**ABSTRACT**

CHOI, HEESUN. The Impact of Visuospatial Characteristics of Video Games on Improvements in Cognitive Abilities. (Under the direction of Sharolyn A. Lane, PhD.)

Previous research has suggested that playing video games has influences in various areas of human cognition and behavior. In particular, a number of studies have investigated improvements of spatial abilities as a result of playing video games, and the results suggested that action video game players outperform non video game players on various measures of spatial abilities. Two main methodological issues with previous gaming studies have been pointed out. First, many findings have been based on cross-sectional research examining the differences in the performance of expert video game players and non-video game players without manipulation of video game experiences, which could not exclude self-selection biases. Second, studies investigated with the commercial genres of video games such as action video games or First person shooting game. Little is known about the influence of particular characteristics of video games such as player viewpoints (perspectives) on the improvements of cognitive abilities. The current study aimed to understand the effects of playing video games on various spatial abilities, including navigation and map performances, spatial attention and mental rotation, and speed of processing, in a training study setting. Furthermore, it examined the impacts of different gaming mechanisms/structures or environmental characteristics of video games on the game training effects. Participants were assigned to one of four groups; First Person Shooter (FPS) game training, Third Person Shooter (TPS) game training, puzzle game training or control non-training group. Participants in the training groups played the assigned games for total 30 hours. Performances in maze tasks, spatial attention, mental rotation and speed of processing were measured at four time points (pre-training, post-10 hours, 20 hours and 30 hours training) to

investigate gradual improvements over time. The results showed that playing the FPS game, but not the TPS or puzzle game, enhanced visuospatial attention ability. These results may suggest that in-game perspectives are important characteristics of video games that impact differently on their effects on particular cognitive ability such as spatial attention. However, no significant improvement was found for navigation and map performances for any game group, suggesting that the cognitive effects of playing a FPS game may not be generalizable to more dynamic and larger-scaled spatial abilities beyond spatial attention.

The Impact of Visuospatial Characteristics of Video Games
on Improvements in Cognitive Abilities

by
HeeSun Choi

A thesis submitted to the Graduate Faculty of
North Carolina State University
in fulfillment of the
requirements for the Degree of
Master of Science

Psychology

Raleigh, North Carolina

2013

APPROVED BY:

| | |
|---|---|
| Sharolyn A. Lane, PhD<br>Committee Chair | Douglas J. Gillan, PhD |
| Anne Collins McLaughlin, PhD | Jing Feng, PhD |

## BIOGRAPHY

HeeSun Choi was born and raised in Seoul, South Korea. She completed her undergraduate studies at Yonsei University in Feb 2007. She earned a dual degree in psychology and business administration with university honors. She worked in SK Telecom, a mobile broadband company in Korea, from 2007 to June 2010 as a product manager for various mobile and internet services. In August 2010, she entered the Human Factors & Ergonomics graduate program in the Department of Psychology at North Carolina State University. She is currently pursuing the PhD in the program, and completed this master's thesis as one step on the path to the doctorate degree.

# TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

**The Impact of Visuospatial Characteristics of Video Games on Improvements in Cognitive Abilities.**

Video gaming is now one of the biggest sources for entertainment, and it also has gained fame for its value as an educational tool or a training technology in various fields including military, educational institutions, and industry. This high level of video game consumption and application increases the importance of our understanding of potential positive and negative influences of video game experience on human cognition (Bailey, West & Anderson, 2010). Findings from video game research can be beneficial to expand applications of video games as educational or training roles, and to increase the effectiveness of video games as well as to decrease their negative influence.

**Influence of Video Games**

A number of researchers have investigated both positive and negative potential effects of playing video games. Previous empirical studies have examined potential effects of playing video games on emotional, physiological and neurological aspects such as the effects of repeated exposure to violent games on emotional responses, aggressive behaviors and school performance (e.g. Gentile, Lynch, Linder, & Walsh, 2004; Koepp, Gunn, Lawrence, Cunningham, Dagher, Jones, Brooks, Bench & Grasby, 1998). For example, one study investigated associations of the video game habits of adolescents and hostility and aggressive behaviors in school (Gentile, Lynch, Linder, & Walsh, 2004). The study found that adolescents who were exposed to greater amounts of violent video games were more hostile, reported getting into arguments with teachers more frequently, were more likely to be involved in physical fights, and performed more poorly in school. Another study using a brain imaging technique, PET, found that dopamine was released in the striatum area when the participants played a video game in which they moved a tank through a battlefield to destroy enemies (Koepp et al., 1998). Considering that dopamine has been known to be involved in learning and feelings of reward, the results suggest that the release of dopamine or stress hormones may be related to motivation and win/lose performance in playing video games as well as to violence and harm (Koepp et al., 1998).

While potential negative influences of video games in human behavior changes have been investigated, a number of previous researchers have also focused on the effect of playing video games on various cognitive skills and abilities. Past studies suggest that playing video games improves or alters a broad range of cognitive abilities from sensory, attention and perception to high-level cognitive functioning (e.g. Barlett, Vowels, Shanteau, Crow, & Miller, 2008; Green & Bavelier, 2003; 2007, Chisholm, Hickey, Theeuwes, & Kingstone, 2010; Feng, Spence, & Pratt, 2007). It has been found that playing video games positively influence visual search performance (Castel, Pratt, & Drummond, 2005; Dye, Green, & Bavelier, 2009), and improves visual attention (Green & Bavelier, 2003, 2006; Spence, Yu, Feng, & Marshman, 2009) and speed of processing (Dye, Green, & Bavelier, 2009). Also, video game players showed more precise multisensory temporal processing abilities (Donohue, Woldrff, & Mitroff, 2010). Other studies have reported that video game playing is negatively related to proactive cognitive control (Bailey, West, & Anderson, 2010), and may reduce attentional capture (Chisholm, Hickey, Theeuwes, & Kingstone, 2010).

**Video Games and Spatial Ability**

Among many skills and cognitive abilities that video games may extend or alter, spatial cognition has relatively strong potential to be improved by playing video games because many popular video game genres such as action video games demand a high level of spatial cognitive skills (Spence & Feng, 2010). Spatial cognition is essential to represent, organize, understand, and navigate the environment, to attend to specific objects, to manipulate objects, and to communicate information about objects and the environment to others (Spence & Feng, 2010), and these spatial abilities are considered to be one of the fundamental abilities for survival as well as everyday life.

Most previous research investigating the effects of playing video games on spatial abilities concentrated on small-scaled spatial cognitive skills through relatively simple visuospatial tasks with the use of static paper-and-pencil psychometric or computer-based measures (Richardson, Powers, & Bousquet, 2011) such as mental rotation, visualization, embedded figures, visual search, paper folding, form boards, block design, and distribution of visual attention (e.g. Castel et al., 2005; Feng et al., 2007; Green & Bavelier, 2003; 2006; 2007; Murphy & Spencer, 2009 ). For example, one of the experiment paradigms often used in video game studies is the Useful Field of View (UFOV). The UFOV is described as the total area of the visual field within which individuals can obtain useful information without moving their head or eye (Ball, Beard, Roenker, Miller, & Griggs, 1988). In a typical UFOV test, participants are asked to detect targets that are presented for a brief moment at varying degrees (eccentricity) from the center of the visual field, and the spatial distribution of attention is assessed. Some researchers incorporated this paradigm to examine spatial attention abilities of video game players, and found video game players outperform non-video game players in the UFOV tasks (e.g. Feng et al., 2007; Green & Bavelier, 2006; Wu, Cheong, Feng, D'Angelo Alain, & Spence, 2012)

Compared to relatively simple small-scaled spatial cognition, however, there have been only limited studies examining larger-scaled or more complex spatial skills and abilities such as using maps, navigation and way-finding, comprehension of spatial narrative information, etc. However, the impact of playing video games has been shown to transfer to other relevant visuospatial tasks, suggesting general benefits for video game training (Sanchez, 2012). For example, previous studies found that some video game experience is associated with better performance in a laproscopic surgery task (Rosenberg, Landsittel, & Averch, 2005), golf-putting (Fery & Ponserre, 2001) and science learning (Sanchez, 2012). These findings suggest that there are changes or enhancement in spatial thinking or strategies due to video game experience (Sanchez, 2012).

Among various general and dynamic everyday spatial tasks, navigation or way-finding performance may also be enhanced by video game training. Navigation / way-finding ability is considered to be a complex ability that requires various fundamental spatial abilities including spatial sensory, attention and cognition. Many video games, especially action video games, often involve navigation tasks such as searching targets while wandering around the maze-like environment, and due to these cognitive demands, video gaming experience may improve virtual or even real navigation tasks (Richardson, Powers, & Bousquet, 2011).

However, only a few studies have examined the effect of video game experience on navigation / way-finding performance, and the findings are not decisive. One study found that gaming experience may improve navigation performance in virtual, but not in a real navigation environments (Richardson, Powers, & Bousquet, 2011), while others have reported no relationship between playing video games and performance in learning in a virtual radial arm task (Astur, Tropp, Sava, Constable, & Markus, 2004), or a virtual large-scale multi-segment maze (Castelli, Corazzini, & Geminianin, 2008).

**Characteristics of Video Games**

One of the major issues in previous gaming research is that many studies have only investigated limited genres of video games. For example, it has been widely assumed that action video games have the strongest influence on spatial skills, and among the action video games, First Person Shooting (FPS) games have been most often used in gaming studies, while puzzle games (e.g. Tetris) were most often used for control groups (e.g., Green & Bavelier, 2003; 2006; 2007; Boot, Kramer, Simons, Fabini, & Gratton, 2008).

An action video game can be defined as a game with a certain set of features in the game mechanism and structures including extraordinary speed (both in terms of very transient events and in terms of velocity of moving objects), a high degree of perceptual, cognitive, and motor load to execute an accurate motor plan (multiple items that need to be tracked and/or kept in memory, multiple action plans that need to be considered and quickly executed typically through precise and timely aiming at a target), unpredictability (both temporal and spatial), and an emphasis on peripheral processing (with important items most often appearing away from the center of the screen) (Green & Bavelier, 2009). Among action video games, some games have an egocentric viewpoint which is the first-person perspective (players see the environment and actions through the eyes of the players' characters or avatars), while some action games have third-person perspectives (players see from the behind and slightly above of the characters or avatars they are controlling) or aerial perspectives (bird's eye view). One of the most famous video game genres, FPS game, requires executing tasks from a first-person's viewpoint (perspective), and also includes particular spatial characteristics such as a high level of realism / details and 3D environment. Most previous researchers have been interested in FPS games, and this specific game genre has been predominantly used in previous studies (e.g. Boot et al., 2008; Green & Bavelier, 2003; 2006; Jing et al., 2007). It seems the practice of those games would be most likely to enhance skills in spatial be**c**ause of the obvious needs for spatial skills and quick reflexes in the FPS games cognition (Spence & Feng, 2010). However, there is weak empirical evidence that FPS games or the particular action genres are more effective than other games as a training tool for spatial abilities, or that specific visuospatial characteristics such as in-game viewpoint/ perspective are the important elements that influence spatial cognition.

One previous study conducted by Santone (2009) investigated the relationships between spatial skills and visuospatial characteristics of video games. He clustered participants based on the 31 visuospatial characteristics found in the most-played video games of participants, and compared spatial abilities between clusters. The examples of the visuospatial characteristics used in his study includes 'First-person Perspective', 'Third-person Perspective', '3D Environment' and 'Shooting/Throwing Things at Enemies/Targets'. Based on the collected data, Santone suggested nine fundamental visuospatial game characteristics associated with spatial abilities, which can be divided into two primary axes: in-game perspectives (viewpoints; First-person, Third-person-over-the-shoulder and Third-person-side view) and environmental characteristics (3D, 2D, High reality, Low Reality, High detail and Low detail). He examined the clusters of video game players who experience the more intense visuospatial video game environment that comes from higher dimension (e.g. 3D), higher realism and higher detail, as compared with the clusters of video game players who experience with weaker visuospatial environments (Santone, 2009). Also, the perspectives of video games were investigated in his study as one of the major elements influencing the development of spatial abilities. Santone (2009) found that a combination of environmental characteristics and perspectives of video games were associated with the spatial abilities of players. For example, the results suggested that the third-person perspective is a visuospatial characteristic of video games associated with players who score low relative to players in other clusters on performances in spatial ability tasks of visualization, mental rotation, and perspective prediction. Another interesting finding was that a general training approach involving 2D games with low realism and detail, may be beneficial for improving a wide range of spatial abilities including spatial visualization and mental rotation as effectively as do action video games with 3D and high realism features. These findings imply that visuospatial characteristics such as perspective, detail, realism and dimension may influence training effects of video games in spatial abilities beyond gaming mechanisms (e.g. high-speeded shooting game). This study supported the hypothesis that in-game perspective may be associated to spatial ability scores. However, this study was a cross-sectional study in which the subjects were assigned to the clusters based on their most-played game. The game players, however, might have also played various types of games that do not fit the game type the cluster represents, and the data could not exclude possibilities that other gaming experiences influenced the performance differences or that there were pre-exiting differences in cognitive abilities.

