive impairment. J Clin Exp Neuropsychol 2011 Dec; 33(10): 1069-78