Effects of Action Video Game on Attention Distribution: A Cognitive Study*

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Abstract. Based on the previous researches, Flanker compatibility effect paradigm was applied to explore the degree where people process the visual information presented on to-be-ignored locations. In present study, this paradigm was used to investigate attention distribution of Video Game Players (VGPs) and Non Video Game Players (NVGPs). The results suggested, under low perceptual load, VGPs tried to focus their attention on the task at-hand whereas the NVGPs tried to explore the adjacent locations with the left-over resources from the research task; however, under high perceptual load, the players would process the visual information at the adjacent locations of the target with the left-over resources, because they had comparatively greater attention capability, whereas the non-players focused their attention on the target locations to finish the search task. To conclude, the present study suggested that action video game play could not only enhance the attention capacity but also cause a different way of attention distribution in different perceptual load situations.

Keywords: Action Video Game; Focused Attention; Perceptual Load; Attention Distribution.

1 Introduction

Traditional attention theory suggested a limited capacity of attention resource, meaning that, at a given time unit, people were just able to pay attention to a limited subset rather than all information in the visual field. Therefore, one of the most important functions of our visual system was to search for and select the relevant information for the task at hand and at the same time to ignore the interference from the irrelevant stimuli (e.g., Castel, Pratt & Drummond, 2005; Lavie, 2005). For example, when driving on the road, drivers must focus on the road ahead instead of being attracted by the kite in the sky. However, a boy at the roadside that should be considered as "irrelevant" information will turn into relevant information by running across the road to chase a ball. Therefore, how do people allocate their attention to help them to effectively select useful information from the visual field which contains a huge amount of distracting stimuli?

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1.1 Effect of Video Games on Attention Processing

In the experiments conducted by Eriksen and Hoffman (1973, 1974), some letters were randomly presented around the fixation point one by one, and participants were required to discriminate the target letter from the others. They found that the participants could react 30-40 ms faster when the target letter was presented at the cued location. This result was also proved by Hoffman (1975) in his study. However, some researchers thought that this progress was not concerned with visual search and selection because the letters were presented one by one. Some other studies (e.g. Eriksen & Collins, 1969; Jonides, 1980; Posner, Snyder, & Davidson, 1980; Yantis & Johnston, 1990; Johnson & Yantis, 1995) required participants to search for and select targets from some other to-be-ignored stimuli, and the results indicated that people could also perform better when targets presented at the cued locations. Jonides (1980, 1983) explained this with attention resource theory. He thought that participants, when searching for targets, allocated their attention resource to different locations in the visual field. To promote their searching efficiency, they allocated a greater proportion of their attention resource on the cued location whereas a smaller part at the uncued locations. Therefore, they could process the information presented at the cued locations faster than that at the uncued locations. Some other researchers (e.g. Johnson & Yantis, 1995; Muller, 2003) found similar results and pointed out that cues could influence attention's allocation; that is, more attention resource would be distributed at the cued locations where the visual information could be processed faster, whereas less resource at other locations.

Researchers (e.g., Eriksen & Yeh, 1985; Yantis & Johnston, 1990) also found that participants performed better at cued locations (the cue was 100% valid) in a visual search task, and that at the uncued locations which were also called the to-be-ignored locations, the interference from the distracting stimuli decreased significantly. Therefore, they thought that under conditions where the cue was 100% valid, most attention resource of the participants would distribute at the cued locations and little (or even none) at the to-be-ignored locations, which was also the reason why there was no distractor interference.

Many researchers had noted the effects of video-game playing on various aspects of cognition including visual attention (e.g. Castel, Pratt, & Drummond, 2005; Dorval & Pepin, 1986; Gopher, Weil, & Bareket, 1994; Green & Bavelier, 2003; Green & Bavelier, 2006a; Green & Bavelier, 2006b; Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994; Li & Atkins, 2004; McClurg & Chaille, 1987; Yuji, 1996). In 2003, Green and Bavelier, using the Flanker compatibility effect which was a standard experimental paradigm in attention studies, measured the attention resource of both action video-game (we would explain action video game in the following part) players (VGPs) and non-video-game players (NVGPs) (Green & Bavelier, 2003). In their experiment, subjects were required to finish a target task (searching through the display to determine whether a square or diamond was presented) while ignoring the to-be-ignored distractors (other shapes such as triangle). When the target task was made very difficult by increasing the number of to-be-ignored distractors, NVGPs had to devote all their available attention resource to the target task and had no left-over resource to deal with the distractors. However, at the same difficulty level, VGPs, successfully finished the target task, and still had left-over resource to process the distractors. The results indicated that VGPs rather than NVGPs had an enhanced attention capacity and were able to process more visual information at a given time period.