First and third-person perspectives in video game playing may provide different experiences to game players. For example, due to the nature of the first-person viewpoint, players may experience more immersion during game playing with first-person viewpoint than third-person viewpoint playing. Previous studies examined the effects of perspective (viewpoint) in perceptual and cognitive performance in 3-dimensional virtual environments including video games and augmented reality (Amorim, Trumbore, & Chogyen, 2000). Kallinen, Salminen, Ravaja, Kedzior and Sääksjärvi (2007) showed that first-person view playing generated higher feelings of spatial presence and cognitive involvement than video game playing with third-person view. Schuurink and Toet (2010) examined the experiences in the 3D virtual environment named the Second Life and found that the users experience more control over the avatar and the events when they used the third-person perspective, but viewing perspectives (first-person vs. third-person) did not bring strongly different affective appraisal in arousing or pleasant. Other studies had also examined different influences of perspectives in spatial cognition. In the Salamin, Thalmann and Vexo (2006) study, users were generally better to evaluate the distances, anticipate and extrapolated the trajectory of mobile objects when using the third-person perspective in a virtual reality environment, compared to the first-person perspective. This result might be due to the larger field of view provided by the position of the camera for the third-person perspective, but there would be some additional benefits of this viewpoint because the users could appreciate the spatial relations of objects based on their landmark (the position of their head and hands) (Salamin, Thalmann, & Vexo, 2006).

Several studies may suggest that first and third-person in-game viewpoints provide different cognitive experiences while game playing, while previous research mainly focused on the first-person game and assumed it is in particular the first person perspective that allows for cognitive improvement (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010). However, only little is known about how different perspectives influence the improvement of spatial cognitive abilities while training with games, and more direct empirical evidence is needed for the effects of viewpoints in video games to be understood.

**Methodological Issues in Video Game Studies: Cross-sectional vs. Training study**

It has been suggested that there are methodological issues in many previous studies which limit the validity of their findings. One major issue is that many video game studies have been based on cross-sectional studies that examined performance of video game players and non-players in various cognitive abilities without manipulating video game exposure or observing the development of spatial/cognitive skills over time (Boot, Blakely, & Simons, 2011; West, Stevens, Pun, & Pratt, 2008). Due to the nature of the methodology, there would be a critical selection error, and differences between video game players and non-players may be falsely attributed to the effects of playing video games. This methodological problem makes it difficult to determine if people who already have higher spatial abilities are drawn to playing more video games or if the playing of video games actually enhance targeted spatial or cognitive skills. In addition, a third factor (e.g., executive functioning) might influence both spatial performance and gaming (Boot, Blakely, & Simons, 2011).

There have been training studies that showed the causal effects of video game experiences on cognitive improvements after a certain amount of video game training. Some studies found significant enhancements after total 10 hours of video game training which consisted of 1hr sessions for 10 consecutive days (Green & Bavelier, 2003), 1 or 2 hour trainings within a maximum period of 3 weeks (Wu et al., 2012), or1 or 2 hour trainings within a maximum period of 4 weeks (Feng et al., 2007), whereas one study did not find the significant improvement in a wider range of cognitive abilities, including attention, memory, and executive control, after 21.5 hours of video game trainings (Boot et al., 2008). Repeated measures during longitudinal game training would allow examining how video game experience may gradually change or enhance cognitive abilities over the time. However, there was no video game training research that successfully presented gradual improvement over certain hours of video game practice.

**Video Gaming Expertise**

Another point to be addressed is that most gaming studies have focused on particular cognitive or spatial abilities as a result of playing video games, yet there is only a little attention paid to the investigation of developments of video game playing skill itself. Most studies have investigated the relationship between the amount of gaming experiences and cognitive abilities. There has been little study investigating the relationship between skill levels in video game playing and cognitive abilities. One researcher (Green & Bavelier, 2006) examined the relationship between improvement in action video game and spatial attention abilities, and found improvements of gaming and spatial abilities were positively correlated with each other. But it still remains unclear how the levels of game expertise of a player are developed by game training and how they are associated with the performance of spatial abilities.

**Current Study**

The present study aimed to investigate the development of cognitive abilities (mainly focusing on spatial cognition) as players interact with video games that are characterized by different gaming elements. Three different video games were used to examine the impact of video games with different spatial features on the development of cognitive abilities. The video games used for the first group (FPS game group) and the second group (Third Person Perspective (TPS) game group) had different in-game viewpoints (First person perspective vs. Third person perspective), while both had same gaming structures which generally require a player to search the environment and react quickly to the sudden appearance of enemies by scanning the screen constantly. One puzzle game was used for the third group to examine the effects of gaming structure on the improvements of spatial performances, by comparing improvements in cognitive tasks between puzzle game group and the action game (the FPS and the TPS) training groups. The action game playing would impact spatial abilities and processing speed due to spatially challenging tasks in a fast-speeded environment. The impact of visuospatial characteristics (specifically, in-game perspective) of video games on spatial abilities were examined by comparing performances between the FPS and TPS game training groups. As suggested in the previous literatures that perspectives of video games provided different cognitive experience (Amorim et al., 2000; Schuurink & Toet, 2919) during playing and the third-person perspective was associated with lower spatial abilities of players than the first-person perspective (Santone, 2009), it was expected that the first-person perspective would be positively associated with greater improvement in spatial abilities than the third-person perspective.

Also, one control non-game training group was included to compare their performance in cognitive measures with three game training groups to examine the effects of game playing experience alone or to see any potential test-retest effect in the repeated measures.

Small-scaled spatial abilities were measured with the Attention Visual Field test, which is a UFOV-type task assessing visual distribution of attention (eccentricity), and the mental rotation task. Also, more dynamic spatial ability was assessed with a maze task, and a reaction time task was included to measure speed of processing.

The main hypotheses are outlined below.

**Hypothesis 1:** The FPS game group and the TPS game group would show superior performances in small-scaled spatial cognitive tasks (the AVF and the mental rotation) compared to the Puzzle and the control groups after video game training, which would suggest that action gaming influences spatial skill improvements.

**Hypothesis 2:** The FPS game group would show significantly greater improvements in spatial cognitive tasks compared to the TPS, which would suggest that the visuospatial characteristics (in-game viewpoint/perspective) of the FPS video game impact the developments of spatial attentional and cognitive abilities.

**Hypothesis 3:** The FPS and the TPS game training groups would significantly improve their navigation/way-finding performances in the maze task after game playing, whereas the puzzle and control group would not improve, which would suggest that the effect of playing action games is transferred to more dynamic spatial cognitive skills beyond small-scaled spatial attention or spatial cognitive abilities.

**Hypothesis 4:** The action game training (the FPS and the TPS game), but not the puzzle game training, would significantly enhance processing speed, which would suggest that the fast-speeded game environment impacted speed of processing ability.

**Hypothesis 5:** Significant improvements in spatial and cognitive tasks would be found after 20 hours or 30 hours of playing, which would suggest relatively extensive gaming experiences are needed to bring cognitive changes.

There were additional hypotheses regarding to game performance and self-reported measures.

In regard to the gaming skill improvement, it was expected the FPS and TPS gaming expertise levels would be highly correlated due to the highly similar gaming experience. However, for the remaining training groups it was expected that participants would develop their gaming skills only in the video game on which they were trained. **(Hypothesis 6)**

Perceived game playing difficulty and task engagement levels were measured throughout gaming sessions to investigate if they moderate the relationships between the effects of playing games and cognitive abilities. It was expected that the different video game conditions may generate different task engagement or perceived difficulty levels in players which may influence improvements in cognitive measures. In particular, it was hypothesized that perceived difficulty and engagement would be highest for the FPS game group. **(Hypothesis 7)**

# Method

## Participants

A total of 44 male participants (aged 18 to 21 years, *M* = 19.28, *SD* = .93) with normal or corrected-to-normal vision were recruited from a large university located in southeastern U.S. The participants from introductory psychology class signed up voluntarily for their participations via an experiment recruiting system. There were initially four more participants signed up for the experiment and completed the pre-training sessions, but they were excluded because they dropped out after the first session. One of the drop-out participants was in the control group, and the rest of three participants were in the experimental groups. Two drop-out participants reported they do not play video games currently or within the last six months and two reported they do play currently or within the last six months, while all four participants were not regular game players as they reported '0 times a week' for the question regarding to how often they play/played video games.

Only male participants were recruited to avoid potential interaction effects of gender on the relationship between spatial abilities and game experiences. It has been widely reported that there are gender differences in spatial abilities (Saccuzzo, Craig, Johnson, & Larson, 1995), and one gaming study (Santone, 2009) found that there are gender-based differences in the relationship of video game play and spatial ability. Because gender differences were not a focus of the current study, the causal relationship between video game training and spatial performances within one gender was examine before generalizing to both genders.

The participants received course credits, and additional monetary compensation was given to the participants who were in video game training groups. They received $10 compensation each time they came for the follow-up in-laboratory sessions. Participants who completed all 30 hour training received total $30.

One participant dropped out before completing the last session, and another participant was also excluded in the data analyses because he had an inordinate video gaming habit (reported playing 44 times a week and 1.5 hours per each time). As a result, the final sample size of 42 was analyzed.

The 40 participants reported they play video games currently or played within the last six months. The remaining two participants reported they had played video games before but not within the last six months, and no one indicated that they had never played before. The participants reported that they played video games an average of 3.14 times a week (Current player $M$ = 3.30; Not current player $M$ = 0) and played 1.71 hours each time (Current player $M$ = 2.76; Not current player $M$ = .50). Average self-assessed game playing expertise was 3.49 in 5-points Likert scale (1:Poor to 5:Excellent) (Current player $M$ = 3.53; Not current player $M$ = 2.50). See Table 1 for the group differences in the participants' characteristics. The four groups were not significantly different in age, gaming habits and self-assessed gaming expertise.

Table 1. Participants' demographic characteristics.

| | Control group | FPS group | TPS group | Puzzle group |
|---|---|---|---|---|
| N | 11 | 11 | 11 | 9 |
| Age (Year) | 19.82 (.75) | 19.27 (1.10) | 18.91 (.83) | 19.22 (.83) |
| Gaming Frequency (Times per Week) | 3.91 (4.11) | 2.4 (1.71) | 2.77 (2.07) | 3.56 (2.56) |
| Gaming Duration (Hours per each time) | 1.77 (.98) | 1.64 (.92) | 1.68 (1.03) | 1.79 (1.00) |
| Self-assessed Game skills (1:Poor - 5:Excellent) | 3.36 (.81) | 3.55 (.93) | 3.55 (.82) | 3.44 (.53) |

Values are the mean (SD). No significant group difference in all characteristics.

## Design

The present study used a mixed model MANOVA design, with the dependent variables of speed of maze way-finding, accuracy of map drawing, spatial attention accuracy (20° and 30°), mental rotation performance and speed of processing. The within-subjects variable was session (pre, post-10hr, post-20hr and post-30hr), and the between-subject factor was group (control, FPS game training, TPS game training and Puzzle game training group). Participants were randomly assigned to one of the four groups. A repeated design with four trial blocks (measurement time points) was employed to examine gradual cognitive improvements over the time period of 30 hours training.

## Apparatus & Stimuli

*Questionnaire*. The Video Game Questionnaire was used to collect prior game experience of the participants. The questionnaire consisted of total five questions. It included questions about whether each participant had previous game experience, and how often and how long he plays video games weekly. Also it asked how well participants think they play video games. The questions is in 1-5 Likert scale (1 is poor and 5 is excellent). The last question asked whether participants had played the video games which were used in the current experiment. See appendix A for the questionnaire.

*Video Games.* Two commercial video games were used for training of each of three game training groups; the First Person Shooting (FPS) game, the Third Person Shooting (TPS) game, and Puzzle game group. For both the FPS and the TPS groups, the BeGone (NPlay© ,

2013) game was used. The BeGone game is a browser-based multiplayer shooting game, and has all of the representative characteristics of action video games. The goal of this game is to find enemies and kill them by shooting guns, while trying not to get shot and killed by enemies. A keyboard was used to move, jump and do relevant actions including changing weapons and a mouse was used to move a viewpoint, aim and shoot. In the game setting option, it allows players to change gaming viewpoint to either first-person or third-person. See Figure 1 for the screens of the game stimuli used in the current experiment. For the purpose of the current study, the viewpoints were selected for the participants in each group and the participants were asked to maintain the assigned viewpoints during the trainings. A free online Tetris game (Tetris Holding, LLC) was used for the control game training group. The goal of Tetris was to rotate a few types of block shapes to fit in lines. This game may include gaming mechanisms involving in visuo-motor ability, but does not demand high levels of spatial attention, perceptual or cognitive abilities that would be required in action video games. This game was often used as a control game in previous gaming research, and it has been reported that it rarely influence general spatial cognitive abilities (Sims & Mayer, 2002). When a game starts, a block fell from the top, and players make a horizontal line with these blocks in the playing field without gaps. A player can move the blocks sideways and rotate them by 90 degrees. When a complete line is created, the completed line gets removed. Arrow keys and a space bar are used to move and drop the blocks. The screenshot of the Tetris game is also presented in Figure 1.


Figure 1. Screenshots of the video games: BeGone First-person viewpoint mode (top left), BeGone Third-person viewpoint mode (top right), and Tetris puzzle game (bottom)

*Maze Task.* One practice maze and sixteen experimental mazes (4 mazes X 4 experiment sessions) were constructed in a 3D virtual environment. All virtual mazes were the same size (6 X 6 grids) with the starting point (entrance) at the north left corner and the ending point (exit) at the south right corner. Each maze had a few straight corridors and 90 degree turns at intersections. Each maze had a different combination of corridors and locations of intersections. The layouts of mazes were adopted from Shore, Stanford, Macinners, Klein, & Brown (2001). The virtual mazes were presented to participants on the computer display, and the gaze direction and movements were controlled by the direction keys and the mouse. For the exit-finding task, participants were asked to find the exit and move to the exit point, and a stopwatch was used to measure the speed of exit-finding. For the map drawing task, an empty 6 X 6 grid map was provided to participants and the participants were asked to draw the maze map on it with a pen. Figure 2 presents an example screenshot of the maze environments which the participants would saw while doing the maze tasks. Also, see Figure 3 for the layouts of the all sixteen experimental mazes used in the experiment.

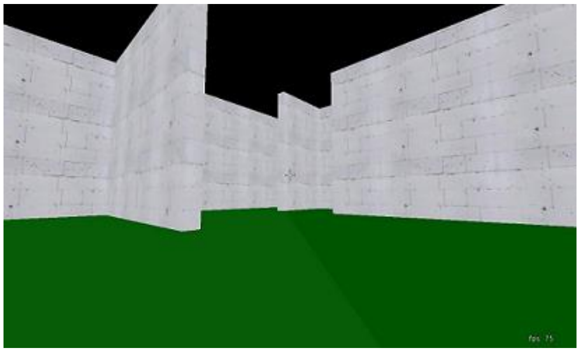

Figure 2. Virtual Maze Screenshot.

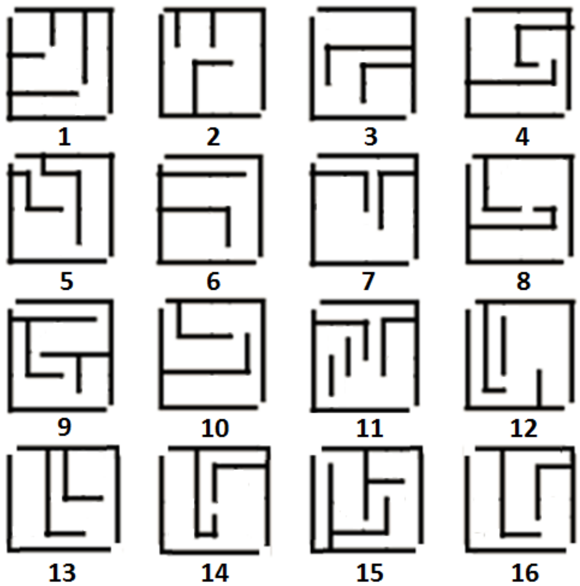


Figure 3. Experimental maze layouts.

*Visual Attention Test.* The Attention Visual Field (AVF) test was used to measure spatial attention abilities. The AVF task assesses the ability to detect and localize a target among distracters over a visual field. This task assesses the spatial distribution of attention resources over a field of view. The test was comparable with the UFOV-type tests used in the previous studies examining visual attention (Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003; Spence et al., 2009). The test version developed for previous gaming research of Feng et al. (2007) was adopted for the current experiment with a change of a response input device from a keyboard to a mouse. The stimuli were presented on the foveal vision area (e.g., the center) of the light-gray screen. In each trial, a fixation square was presented for 600 msec followed by target stimulus display. The target stimulus consists of one filled-squared target and 23 distracters which were unfilled square boxes and presented at an eccentricity of 20° or 30° in one of eight spaced directions. The location of the target stimuli was randomly selected among 16 positions with equal numbers of appearance at each position. The exposure time of target stimulus was randomly set to one of 10, 20 or 30 msec. After the target stimulus was displayed, there was a masking screen, and then a response cue was displayed for participants to make their indication in which of the eight possible directions the target was appeared by clicking the answer box among eight boxes in each direction. RT and accuracy data were collected. Figure 4 presents the example stimuli screens for the task.

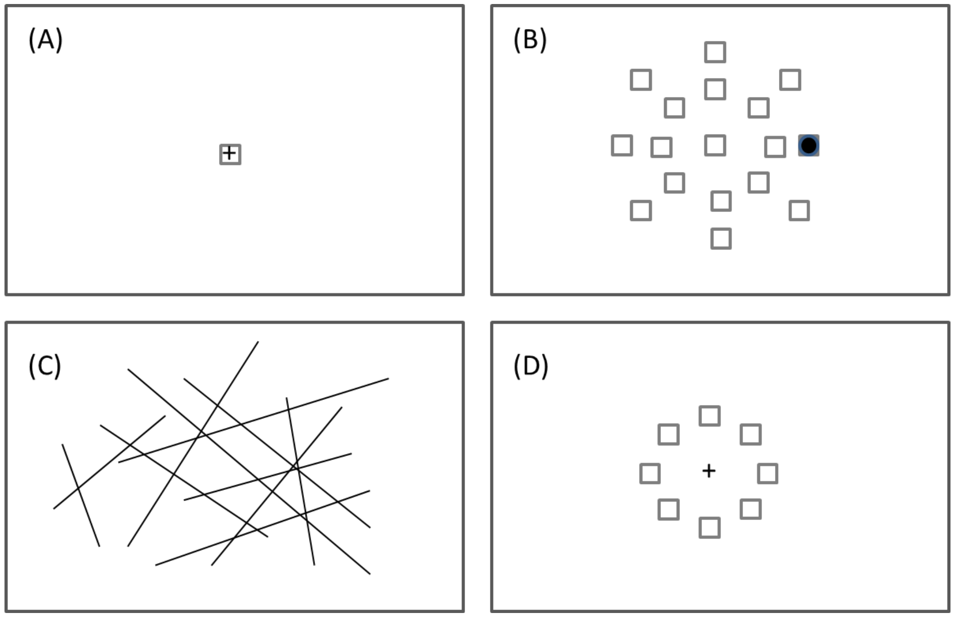


Figure 4. AVF task trial. (A) Fixation square screen. (B) Target stimulus screen. (C) Masking screen. (D) Answer screen.

*Mental Rotation Task*. The mental rotation test was included to assess spatial cognitive abilities. The task measured an ability to mentally represent and manipulate physical objects. The mental rotation test used in the current study was a free computer-based test provided by the Online Psychology Laboratory (opl.apa.org). In the mental rotation experiments, there were total 48 trials asking participants to determine whether the two 3D shapes presented in the screen were the same or not when they are rotated in different degrees. Speed of response (RT) was collected.

*Speed of Processing.* A choice RT task was used to measure the speed of processing. Colored square shapes were presented either to the left or right side of the screen, and participants were asked to press the '/' key if it was shown in the right side, or the 'z' key if it was shown in the left side. Fifty trials were presented with random assignments of twenty five trials for each direction.

*Perceived Task difficulty and Engagement.* How difficult participants felt the game trainings were, and levels of game playing engagement were measured. The NASA-TLX (Hart & Staveland, 1988) was used to assess perceived game playing difficulty. Participants who were in video game training groups were asked to rate their perceived task (game training) difficulty in six different workload dimensions including mental demand, physical demand, time demand, performance success, effort and frustration on a 7 point Likert scale (Appendix B). In addition, to measure the levels of task engagement, participants received ten statements and were asked to rate how well each statement explained their experience. The statements in the task engagement questionnaire included expressions for different categories of task engagement such as focused attention, felt involvement, novelty, energetic arousal, interest, motivation and concentration, etc. Statements were partly adopted from the work of O'Brien and Toms (2010). See the Appendix C for the questionnaire. The scale was administered using a seven-point Likert scale from “strongly disagree” to “strongly agree”.

**Procedure**

There were total four in-laboratory sessions. Before the beginning of the first session, participants were provided the information about the procedures and schedules of the entire experiments, and they were asked to complete the consent forms. The participants were informed that the experiments must be completed within two months. They were assigned to one of four groups; control group, FPS game training group, TPS game training group and control game (puzzle game) training group.

During the pre-training experiment (the 1st session), participants were asked to fill out the questionnaire regarding to their video game play experiences and habits. Next, the maze task, AVF test, mental rotation test and RT task were executed. The order of tasks was rotated for each participant to control for order effects.

The maze tasks consisted of four virtual environment maze trials, and each maze task took approximately three minutes. First, the learning session started and participants had 60 seconds to move around freely in the maze and learned about the environment. A first-person view of the entrance to the maze was displayed in the screen and the participants started navigating in the maze by controlling the keyboard and the mouse. The leaning session was followed by the test session for each maze. After one minute of learning session, there was a 15-20 second interval, and then the maze test session started. The participants were asked to find the shortest way to the exit and move to that point. The participants were instructed to complete the task (exit-finding) as fast as they could. The length of time from the starting point to the ending point was recorded with a stop watch. After completing the exit-finding task, the map drawing task was given. The participants were asked to draw the map of the maze that they just completed on the grid. The participants were provided two practice trials before the four actual trials.

The AVF test took approximately 15 to 20 minutes depending on participants' speed. A brief written instruction explaining the steps of the task was provided before the test started. After the participants read the instruction, the experimenter additionally explained about the task with example screen shots if the participant needed more details. Participants completed a practice session which consisted of 24 trials. The actual test session consisted of total 288 trials in three blocks with two short breaks between the blocks. During the task, participants were asked to position their head fixed on the chin rest to prevent head movements.

The mental rotation test consisted of 48 trials and the total test took approximately five minutes to complete. An instruction and two sample trials were provided before starting the test. The choice RT test took less than five minutes. An instruction and practice trials were provided followed by total 50 actual trials.