In addition to possessing greater attention capacity, VGPs could allocate or distribute their attention more efficiently. Research by Greenfield and colleagues (1994) measured experts and novice VGPs' capacity of distributing attention and the results indicated that experts could allocate their attention more efficiently than novices (experts could detect the presentation of the target at locations where targets were presented at a very low probability with no increment of reaction time compared with at locations where targets were presented at 50% probability; while novices showed reaction time increment). Furthermore, studies by Green and Bavelier (2006b) and Castel and Pratt and Drummond (2005) suggested that, with greater attention capacity, action-video-game players, were able to distribute their attention more efficiently, search and select targets from distracting stimuli more efficiently.

1.2 Hypothesis of Present Study

Therefore, based on these experiments discussed above, it could be suggested that video game playing could play an important role in enhancing attention resource and its allocation efficiency or visual search efficiency. Besides that, spatial cue, spatial position and perceptual load could affect attention distribution, and training could influence attention capacity, which improves searching efficiency. Moreover, action video game would affect spatial attention processing, perceptual processing and attention allocation.

In some video games (e.g., Counter-Strike, CS), the targets appear at fixed locations (for example, the bomb or the hostage) and the players are required to finish their task at these fixed locations. However, in most such games, “enemies” may pop up anywhere at any time and the penalty for failing to detect their appearance is great (death, for example). As discussed above, people always allocate most of their attention resource at the cued locations and little at the to-be-ignored locations; and therefore we propose a hypothesis that video game experience may influence the spatial distribution of players’ attention resource. We will explore different methods of allocating attention between VGPs and NVGPs under different perceptual load, and how the players allocate their left-over attention resource under different perceptual load.

2 Method

2.1 Participants

18 participants with normal or corrected vision, aged between 19 and 25, were placed into one of two groups, VGPs or NVGPs. All 9 VGPs were Counter-Strike (CS) players with a minimum of 2 hours of CS play per day and 6 days a week at least in the past 6 months. None of the 9 NVGPs had little action video-game experience in the past.

2.2 Apparatus

All the tasks were completed on 19 inch CRT computers with resolution of 600X800 and refreshing rate of 85Hz.

2.3 Design and Procedures

Studies by Lavie and his colleagues (Lavie et al., 2004; Lavie, 2005) indicated that the left-over attention resource of the participants from the task was not simply turned off. Instead it was distributed at the adjacent locations. In present experiment, we used a cue with validity of 70% and therefore the participants, with their attention resource directed to the pre-cued locations, had to search for the target shape from four possible locations in each trial. The Flanker compatibility effect was also used in this experiment.

All stimuli were identical to those used in Green & Bavelier (2006b). There were three categories including targets, fillers and distractors (see Figure 1). The target set consisted of a square and a diamond. The filler set included a house-like pentagon, an upside-down pentagon, a sideways trapezoid, a triangle pointing up and one pointing down. Both the target and filler stimuli subtended an average of 0.6° vertically and 0.4° horizontally. The distractor set consisted of a square, a diamond and an ellipse which were presented peripherally (4.2°to the right or left of fixation). According to cortical magnification factor (Rovamo & Virsu, 1979; Green & Bavelier, 2006a), the distractors subtended 0.9°vertically and 0.5°horizontally.

In the experiment, eight circular frames were presented around the fixation point at a distance of 2.1°. The center of each circular frame was 2.1°away from that of adjacent one. Both the target and filler shapes were presented inside these circular frames, whereas the distractors were presented outside of the circular frames. In each trial, one member of the target set always appeared in one of the four circular frames up, down, to the right or to the left of the fixation point; and also one member of the distractor set always appeared outside the ring of the circular frames, either near the target or to the opposite side of the target. No filler was presented when perceptual load was low and seven fillers were presented inside the other seven circular frames when perceptual load was high.