When all cognitive tests were completed, the participants had a five minute break. After the break, the video game session started. Participants were asked to read a written instruction which included general descriptions, objectives and controls of two video games; the BeGone© and the Tetris. Participants were asked to play the BeGone game twice; one with the first-person viewpoint (perspective) and one with the third-person viewpoint (perspective). With each viewpoint, participants had five sessions; each session ended when all of players in either of two teams were dead or session time of two minutes was reached. The numbers of kills and deaths the participant scored in total five sessions were recorded and the ratio of kills/deaths in the five sessions was used as a performance score. Participants were also asked to play the Tetris game for five minutes, and the game scores they earned in the game were collected. Participants had practice sessions before playing the BeGone and the Tetris game, and the order of three video game playing were rotated for each participants to prevent the order effect.

After the pre-training in-laboratory session (the first session) was completed, each participant received an email that contained information regarding the group to which they were assigned among four groups as well as the detailed instructions for their individual game training procedures. The participants were instructed to play the assigned game (BeGone with first-person perspective, BeGone with third-person perspective or Tetris) individually at any site they chose for a total of ten hours during the next 10-14 days (no more than two hours in a single time). The participants were asked to record the dates and time they played the games. They were also asked to avoid any other video game playing during this experiment period if possible. Participants scheduled their second in-laboratory sessions via an online scheduling system when they completed or anticipated completing ten hours. The participants in the control group received an email without any instruction regarding to video game training, and were asked to simply schedule their second laboratory experiment in 10 to 14 days.

In the post-10hour session (the second session), the game training logs were collected first, and participants were asked to fill out two questionnaires; the perceived task difficulty and the task engagement surveys. The cognitive tasks including maze tasks, the AVF test, the mental rotation and the RT task were conducted in the same manner as the pre-training session. After cognitive tests were completed, the participants were asked play the same video games (BeGone with first-person viewpoint, BeGone with third-person viewpoint and

Tetris) and their performances were measured in the same manner. There were no practice trials for cognitive tasks and video game playing in the follow-up sessions. The orders within four cognitive tasks and within three video games were switched for each session to minimize the order effects. Each participant had the post-20hr (the third) session and the post-30hr (the final) sessions which were conducted after every additional 10 hours of individual video game playing. The procedures were same for all follow-up sessions.

The participants who were in the game training groups received $10 at the end of each follow-up session. At the end of the experiment, participants were provided a debriefing via email that gave the information about the current study.

## Results

### Preliminary Analyses and Data Encoding Processes

The participants were asked to schedule their follow-up sessions in 10-14 days after the previous session. The mean period between the sessions was longer than the requested period (*M* = 16.71 days, *SD* = 7.75). The second session was conducted after an average of 14.83 days (SD = 14.83) from the first session, the third session was conducted after 18.88 days (SD =8.51) and the final session was conducted after 16.43 days (SD = 8.51). There were no group differences in the session intervals (game training periods) across the three between-laboratory session periods, [$F(3,38) = 1.071$, $p = .18$].

For the maze performance, speed of exit-finding and accuracy of map drawings were collected. Because each maze had different combinations of corridors, the baseline times for each maze to move from the start to the end would be different. To adjust these different baseline times, the distances of the shortest route from the starting point to the ending point were calculated, and the measured speeds of the participants were divided by these calculated distances and encoded as the adjusted times. Also, to adjust the different difficulty levels of the maze maps, accuracy for each maze was calculated for map drawing performance. For each maze, each wall had ten points and the earned points over the total points for all walls were used as the map drawing accuracy. Deductions were made when the participants drew the line in an incorrect position (-2 points), direction (-2 points) or length (-2 points) and made a minor mistake (-1 point; e.g., slightly longer or shorter line, or slightly off-angle). Also there were deductions in accuracy points when the participants omitted a line (-10 points) or falsely included an incorrect line (-5 points). Two raters assessed the map drawings, and the average of two scores was used for a final map drawing accuracy. The inter-rater correlation was .94 ($p$ <.001).

To analyze the AVF task data, RT and accuracy for trials at 20° eccentricity and 30° eccentricity were recoded separately. Trials were excluded if RT was longer than 10000 msec or shorter than 100 msec.

For the game performance measures, in-game scores were collected and transformed to the z scores. In regards to perceived task difficulty and engagement, the mean of three reports (post-10hr, post-20hr and post-30hr sessions) was used.

**Improvements of Cognitive Abilities**

Initially, a mixed model multivariate analysis of variance (MANOVA) was performed with all six dependent measures (speed of the maze exit-finding, accuracy of the map drawing, overall accuracy and speed of the AVF, speed of the mental rotation and choice reaction time). A within-subjects factor was time (pre-training, post-10hr training, post-20hr training and post-30hr training test) and the between subjects factors was the experiment group (Control no-training groups, FPS game training, TPS game training and Puzzle game training). The results of the mixed model MANOVA was Wilks' Lambda= .114, $F$ (45, 69.108) = 1.41, $p$ = .096. Multiple mixed model ANOVAs were conducted separately for each dependent variable, and the results are presented in below.

**Map Drawing Accuracy.** First, a mixed model ANOVA with a within-subjects variable of the time and a between-subjects variable of group was conducted for the DV of map drawing accuracy. The Box's M test for the homogeneity of variance-covariance matrices across design cells produces a non-significant result [$F$(30,3540.209) = 1.31, $p$ = .12]. Significant main effects of time [$F$(3,35) = 5.17, $p$ < .01] was found, which shows practice effect. But the main effect of group was not significant [$F$(3,37) = .88, $p$ = .46], and the interaction of time X group was not significant [$F$(9,85.33) = 1.48, $p$ = .17], suggesting there was no significant game group differences in improvement in the map drawing performances. See Table 2 for the means of map drawing accuracy in four time points in four groups.

Table 2. Mean accuracy of map drawing for four groups for four assessment time points

Measure: Map drawing accuracy

| Group | Time | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|
| Control | 1 | .703 | .053 | .594 | .811 |
| | 2 | .793 | .044 | .703 | .882 |
| | 3 | .770 | .040 | .689 | .852 |
| | 4 | .761 | .049 | .662 | .859 |
| FPS | 1 | .778 | .053 | .670 | .886 |
| | 2 | .845 | .044 | .756 | .935 |
| | 3 | .863 | .040 | .781 | .945 |
| | 4 | .862 | .049 | .764 | .961 |
| TPS | 1 | .834 | .056 | .721 | .948 |
| | 2 | .803 | .046 | .709 | .897 |
| | 3 | .855 | .042 | .769 | .940 |
| | 4 | .838 | .051 | .735 | .941 |
| Puzzle | 1 | .721 | .059 | .601 | .841 |
| | 2 | .785 | .049 | .686 | .884 |
| | 3 | .780 | .044 | .690 | .870 |
| | 4 | .849 | .054 | .741 | .958 |

**Maze Exit Finding Speed.** A mixed model ANOVA with a within-subjects variable of the time and a between-subjects variable of the group was also conducted for the DV of maze exit-finding speed. The Box's M test for the homogeneity of variance-covariance matrices across design cells was significant [$F(30,3540.209) = 1.66$, $p < .05$], therefore Pillai's Trace was reported. Main effects of time [$F(3,35) = 1.41$, $p = .26$] and group [$F(3,37) = .14$, $p = .94$] were not significant. The interaction of time X group was also not significant [$F(9,111) = .78$, $p = .64$], suggesting there was no significant game group differences in speed of exit-finding performances. See Table 3 for the means of map drawing accuracy in four time points in four groups.

Table 3. Mean speed of maze exit-finding for four groups for four assessment time points

Measure: Exit-finding speed (RT/route distance)

| Group | Time | Mean | Std. Error | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|
| Control | 1 | .615 | .023 | .569 | .662 |
| | 2 | .655 | .023 | .608 | .701 |
| | 3 | .636 | .018 | .600 | .673 |
| | 4 | .625 | .020 | .586 | .665 |
| FPS | 1 | .631 | .023 | .585 | .677 |
| | 2 | .650 | .023 | .604 | .696 |
| | 3 | .609 | .018 | .572 | .646 |
| | 4 | .614 | .020 | .574 | .653 |
| TPS | 1 | .652 | .024 | .604 | .700 |
| | 2 | .626 | .024 | .578 | .674 |
| | 3 | .642 | .019 | .603 | .681 |
| | 4 | .621 | .020 | .580 | .662 |
| Puzzle | 1 | .621 | .025 | .570 | .672 |
| | 2 | .674 | .025 | .623 | .725 |
| | 3 | .608 | .020 | .567 | .649 |
| | 4 | .647 | .022 | .603 | .690 |

**Spatial Attention.** To examine whether there would be a significant improvement in visual attention ability with 20 and 30 degree eccentricity, a mixed model MANOVA that included two within-subjects variables of eccentricity (20° and 30°) and time (pre, post-10hr, post-20hr and post-30hr training), and a between-subject factor of group (control, FPS, TPS, Puzzle) was conducted with spatial attention accuracy. The Box's M test for the homogeneity of variance-covariance was not significant [$F(108,3002.089) = 1.19$, $p > .05$]. The main effects of time [$F(3,36) = 13.57$, $p < .01$] was significant, which suggesting there was a general improvement in accuracy, and eccentricity [$F(1,38) = 60.82$, $p < .01$] was also significant, which presenting that the participants performed significantly worse with the 30 degree eccentricity, compared to 20 degree eccentricity. See Table 4 for the means of the AVF accuracy for four times as well as for each eccentricity.

Table 4. Mean accuracy of the AVF performance for four time points / for two eccentricities

Measure: AVF accuracy

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| | Mean | Std. Error | Lower Bound | Upper Bound |
| Time | | | | |
| 1 | .444 | .028 | .387 | .502 |
| 2 | .513 | .024 | .463 | .562 |
| 3 | .567 | .026 | .515 | .619 |
| 4 | .536 | .022 | .492 | .580 |
| Eccentricity | | | | |
| 20° eccentricity | .561 | .024 | .512 | .610 |
| 30° eccentricity | .469 | .020 | .429 | .509 |

None of two-way interactions of time X group [$F(9,87.765) = 1.49$, $p = .16$], time X eccentricity [$F(3,36) = .48$, $p = .70$] and eccentricity X group [$F(3,38) = 1.31$, $p = .29$] were significant. Finally, the results showed a marginally significant three-way interaction of group X time X eccentricity [$F(9,87.765) = 1.91$, $p = .06$, $\eta^2 = 14$]. Post-hoc analysis of the three-way interaction compared group differences (control, FPS, TPS, Puzzle game group) for each eccentricity accuracy and for each time session. The results showed that the FPS game group had significant improvements at 20° eccentricity in the AVF test after playing the FPS game for 10 and 20 hours compared to the pre-training assessment, while the TPS game group or the puzzle game group did not show any improvement (Figure 5). Table 5 presents the pairwise comparison of time points for each group for each eccentricity. The results also showed that the control no-training group significantly improved visual attention accuracy at 20° eccentricity after 30 hours. This result may indicate that there is a potential test-retest effect in the AVF test after extensive test exposures, but this test-retest effect was not found in the TPS game group and the puzzle game group. Considering this possible test-retest effect, no significant improvement in the TPS [$F(3,36) = 1.42$, $p = .25$] and the puzzle game group [$F(3,36) = 1.75$, $p = .17$] might suggest that some aspects of the TPS and the puzzle gaming are negatively associated with spatial attention.

Significant spatial attention improvements in the FPS game training group were also found in spatial attention accuracy in 30° eccentricity, in post-10hr, post-20hr and post-30hr session compared to pre-training performance (Figure 5). Only the FPS game group, but not the control, TPS and puzzle group significantly improved at 30° eccentricity at the follow-up sessions. The results indicated that the first-person perspective was the important component determining the effect of playing games on visual attention ability because the FPS and TPS games used in the current study were the exact same game except for the viewpoint (gaming perspective) settings, and the two games had the exact same gaming mechanisms, environments, speed and activities, etc.

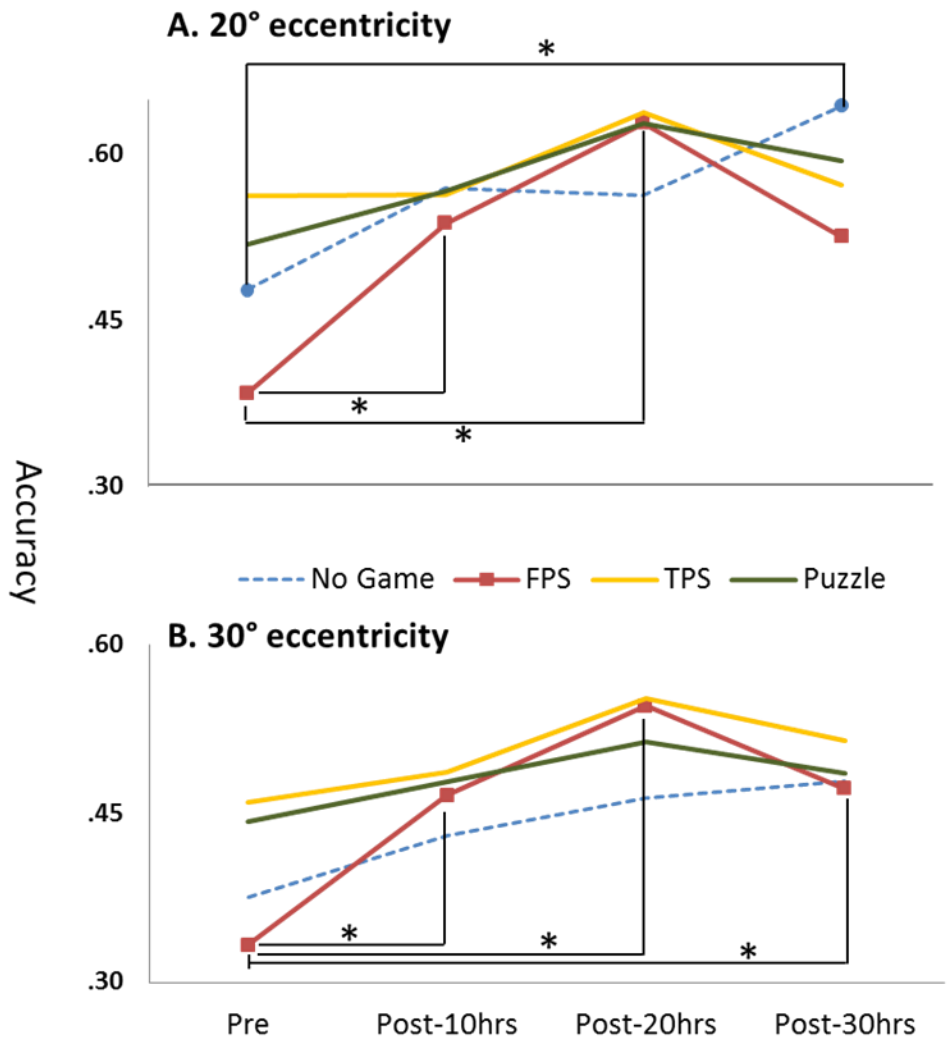


Figure 5. The group differences in the AVF accuracy at 20° (Top) and 30° (Bottom). The three-way interaction (Group X Session X Eccentricity) was significant ($p < .05$). * $p < .05$

Another interesting point with these results was that the FPS game group showed significant improvements in spatial attention at the first post-training test which was conducted after 10 hours of game playing, which may suggest that a relatively short period of game playing may impact spatial attention ability.

Table 5. Pairwise comparison of assessment time points for groups for 20 and 30 degree eccentricity (accuracy).

| Eccentricity | Group | (A) Time | (B) Time | Mean Difference (A-B) | Standard Error | 95% Confidence Interval for Difference Lower | Upper |
|---|---|---|---|---|---|---|---|
| 20 ° | Control | 1 | 2 | -0.092 | 0.047 | -0.223 | 0.039 |
| | | | 3 | -0.086 | 0.044 | -0.207 | 0.035 |
| | | | 4 | -.167* | 0.053 | -0.315 | -0.019 |
| | | 2 | 1 | 0.092 | 0.047 | -0.039 | 0.223 |
| | | | 3 | 0.006 | 0.043 | -0.112 | 0.124 |
| | | | 4 | -0.075 | 0.049 | -0.21 | 0.06 |
| | | 3 | 1 | 0.086 | 0.044 | -0.035 | 0.207 |
| | | | 2 | -0.006 | 0.043 | -0.124 | 0.112 |
| | | | 4 | -0.081 | 0.05 | -0.219 | 0.058 |
| | | 4 | 1 | .167* | 0.053 | 0.019 | 0.315 |
| | | | 2 | 0.075 | 0.049 | -0.06 | 0.21 |
| | | | 3 | 0.081 | 0.05 | -0.058 | 0.219 |
| | FPS | 1 | 2 | -.153* | 0.047 | -0.285 | -0.022 |
| | | | 3 | -.244** | 0.044 | -0.365 | -0.123 |
| | | | 4 | -0.142 | 0.053 | -0.289 | 0.006 |
| | | 2 | 1 | .153* | 0.047 | 0.022 | 0.285 |
| | | | 3 | -0.091 | 0.043 | -0.209 | 0.028 |
| | | | 4 | 0.012 | 0.049 | -0.123 | 0.147 |
| | | 3 | 1 | .244** | 0.044 | 0.123 | 0.365 |
| | | | 2 | 0.091 | 0.043 | -0.028 | 0.209 |
| | | | 4 | 0.103 | 0.05 | -0.036 | 0.241 |
| | | 4 | 1 | 0.142 | 0.053 | -0.006 | 0.289 |
| | | | 2 | -0.012 | 0.049 | -0.147 | 0.123 |
| | | | 3 | -0.103 | 0.05 | -0.241 | 0.036 |
| | TPS | 1 | 2 | -0.002 | 0.047 | -0.133 | 0.13 |
| | | | 3 | -0.076 | 0.044 | -0.197 | 0.045 |
| | | | 4 | -0.01 | 0.053 | -0.158 | 0.138 |
| | | 2 | 1 | 0.002 | 0.047 | -0.13 | 0.133 |
| | | | 3 | -0.074 | 0.043 | -0.193 | 0.044 |
| | | | 4 | -0.009 | 0.049 | -0.144 | 0.126 |
| | | 3 | 1 | 0.076 | 0.044 | -0.045 | 0.197 |
| | | | 2 | 0.074 | 0.043 | -0.044 | 0.193 |
| | | | 4 | 0.066 | 0.05 | -0.073 | 0.204 |
| | | 4 | 1 | 0.01 | 0.053 | -0.138 | 0.158 |
| | | | 2 | 0.009 | 0.049 | -0.126 | 0.144 |
| | | | 3 | -0.066 | 0.05 | -0.204 | 0.073 |
| | Puzzle | 1 | 2 | -0.048 | 0.052 | -0.193 | 0.097 |
| | | | 3 | -0.11 | 0.048 | -0.244 | 0.024 |
| | | | 4 | -0.076 | 0.059 | -0.24 | 0.087 |
| | | 2 | 1 | 0.048 | 0.052 | -0.097 | 0.193 |
| | | | 3 | -0.062 | 0.047 | -0.192 | 0.069 |
| | | | 4 | -0.028 | 0.054 | -0.177 | 0.121 |
| | | 3 | 1 | 0.11 | 0.048 | -0.024 | 0.244 |
| | | | 2 | 0.062 | 0.047 | -0.069 | 0.192 |
| | | | 4 | 0.034 | 0.055 | -0.12 | 0.187 |
| | | 4 | 1 | 0.076 | 0.059 | -0.087 | 0.24 |
| | | | 2 | 0.028 | 0.054 | -0.121 | 0.177 |
| | | | 3 | -0.034 | 0.055 | -0.187 | 0.12 |

Table 5. (Continued)

| Eccentricity | Group | (A) Time | (B) Time | Mean Difference (A-B) | Standard Error | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| 30 ° | Control | 1 | 2 | -0.055 | 0.039 | -0.162 | 0.053 |
| | | | 3 | -0.088 | 0.034 | -0.183 | 0.007 |
| | | | 4 | -0.102 | 0.042 | -0.22 | 0.015 |
| | | 2 | 1 | 0.055 | 0.039 | -0.053 | 0.162 |
| | | | 3 | -0.034 | 0.037 | -0.137 | 0.069 |
| | | | 4 | -0.048 | 0.046 | -0.177 | 0.081 |
| | | 3 | 1 | 0.088 | 0.034 | -0.007 | 0.183 |
| | | | 2 | 0.034 | 0.037 | -0.069 | 0.137 |
| | | | 4 | -0.014 | 0.042 | -0.132 | 0.103 |
| | | 4 | 1 | 0.102 | 0.042 | -0.015 | 0.22 |
| | | | 2 | 0.048 | 0.046 | -0.081 | 0.177 |
| | | | 3 | 0.014 | 0.042 | -0.103 | 0.132 |
| | FPS | 1 | 2 | -.134** | 0.039 | -0.241 | -0.026 |
| | | | 3 | -.213** | 0.034 | -0.308 | -0.118 |
| | | | 4 | -.139* | 0.042 | -0.257 | -0.022 |
| | | 2 | 1 | .134** | 0.039 | 0.026 | 0.241 |
| | | | 3 | -0.079 | 0.037 | -0.182 | 0.024 |
| | | | 4 | -0.006 | 0.046 | -0.135 | 0.123 |
| | | 3 | 1 | .213** | 0.034 | 0.118 | 0.308 |
| | | | 2 | 0.079 | 0.037 | -0.024 | 0.182 |
| | | | 4 | 0.073 | 0.042 | -0.044 | 0.191 |
| | | 4 | 1 | .139* | 0.042 | 0.022 | 0.257 |
| | | | 2 | 0.006 | 0.046 | -0.123 | 0.135 |
| | | | 3 | -0.073 | 0.042 | -0.191 | 0.044 |
| | TPS | 1 | 2 | -0.028 | 0.039 | -0.135 | 0.08 |
| | | | 3 | -0.093 | 0.034 | -0.188 | 0.002 |
| | | | 4 | -0.055 | 0.042 | -0.172 | 0.062 |
| | | 2 | 1 | 0.028 | 0.039 | -0.08 | 0.135 |
| | | | 3 | -0.066 | 0.037 | -0.169 | 0.037 |
| | | | 4 | -0.027 | 0.046 | -0.156 | 0.102 |
| | | 3 | 1 | 0.093 | 0.034 | -0.002 | 0.188 |
| | | | 2 | 0.066 | 0.037 | -0.037 | 0.169 |
| | | | 4 | 0.038 | 0.042 | -0.079 | 0.156 |
| | | 4 | 1 | 0.055 | 0.042 | -0.062 | 0.172 |
| | | | 2 | 0.027 | 0.046 | -0.102 | 0.156 |
| | | | 3 | -0.038 | 0.042 | -0.156 | 0.079 |
| | Puzzle | 1 | 2 | -0.036 | 0.043 | -0.154 | 0.083 |
| | | | 3 | -0.072 | 0.038 | -0.176 | 0.033 |
| | | | 4 | -0.043 | 0.047 | -0.173 | 0.086 |
| | | 2 | 1 | 0.036 | 0.043 | -0.083 | 0.154 |
| | | | 3 | -0.036 | 0.041 | -0.149 | 0.078 |
| | | | 4 | -0.007 | 0.051 | -0.15 | 0.135 |
| | | 3 | 1 | 0.072 | 0.038 | -0.033 | 0.176 |
| | | | 2 | 0.036 | 0.041 | -0.078 | 0.149 |
| | | | 4 | 0.028 | 0.047 | -0.101 | 0.158 |
| | | 4 | 1 | 0.043 | 0.047 | -0.086 | 0.173 |
| | | | 2 | 0.007 | 0.051 | -0.135 | 0.15 |
| | | | 3 | -0.028 | 0.047 | -0.158 | 0.101 |

*$P$ <.05, ** $P$ < .01

**Speed of Processing.** A mixed model ANOVA with a within-subjects variable of the time and a between-subjects variable of the group was also conducted for speed of processing. The Box's M test for the homogeneity of variance-covariance matrices across design cells was not significant [$F(30,3699.887) = 1.28$, $p = .14$]. The main effect of time showed marginal significance [$F(3,36) = 2.63$, $p = .065$], and the main effect of group [$F(3,38) = 1.50$, $p = .23$] was not significant. The interaction of time X group was significant [$F(9,87.765) = 2.92$, $p < .05$], suggesting there was significant game group differences in changes over time in RT performances. Post-hoc analysis revealed that the TPS game group increased reaction time at Sessions 3 and 4 compared to the pre-training session, whereas the FPS game group, the puzzle game group and the control group did not show any significant change over time. See Table 6 for the means of the speed of processing for four groups for four times.