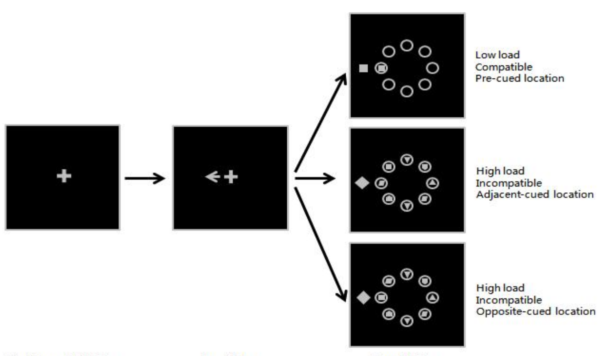

Fig. 1. Sample stimuli and trial experiment procedure

The participants were first given a block of practice of 48 trials and then would start the test until they finished the practice with an accuracy of at least 85%. The test was divided into six blocks, and following each block of 240 trials, participants were given a resting screen telling them to have a rest for at least one minute. Participants were paid for the participation of the experiment which was about 50 minutes.

3 Results

3.1 Analysis of Accuracy

We put the accurate data into a 2x2x2x3 repeated measure analysis of variance with VGP (VGPs vs. NVGPs), perceptual load (low vs. high), distractor compatibility (compatible vs. incompatible) and target location (pre-cued location, adjacent-cued location, and opposite-cued location) as factors. Main effects of distractor compatibility (compatible: 88.7%±0.7; incompatible: 81.7%±1.5), $F(1,16)=40.62$, $p<0.001$, demonstrating the influence of the distractors on the performance of the participants, and target location (pre-cued location : 89.3%±1.3; adjacent-cued location : 80.0%±1.4; opposite-cued location: 86.3%±0.7), $F(2,32)=47.08$, $p<0.001$, suggesting a better performance at the pre-cued locations, were found. Also, the lack of interaction between VGP and any other factors suggested that different level of factors caused the same task difficulty change for the VGPs and NVGPs.

3.2 Analysis of Reaction Time

For the RT analysis, the incorrect trials and the trials with RT longer than 1800 ms or shorter than 200ms were excluded (VGPs: 14.3%±0.06; NVGPs: 15.1%±0.07). Then the filtered data were analyzed in a 2 x 2 x 2 x 3 analysis of variance (ANOVA) with video-game experience (VGP vs. NVGP), perceptual load (low vs. high), distractor compatibility (compatible vs. incompatible) and target location (pre-cued location, adjacent-cued location, and opposite-cued location) as factors. See the results in table 1.

Table 1. Mean Reaction Time in All Levels of 2 x 2 x 2 x 3 Design

	Pre-cued Location				Adjacent-cued Location				Opposite-cued Location			
	Low Load		High Load		Low Load		High Load		Low Load		High Load	
	Com.	Incom.	Com.	Incom.	Com.	Incom	Com.	Incom	Com.	Incom	Com.	Incom
VGPs	545	550	610	618	614	621	938	953	592	604	842	843
NVGPs	517	527	593	583	591	607	851	850	566	586	742	738

Notes: Com. = compatible; Incom. = incompatible.

The analysis revealed main effects of perceptual load (low load: 554ms±56; high load: 661ms±76), $F(1, 16)=114.62$, $p<0.001$, with a shorter RT under low perceptual load than under high perceptual load, indicating that the task difficulty increased with perceptual load increasing, distractor compatibility (compatible: 602ms±63; incompatible: 607ms±63), $F(1,16)=6.41$, $p=0.02$, demonstrating the effect of distractor compatibility on RT, and target location (pre-cued location: 568ms±60; adjacent-cued location: 723ms±90; opposite-cued location: 678ms±69), F(2,32)=83.27, p<0.001. Further analysis revealed that participants responded faster at pre-cued locations than at adjacent-cued or opposite-cued locations, and faster at opposite-cued locations than at adjacent-cued locations. The interaction between perceptual load and target location, F(2,32)=36.73, p<0.001, was found, suggesting a biggest decrement of RT at adjacent-cued locations and a smallest decrement at pre-cued locations with the increment of perceptual load. The interaction between VGP, perceptual load and distractor compatibility reached significant level, F(1,16)=6.65, p=0.02, indicating the VGPs were still processing the distractor under high load, whereas the NVGPs were not.