**Mental Rotation.** Lastly, a mixed model ANOVA with a within-subjects variable of the time and a between-subjects variable of the group was also conducted for mental rotation RT. The Box's M test for the homogeneity of variance-covariance matrices across design cells was significant [$F(30,3699.887) = 3.04$, $p < .05$], therefore Pillai's Trace was reported. Main effect of time was significant [$F(3,36) = 21.06$, $p < .05$], while the main effect of group [$F(3,38) = .66$, $p = .58$] and the interaction of time X group [$F(9,114) = .84$, $p = .59$] were not significant. No interaction effect would suggest there was no significant game group difference in changes over time in mental rotation performance. Table 7 presents the RT means of the mental rotation results for four groups for four times.

Table 6. Mean RT (msec) in the choice reaction time task

| | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|
| Group | Time | Mean | Std. Error | Lower Bound | Upper Bound |
| Control | 1 | 376.000 | 11.735 | 352.243 | 399.757 |
| | 2 | 388.455 | 11.608 | 364.956 | 411.953 |
| | 3 | 371.273 | 12.197 | 346.581 | 395.964 |
| | 4 | 367.909 | 13.840 | 339.891 | 395.927 |
| FPS | 1 | 380.091 | 11.735 | 356.334 | 403.848 |
| | 2 | 383.909 | 11.608 | 360.410 | 407.408 |
| | 3 | 375.000 | 12.197 | 350.309 | 399.691 |
| | 4 | 385.818 | 13.840 | 357.800 | 413.836 |
| TPS | 1 | 371.273 | 11.735 | 347.516 | 395.029 |
| | 2 | 360.091 | 11.608 | 336.592 | 383.590 |
| | 3 | 398.182 | 12.197 | 373.490 | 422.873 |
| | 4 | 418.091 | 13.840 | 390.073 | 446.109 |
| Puzzle | 1 | 393.667 | 12.974 | 367.403 | 419.931 |
| | 2 | 415.000 | 12.833 | 389.021 | 440.979 |
| | 3 | 403.556 | 13.484 | 376.258 | 430.853 |
| | 4 | 415.000 | 15.301 | 384.025 | 445.975 |

Table 7. Mean RT(sec) in the mental rotation task

| | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|
| Group | Time | Mean | Std. Error | Lower Bound | Upper Bound |
| Control | 1 | 2.889 | .334 | 2.214 | 3.565 |
| | 2 | 2.128 | .404 | 1.311 | 2.945 |
| | 3 | 1.835 | .297 | 1.235 | 2.436 |
| | 4 | 1.777 | .334 | 1.101 | 2.454 |
| FPS | 1 | 3.325 | .334 | 2.650 | 4.001 |
| | 2 | 2.213 | .404 | 1.396 | 3.030 |
| | 3 | 1.814 | .297 | 1.213 | 2.414 |
| | 4 | 1.740 | .334 | 1.064 | 2.416 |
| TPS | 1 | 3.192 | .334 | 2.516 | 3.867 |
| | 2 | 1.958 | .404 | 1.141 | 2.775 |
| | 3 | 1.873 | .297 | 1.272 | 2.473 |
| | 4 | 1.820 | .334 | 1.144 | 2.496 |
| Puzzle | 1 | 3.077 | .369 | 2.330 | 3.824 |
| | 2 | 2.862 | .446 | 1.959 | 3.765 |
| | 3 | 2.467 | .328 | 1.803 | 3.131 |
| | 4 | 2.519 | .369 | 1.771 | 3.267 |

**Perceived Game Training Difficulty and Engagement**

The participants who were in one of the three game training groups (FPS, TPS and puzzle), but not participants in the control no-training group, completed two questionnaires (perceived game training difficulty and engagement). To examine any group differences in perceived difficulty or game engagement developed through game training, a mixed model MANOVA was conducted with two within-subjects variables of time (3 levels: post-10hr, post-20hr and post-30hr training) and self-reports (perceived difficulty and game engagement), and a between-subject factor of group (3 levels: FPS, TPS and puzzle game group). A main effect of two reports was significant [$F(1,57) = 59.33$, $p < .01$], showing two measures were different. The three-way interaction was not significant [$F(4,54) = .53$, $p = .71$], and pairwise comparisons showed no difference across three groups in perceived video game difficulty and game playing engagement over time. Table 8 presents the means of the perceived difficulty and the engagement for the three game groups after 10, 20, 30 hours of game training.

**Improvements of Video Gaming Skills**

A mixed model MANOVA with two within-subject variables of time (pre, post-10hr, post-20hr and post-30hr training) and gaming skill in three games (FPS, TPS and Puzzle game performance), and a between-subject factor was group (control, FPS, TPS, Puzzle) was conducted to investigate any improvement in video gaming skill in the three games on which the participants were trained. None of main effects of time [$F(3,36) = 1.75$, $p = .17$], gaming performance [$F(3,37) = .003$, $p = .997$] and group [$F(3,38) = .13$, $p = .94$] were significant.

Table 8. Mean perceived difficulty and engagement of three game groups after 10, 20, 30 hours of game training

| Task | Time | Group | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| Perceived Difficulty (1: Low difficulty - 7: High difficulty) | 2 | FPS | 3.54 | .25 | 3.02 | 4.06 |
| | | TPS | 3.24 | .25 | 2.72 | 3.76 |
| | | Puzzle | 3.46 | .28 | 2.89 | 4.03 |
| | 3 | FPS | 3.57 | .28 | 3.00 | 4.15 |
| | | TPS | 3.06 | .28 | 2.49 | 3.64 |
| | | Puzzle | 3.58 | .31 | 2.95 | 4.22 |
| | 4 | FPS | 3.88 | .24 | 3.39 | 4.38 |
| | | TPS | 3.24 | .24 | 2.74 | 3.73 |
| | | Puzzle | 3.48 | .27 | 2.93 | 4.03 |
| Engagement (1:Low engagement - 7:High engagement) | 2 | FPS | 4.89 | .35 | 4.18 | 5.60 |
| | | TPS | 5.12 | .35 | 4.41 | 5.83 |
| | | Puzzle | 4.91 | .38 | 4.13 | 5.69 |
| | 3 | FPS | 5.09 | .28 | 4.52 | 5.66 |
| | | TPS | 4.79 | .28 | 4.22 | 5.36 |
| | | Puzzle | 4.80 | .31 | 4.17 | 5.43 |
| | 4 | FPS | 4.83 | .34 | 4.13 | 5.52 |
| | | TPS | 4.56 | .34 | 3.87 | 5.26 |
| | | Puzzle | 4.77 | .38 | 4.00 | 5.54 |

Interaction effects of group x time on three gaming performance were not significant [$F(18,93.82) = .72$, $p = .78$].These results suggest that none of the gaming skills assessed by in-game scores (kill/death ratio in the FPS and the TPS game; earned score in the puzzle game) improved significantly over time, nor gaming performances were different in the four groups. See Table 9 for the mean gaming performance scores for four groups at four time points.

Table 9. Mean gaming performance scores for four groups at four time points

Measure: Game performance (z score)

| Task | Group | Time | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| FPS (BeGone© First-person Perspective Mode) | Control | 1 | .486 | .316 | -.154 | 1.127 |
| | | 2 | .053 | .321 | -.596 | .702 |
| | | 3 | -.195 | .264 | -.729 | .340 |
| | | 4 | .057 | .323 | -.598 | .712 |
| | FPS | 1 | -.094 | .316 | -.735 | .547 |
| | | 2 | .301 | .321 | -.348 | .950 |
| | | 3 | -.343 | .264 | -.877 | .191 |
| | | 4 | .146 | .323 | -.508 | .801 |
| | TPS | 1 | -.242 | .316 | -.883 | .398 |
| | | 2 | -.037 | .321 | -.686 | .612 |
| | | 3 | .305 | .264 | -.229 | .839 |
| | | 4 | -.206 | .323 | -.861 | .449 |
| | Puzzle | 1 | -.360 | .350 | -1.069 | .348 |
| | | 2 | .020 | .354 | -.698 | .737 |
| | | 3 | .166 | .292 | -.425 | .756 |
| | | 4 | -.107 | .358 | -.830 | .617 |
| TPS (BeGone© Third-person Perspective Mode) | Control | 1 | .088 | .263 | -.445 | .620 |
| | | 2 | -.135 | .453 | -1.052 | .782 |
| | | 3 | -.290 | .144 | -.581 | .001 |
| | | 4 | -.241 | .288 | -.825 | .342 |
| | FPS | 1 | -.168 | .263 | -.700 | .364 |
| | | 2 | .529 | .453 | -.389 | 1.446 |
| | | 3 | -.242 | .144 | -.533 | .049 |
| | | 4 | .320 | .288 | -.263 | .904 |
| | TPS | 1 | -.053 | .263 | -.585 | .479 |
| | | 2 | .143 | .453 | -.774 | 1.060 |
| | | 3 | -.077 | .144 | -.368 | .214 |
| | | 4 | -.102 | .288 | -.685 | .481 |
| | Puzzle | 1 | -.090 | .291 | -.679 | .498 |
| | | 2 | .393 | .501 | -.621 | 1.407 |
| | | 3 | -.075 | .159 | -.397 | .247 |
| | | 4 | .054 | .319 | -.591 | .699 |

Table 9. Continued

| Task | Group | Time | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| Puzzle (Tetris) | Control | 1 | -.397 | .239 | -.881 | .087 |
| | | 2 | -.089 | .325 | -.746 | .568 |
| | | 3 | .070 | .281 | -.499 | .638 |
| | | 4 | -.024 | .370 | -.772 | .724 |
| | FPS | 1 | -.390 | .239 | -.874 | .094 |
| | | 2 | .158 | .325 | -.499 | .815 |
| | | 3 | -.034 | .281 | -.603 | .534 |
| | | 4 | .103 | .370 | -.645 | .852 |
| | TPS | 1 | -.202 | .239 | -.686 | .282 |
| | | 2 | .028 | .325 | -.629 | .685 |
| | | 3 | -.117 | .281 | -.686 | .452 |
| | | 4 | .136 | .370 | -.612 | .884 |
| | Puzzle | 1 | -.104 | .264 | -.639 | .431 |
| | | 2 | .083 | .359 | -.643 | .809 |
| | | 3 | .455 | .311 | -.174 | 1.084 |
| | | 4 | .494 | .409 | -.334 | 1.321 |

# Discussion

The current study aimed to investigate the impacts of playing video games with different visuospatial characteristics or gaming mechanisms on development of cognitive abilities, including navigation/wayfinding, spatial attention, mental rotation and speed of processing, during 30 hours of game training.

## Impacts of Gaming Perspective on Spatial Attention

The current results only partially supported the first hypothesis that the action game training (FPS and TPS game) would enhance small-scaled spatial cognitive tasks (spatial attention and spatial visualization) and the first-person in-game perspective would have extra benefits in spatial cognitive improvement. The results did not show any significant improvement in any of game-training groups in the mental rotation task, but significant improvement was found in the FPS game training group in the AVF task. This finding is consistent with previous findings (Dye, Green, & Bavelier, 2009; Green & Bavelier, 2003; 2006; Spence & Feng, 2010) that playing FPS video games improved visual attention abilities, and it confirmed the potential of FPS video games as a tool to train spatial attention. Interestingly, training with the TPS video game did not successfully enhance spatial attention, which was not consistent with our hypothesis. These results suggest that a gaming mechanism and structure of the action game that involves spatially challenging activities such as searching both proactively and reactively in environments and targets, responding to unnatural stringent targets over a wide visual field and requiring visuomotor controls in fast-speeded conditions, may not, by themselves, significantly influence visual attention ability. The current findings, however, suggest that specific visuospatial characteristics of video games, such as in-game viewpoints, may be the critical elements impacting the effects of playing video games on cognitive improvements such as spatial attention abilities.

There would be several possible explanations why and how a first and a third-person perspective differently impact spatial attention. First, the different impacts of a first and a third-person perspective might be due to different immersion experiences during game playing. The game with a first-person perspective may provide better immersion because the environment matches the player’s personal point of view, whereas the game with a third-person perspective would externalize experiences in which players have another person's point of view during game playing (Kallinen et al., 2007; Havranek, Langer, Cheetham & Jäncke, 2012). During the game, players may scan the screen or selectively pay attention in a more naturalistically way during playing with a first-person viewpoint, whereas, in the third-person view, players may scan and focus over the gaming environment differently even though the activities and gaming mechanisms stays same. Due to different levels of spatial presence that can be defined as a the feeling of actually being in the virtual environment while transiently being unaware of the technology that delivers the stream of virtual input to the sense (Havranek et al., 2012), players may focus more on game playing and be less distracted by the outside of the game environment while playing. Therefore, the first-person shooting game may deliver more effective cognitive training, compared to the third-person game or other types of video games. However, one of the previous studies (Kallinen et al., 2007) investigating attentional differences in first-person and third-person perspectives did not find significant differences measured by eye-tracking data. Further research may be needed to understand how different immersion / presence experiences would impact cognitive abilities. For example, visual scan patterns can be recorded and to examine differences in the attentional and perceptual process during game playing either with a first or a third person viewpoint.

Different cognitive impacts of gaming perspective would be also explained by different levels of control that players would have during a FPS and TPS game playing. Third person perspectives may allow players to have better control of their actions as responding to the environments, whereas it may be more difficult to control with first-person perspectives due to relatively less spatial cues compared to third-person perspective. A previous study (Schuurink & Toet, 2010) showed that participants experience more control over the avatar and the events when using the third-person perspective. Also, third-person game playing may provide benefits in terms of spatial controls because the avatar is not visible in the first-person perspective, and it may make it harder to judge distances and to anticipate and extrapolate motion trajectories (Salamin, Thalmann, & Vexo, 2006). Because game playing with first-person perspective may be more challenging in terms of control, it might lead to stronger influence in cognitive improvements. However, the current results did not show any significant group difference in perceived game playing difficulty. Further research would be needed to assess non-self-reported difficulty and control levels that players experience with playing with first-person and third-person perspectives.

Spatial attention improvement only in the FPS game group might be explained alternatively by different levels of motivation of game players when they play either with first-person or third-person viewpoints. Game players may particularly prefer to play with a first-person or a third-person perspective. However, the results suggested that the FPS and TPS game groups did not differ statistically in self-reported engagement; therefore, the in-game perspective itself would strongly account for their differences in spatial attention performance.

Future research should more closely investigate why and how video game players perceive and experience games differently when they play with particular viewpoint to find out the underlying reason of different impacts of different in-game perspectives on cognitive ability.

**Impacts of Playing Games on Navigation / Map Performances**

The current study failed to find any significant improvement in maze exit-finding and map drawing tasks in any video game groups after game training. It was hypothesized that the FPS game group would be superior in environment maze tasks to the TPS game group and the puzzle game group, and that the TPS game group would perform significantly better than the puzzle game group, which would suggest that the mechanism of the shooting action game significantly enhanced visual attention and that there are additional benefits of the first-person viewpoint on visual attention beyond that accounted for by just the game mechanism. However, the failure to find a significant effect of game type on maze performance would suggest that the effects of playing FPS video games on spatial cognition are not transferred to more dynamic and larger-scaled spatial skills such as navigation/way-finding.

The experimental manipulation may have failed to generate significant difference in improvement in maze performances. The navigation skill measures (speed of exit-finding in mazes and map drawing accuracy) in the current study might not be valid to assess navigation skills, given that the errors or deviations that participants made during navigating mazes and finding exits could not be assessed because the program from which virtual mazes were developed did not record the actual route the participants had in a virtual environment. There might be different accuracy improvements in the experimental groups that were not detected in the current experimental settings. Furthermore, the maze stimuli may have failed to generate significant differences due to relatively easy maze environments (e.g. ceiling effect).

**Causal Effects of Playing Games on Cognitive Abilities & Other Findings**

The current study explored the causal effect of playing a FPS game on spatial attention ability within a training study setting. The results that only the FPS game training, not the TPS game training, significantly improved spatial attention would provide strong evidence for a causal relationship between playing video games and cognitive improvements. It has been pointed out that different outcomes of experimental (game training) and control(no-game training or control game training) groups in video game training studies might be due to differential expectations of participants about whether or how much they think game training should affect their performance on outcome measures (Boot, Blakely, & Simons, 2011). In the current study, because the FPS game and the TPS game groups received training with the exact same game with only different in-game perspective settings, equal improvements across the training conditions would be expected. The result that there was a significant improvement in the AVF test only for the FPS game group suggests that the improvement was not due to differential expectations, but rather due to the influence of playing FPS games.

In terms of the relationship between hours of playing video games and cognitive changes, it was anticipated that significant improvements would not be found until participants achieve extensive game play hours. However, the significant improvements in visual attention were found in the FPS game group after a cumulative total 10 hours of game training. This result would suggest that extensive hours of game training may not be always necessary to bring cognitive effects, and relatively short game playing with certain video games such as a FPS game may be enough to impact on cognitive ability.

There were results suggesting TPS game playing and puzzle game (Tetris) playing may be associated with changes in spatial attention and processing speed. The results showed test-retest effects in the AVF test were found only in the control group but not in the TPS or puzzle game training group. No significant improvement in the TPS and the puzzle game group might suggest that some aspects of the TPS and the puzzle game experience are negatively associated with spatial attention. Furthermore, the results revealed that the TPS game group decreased speed of processing over time, whereas the FPS game, the puzzle game and the control group did not show any significant changes. This result may suggest that the TPS game negatively impacted speed of processing. However further research would be needed to understand why TPS or puzzle game may be negatively associated with particular cognitive abilities such as spatial attention or processing speed

**Limitations and Future Directions**

One limitation of the present study is the reliability of participants' self-reports of their video game playing. Participants were asked to play the games individually in any environment they chose and submitted the records of their self-diaries. I was not able to control or track the exact hours and schedules of the participants' game playing. Also, participants came back for their next sessions at their convenience, and the time between sessions was not controlled. Many participants returned later than was requested, and the periods between in-laboratory sessions varied across the participants. However, validity threats due to maturation and history issues would not be critical in the current study because difference between groups in the time of return was not significant.

The current study only examined particular game types and in-game characteristic of viewpoint (First-person vs. Third-person perspective), and found significant effects of in-game viewpoint on improvements in visual attention ability. However, many other aspects of video games, game mechanisms, motor controls, contents, or training conditions might contribute to the development of various cognitive performance and abilities. Future studies need to examine how different aspects of video games result in improvements in certain skills and abilities as a result of playing those games. In particular, visuospatial characteristics of video games such dimensions (2D or 3D), realism (High vs. Low), game speed (High vs. Low), and training conditions (e.g. distribution of game playing) can be separately manipulated in the experiment while controlling other features and game tasks to investigate the impacts of each characteristic on the development of cognitive skills. The current study only compared first-person and third-person (over the shoulder) viewpoints. It would also be useful to examine different gaming perspective such as aerial perspective (from the sky) as a comparison to first-person and third-person perspectives.

The current study used limited measurements for navigation performance (map drawing and exit-finding), spatial attention (AVF task) and spatial cognitive abilities (mental rotation). In further studies, various measurements may be needed to examine what specific spatial performances may be trained by playing video games. For example, assessment of distance traveled or accuracy in spatial judgments can be used to measure navigation skills. Also, navigation tasks in real world environments can be used in further studies to investigate how virtual environment experiences transfer to cognitive improvements in real world environments. Furthermore, future studies may need to examine if cognitive changes from video game experiences are permanent or transitory.

**Implications and Applications**

In conclusion, the results of this study supported the use of video games as a tool to train spatial attention ability, and demonstrated the impact of the specific visuospatial characteristics of video games on cognitive training. The findings of the present study provide empirical evidences regarding the cognitive influence of perspectives in games or virtual environments where a first-person and a third-person perspective are differently associated with changes in spatial attention. Furthermore, the present study would have possible implications for educational, industrial or military fields where games are diversely used to improve or change cognitive and behavioral performances. Serious games can be developed as an intervention tool by manipulating specific characteristics or elements of video games such as in-game perspective to train particular cognitive abilities and skills such as spatial ability.

## REFERENCES


Achtman, R.L., Green, C.S., & Bavelier, D. (2008). Video game as a tool to train visual skills. *Restorative Neurology and Neuroscience*, 26, 435-446.

Amorim, M., Trumbore, B., & Chogyen, P.L. (2000). Cognitive repositioning inside a desktop VE: The constraints introduced by first- versus third-person imagery and mental representation richness. *Presence, 9*(2), 165-186.

Astur, R. S., Tropp, J., Sava, S., Constable, R. T., & Markus, E. J. (2004). Sex differences and correlations in a virtual Morris water task, a virtual radial arm maze, and mental rotation. *Behavioral Brain Research*, *151*, 103–115.

Bailey, K., West, R., & Anderson, C.A. (2010). A negative association between video game experience and proactive cognitive control. *Psychophysiology, 47*, 34-42.

Ball, K., Beard, B., Roenker, D., Miller, R. & Griggs, D.  (1988). Age and visual search: Expanding the Useful Field of View. *Journal of the Optical Society A*, *5*(12), 2210-2219.

Barlett, C.P., Vowels, C.L., Shanteau, J., Crow, J., & Miller, T. (2008). The effect of violent and non-violent computer games on cognitive performance. *Computers in Human Behavior, 25*, 96-102.

Bartholow, B.D., Bushman, B.J., & Sestir, M.A. (2006). Chronic violent video game exposure and desensitization to violence: Behavioral and event-related brain potential data. *Journal of Experimental Social Psychology, 42*(4), 532-539.

Bavelier, D., Achtman, R.L., Mani, M., & Föcker, J. (2011). Neural bases of selective attention in action video game players. *Vision Research, 61*, 132-143.

Bavelier, D., Green, C.S., Han, D.H., Renshaw, P.F., Merzenich, M.M., & Gentile, D.A. (2011). Brains on video games. *Nature Reviews Neuroscience, 12,* 763-768.

Benbow, C. P., Stanley, J. C., Kirk, M. K., & Zonderman, A. B. (1983). Structure of intelligence in intellectually precocious children and in their parents. *Intelligence*, *7*, 129-l 52.

Blumberg, F.C. (2011). Ramifications of video game play for academic learning and cognitive skill acquisition: Introduction. *Child Development Perspectives, 5*(2), 73-74.

Boot, W.R., Blakely, D.P., & Simons, D.J. (2011). Do action video games improve perception and cognition?. *Frontriers in Psychology, 2*(226), 1-6.

Boot, W. R., Kramer, A.F., Simons, D.J., Fabini, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta Psychologica, 129,* 387-398.

Boot, W.R., Champion, M., Blakely, D.P., Wright, T., Souders, D.J., & Charness, N. (2013). Video games as a means to reduce age-related cognitive decline: attitudes, compliance, and effectiveness. *Frontiers in Psychology, 4*(13), 1-9.

Castel, A.D., Pratt, J., & Drummond, E. (2005). The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica*, *119*, 217-230.

Castelli, L., Corazzini, L.L., & Geminiani, G.C. (2008). Spatial navigation in large-scale virtual environments: Gender differences in survey tasks. *Computers in Human Behavior, 24*, 1643-1667.

Chisholm, J.D., Hickey, C., Theeuwes, J., & Kingstone, A. (2010). Reduced attentional capture in action video game players. *Attention, Perception & Psychophysics*, *72*(3), 667-671.

Colzato, L.S., van Leeuwen, P.J.A., van den Wildenberg, W.P.M., & Hommel, B. (2010). DOOM'd to switch: Superior cognitive flexibility in players of first person shooter games. *Frontiers in Psychology*, *1*, 1-5.

Darken, R.P., & Peterson, B. (2001). Spatial orientation, wayfinding, and representation. In K. Stanney (Ed.), *Handbook of Virtual Environment Technology* (pp. 493-518). New Jersey: Lawrence Erlbaum Assoc.

Donohue, S.E., Woldorff, M.G., & Mitroff, S.R. (2010). Video game players show more precise multisensory temporal processing abilities. *Attention, Perception, & Psychophysics*, *72*(4), 1120-1129.

Dye, M.W.G., Creen, C.S., & Bavelier, D. (2009). Increasing speed of processing with action video games. *Current Directions in Psychological Science*, *18*(6), 321-326.

Edwards, J.D., Vance, D.E., Wadley, V.G., Cissell, G.M., Roenker, D.L., & Ball, K.K. 2005). Reliability and validity of useful field of view test scores as administered by personal computer. *Journal of Clinical and Experimental Neuropsychology*, *27*, 529–543.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science*, *19*(10), 850-855.

Fery, Y.A., & Ponserre, S. (2001). Enhancing the control of force in putting by video game training. *Ergonomics, 44*, 1025-1037.

Gentile, A.D., Lynch, P.J., Linder, J.R., & Walsh, D.A. (2004). The effects of violent video game habits on adolescent hostility, aggressive behaviors, and school performance. *Journal of Adolescence, 27*, 5-22.

Gillner, S., & Mallot, H.A. (1998). Navigation and acquisition of spatial knowledge in a virtual maze. *Journal of Cognitive Neuroscience*, *10*(4), 445-463.

Green, C.S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, *423*, 534-537.

Green, C.S., & Bavelier, D. (2006). Effect of action video games on the spatial distribution of visuospatial attention. *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 1465-1478.

Green, C.S., & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of vision. *Psychological Science*, *18*(1), 88-94.

Green, C.S., & Bavelier, D. (2008). Exercising your brain: A review of human brain plasticity and training-induced learning. *Psychology and Aging, 23* (4), 692-701.

Green, C.S., & Bavelier, D. (2012). Learning, attentional control, and action video games. *Current Biology, 22*(6), 197-206.

Green, C.S., Li, R., Bavelier, D. (2009). Perceptual learning during action video game playing. *Topics in Cognitive Science*, 1-15.

Greenfield, P.M., DeWinstanley, P., Kilpatrick, H., & Kaye, D. (1994). Action video games and informal education: Effects on strategies for dividing visual attention. *Journal of Applied Developmental Psychology*, *15*, 105-123.

Hart, S., & Staveland, L. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P.Hancock & N. Meshtati (Eds.), *Human mental workload* (pp. 139-183). Amsterdam:North Holland.

Havranek, M., Langer, N., Cheetham, M., & Jäncke, L. (2012). Perspective and agency during video gaming influences spatial presence experience and brain activation patterns. *Behavioral and Brain Functions, 8*(34), 1-13.

Hubert-Wallander, B., Green, C.S., & Bavelier, D. (2010). Stretching the limits of visual attention: the case of action video games. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(2), 222 -230.

Kallinen, K., Salminen, M., Ravaja, N., Kedzior, R., & Sääksjärvi, M. (2007). Presence and emotion in computer game players during 1st person vs. 3rd person playing view: Evidence from self-report, eye-tracking, and facial muscle activity data. *Proceedings of the PRESENCE 2007.* Barcelona: Spain.

Karle, J.W., Watter, S., & Shedden, J.M. (2010). Task switching in video game playing: Benefits of selective attention but not resistance to proactive interference. *Acta Psychologica*, 134, 70-78.

Kitchin, R., & Blades, M. (2002). The cognition of geographical space. London: I.B. Tauris.

Koepp, M.J., Gunn, R.N., Lawrence, A.D., Cunningham, V.J., Dagher, A., Jones, T., Brooks, D.J., Bench, C.J., & Grasby, P.M. (1998). Evidence for striatal dopamine release during a video game. *Nature*, *393*(6682), 266–268.

Kozlov, M., & Johansen, M.K. (2010). Real behavior in virtual environments: Psychology experiments in a simple virtual-reality paradigm using video games. *Cyberpsychology, Behavior, and Social Networking. 13*(6), 711-714.

Lövdén, M., Herlitx, A., Schellenbach, M., Grossman-Hutter, B., Krüger, A., & Lindenberger, U. (2007). Quantitative and qualitative sex differences in spatial navigation. *Cognition and Neurosciences, 48*, 353-358.

Lövdén, M., Schellenbach, M., Grossman-Hutter, B., Krüger, A., & Lindenberger, U. (2005). Environmental topography and postural control demands shape aging-associated decrements in spatial navigation performance. *Psychology and Aging*, *20*, 683-694.

Moffat, S.D., Hampson, E., & Hatzipantelis, M. (1998). Navigation in a “virtual” maze: Sex differences and correlation with psychometric measures of spatial ability in Humans. *Evolution and Human Behavior*, *19*, 73-87.

Murphy, K., & Spencer, A. (2009). Playing video games does not make for better visual attention skills. *Journal of Articles in Support of the Null Hypothesis, 6*(1), 1-18.

O'Brien, H. L., & Toms, E. G. (2010). The Development and Evaluation of a Survey to Measure User Engagement. *Journal of the American Society for Information Science and Technology, 61*(1), 50-69.

Richardson, A.E., Powers, M.E., & Bousquet, L.G. (2011). Video game experience predicts virtual, but not real navigation performance. *Computers in Human Behavior*, *27,* 552-560.

Saccuzzo, D.P., Craig, A.S., Johnson, N.E., & Larson, G.E. (1996). Gender differences in dynamic spatial abilities. *Personality and Individual Differences*, *21*(4), 599-607.

Salamin, P., Thalmann, D., Vexo, F. (2006). The benefits of third-person perspective in virtual and augmented reality? Proceedings of *the 13th ACM Symposium on Virtual Reality Software and Technology*. Limassol: Cyprus.

Santone, A.L. (2009). *Visuospatial characterization and analysis of spatial abilities of video game players*. (Unpublished doctoral dissertation). Purdue University, West Lafayette, Indiana.

Sanchez, C.A. (2012). Enhancing visuospatial performance through video game training to increase learning in visuospatial science domain. *Psychonomic Bulletin and Review, 19,* 58-65.

Schomaker, J., Tesch, J., Bülthoff, H.H., & Bresciani, J. (2011). It is all me: The effect of viewpoint on visual-vestibular recalibration. *Experimental Brain Research, 213,* 245-256.

Schuurink, E.L., & Toet, A. (2010). Effects of third person perspective on affective appraisal and engagement: Findings from second life. *Simulation & Gaming, 41*(5), 724-742.

Shelton, A.L., & Pippitt, H.A. (2007). Fixed versus dynamic orientations in environmental learning from ground-level and aerial perspectives. *Psychological Research, 71,* 333-346.

Shore, D.L., Stanford, L., Macinners, W.J., Klein, R.M., & Brown, R.E. (2001). Of mice and men: Virtual Hebb-Williams mazes permit comparison of spatial learning across species. *Cognitive, Affective & Behavioral Neuroscience, 1,* 83-39.

Sims, V. K., & Mayer, R.E. (2002). Domain specificity of spatial expertise: The case of video game players. *Applied Cognitive Psychology, 16,* 97-115.

Spence, I., Yu, J.J., Feng, J., & Marshman, J. (2009). Women match men when learning a spatial skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 1097-1103.

Spence, I., & Feng, J. (2010). Video games and spatial cognition. *Review of General Psychology, 14*, 92-104.

Troberg, E., & Gillan, D.J. (2007). Measuring spatial knowledge: Effects of the relation between acquisition and testing. *PROCEEDINGS of the Human Factors and Ergonomics Society 51st Annual Meeting.* Baltimore, MD: Human Factors and Ergonomics Society.

Ustinova, K.K., Perkins, J., Szostakowski, L., Tamkei, L.S., & Leonard, W.A. (2010). Effect of viewing angle on arm reaching while standing in a virtual environment: Potential for virtual rehabilitation. *Acta Psychologica, 133*, 180-190.

West, L.G., Stevens, S.A., Pun, C., & Pratt, J. (2008). Visuospatial experience modulates attentional capture: Evidence from action video game players. *Journal of Vision, 8*(16):13, 1-9.

Wu, S., Cheng, C. K., Feng, J., D'Angelo, L., Alain, C., & Spence, I. (2012). Playing Videogames Induces Neuroplastic Change. *Journal of Cognitive Neuroscience, 24*, 1286-1293.

# APPENDICES

# Appendix A

## Video Game Experience Questionnaire

# Questionnaire

**Age:** (______________)

**1. Do you play video games (including all the platforms such as PC, Wii, PSP, etc.)?**

A. Yes, currently or within the last six months.

B. Yes, but not within the last six months.

C. No, I have never played video games.

(If you do not play currently and/or recently, or you never played video games before, you may finish the survey here.)

**For the Following two questions, please indicate your answer in numbers.**

**2. If you play video games currently or have played within the previous 6 months, please indicate how often you play/played video games.**

Approximately (_________) times a week

*Example: Approximately ( 2 ) times a week. If you rarely play, please put 0 in the blank.

**3. How many hours you play each time on average?**

Approximately (_________) hours per each time playing

*Example: Approximately ( 2 ) hours per each time playing. If you rarely play, please put 0 in the blank.

**Please indicate your answer by circling the number 1 through 5 above the answer that most clearly applies to you.**

**4. How well do you think you play video games in general?**

1-------------------------2-------------------------3-------------------------4-------------------------5

(Poor) (Below Average) (Average) (Good) (Excellent)

**5. Have you played the games listed below?**

- BeGone ( Y / N )
- Tetris ( Y / N )

# Appendix B

## Perceived Task Difficulty Questionnaire

ID:___________

[Task difficulty Questionnaire]

"The task" in the following questions indicates the video game playing experience you ha
the past period.

[Mental Demand] How mentally demanding was the task?

1---------------2---------------3---------------4---------------5---------------6---------------7

Very Low ... Very High

[Physical Demand] How physically demanding was the task?

1---------------2---------------3---------------4---------------5---------------6---------------7

Very Low ... Very High

[Temporal Demand] How hurried or rushed was the pace of the task?

1---------------2---------------3---------------4---------------5---------------6---------------7

Very Low ... Very High

[Performance] How successful were you in accomplishing what you were asked to do?

1---------------2---------------3---------------4---------------5---------------6---------------7

Perfect ... Failure

[Effort] How hard did you have to work to accomplish your level of performance?

1---------------2---------------3---------------4---------------5---------------6---------------7

Very Low ... Very High

[Frustration] How insecure, discouraged, irritated, stressed and annoyed were you?

1---------------2---------------3---------------4---------------5---------------6---------------7

Very Low ... Very High

# Appendix C

## Task Engagement Questionnaire

ID:_______________

[Playing Engagement Questionnaire]

**Read the following statements and indicate your answer by circling the number 1 through 7 that most clearly applies to your experience.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Disagree Somewhat | Neither Agree nor Disagree | Agree Somewhat | Agree | Strongly Agree |

I enjoyed the video game playing.
1---------------2---------------3---------------4---------------5---------------6---------------7

I felt energetic while I play the video game.
1---------------2---------------3---------------4---------------5---------------6---------------7

I was absorbed in the game.
1---------------2---------------3---------------4---------------5---------------6---------------7

The time I spent playing the game just slipped away.
1---------------2---------------3---------------4---------------5---------------6---------------7

I was motivated to play the video game.
1---------------2---------------3---------------4---------------5---------------6---------------7

The gaming experience was interesting and fun.
1---------------2---------------3---------------4---------------5---------------6---------------7

I could fully concentrate and be engaged to play the video game.
1---------------2---------------3---------------4---------------5---------------6---------------7

I felt involved in the game.
1---------------2---------------3---------------4---------------5---------------6---------------7

I was really drawn into the game.
1---------------2---------------3---------------4---------------5---------------6---------------7

I continued to play the game out of curiosity.
1---------------2---------------3---------------4---------------5---------------6---------------7