The main effect of VGP/NVGP group was not significant (VGPs: 622±76; NVGPs: 588±44), F(2,32)=2.1, p=0.17, suggesting that the difference on the compatibility effect between VGPs and NVGPs was not caused by their reaction time.

3.3 Distractor Compatibility Effect under High and Low Perceptual Load

The results suggested that the cue with a validity of 70% could effectively help the participants focus their attention at the pre-cued locations. Therefore, to better explore the spatial distribution of attention resource, we analyzed the Mean difference RT compatible and incompatible conditions and a 2x2 repeated analysis of variance was done to study the size of the distractor compatibility effect with VGP (VGPs vs. NVGPs) and perceptual load (low vs. high) as factors.

Main effect of perceptual load (low load: 5.31ms±1.95; high load: -1.65ms±1.44), F(1,16)=10.39, p=0.005, was found, with a bigger size of compatibility effect under low percptual load than under high load, indicating that more attention resource was left over under low load than under high load. The main effect of VGP was not significant (VGPs: 3.69ms±1.90; NVGPs: -0.02±1.89), F(1,16)=0.91, p=0.19, but VGP interacted significantly with perceptual load, F(1,16)=33.46, p<0.001, demonstrating a larger decrement on the size of the distractor compatibility effect for NVGPs than VGPs with the perceptual load increasing. We further noted that VGPs showed a

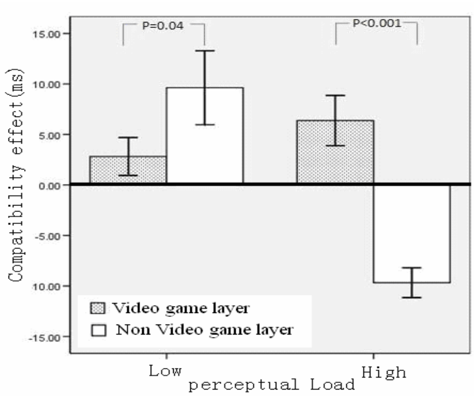

Fig. 2. Compatibility effect under high and low perceptual load

bigger size of distractor compatibility effect under high perceptual load, $F(1,16)=31.01$, $p<0.001$, whereas a smaller one under low load, $F(1,16)=4.74$, $p=0.045$, than NVGPs. See the results in figure 2.

4 Discussion

In present experiment, we used the cue with a validity of 70% which could also effectively help the participants to focus their attention on the pre-cued locations, and therefore one of the two target shapes was presented at three kinds of possible locations – pre-cued locations, adjacent-cued locations and opposite-cued locations. It was noted that participants performed best when targets were presented at pre-cued locations with the shortest RT. However, we also found that they performed better at opposite-cued locations than at adjacent-cued locations with higher accuracy and shorter RT. Eriksen and his colleague(Eriksen & Yeh, 1985) found the same phenomenon and they called it second-cue-location effect; that is, participants performed better at second-cue-locations (the location exactly to the opposite side of the pre-cued location) than at other locations with pre-cued location excluded. Furthermore, the interaction between perceptual load and target location also supported the second-cue-location effect that the participants showed the biggest increment on RT at adjacent-cued locations and the smallest one at pre-cued locations with the perceptual load increasing.

The present study found a trend that VGPs than NVGPs showed a smaller size of distractor compatibility effect when the task difficulty level was low and a bigger one when the task difficulty level was high. When the perceptual load was high, the VGPs showed a bigger size of distractor compatibility effect than the NVGPs, indicating that VGPs not only possessed greater attention resource capability but that they were still processing the distracted stimuli with no decrement of the target search performance. However, when the perceptual load was low, the NVGPs showed a larger size of distractor compatibility effect than the VGPs, indicating that the VGPs were trying to focus their attention on the pre-cued locations whereas the NVGPs would rather like to distribute the left-over attention resource at the adjacent locations.

The author had an interview with some of the participants on the internet and proposed a suggestion as follows. The participants of the VGP group were all CS (Counter-Strike) players with a minimum of 2 hours per day and 5 days a week at least in the past six months and the low and high perceptual load conditions in the experiment probably corresponded to the "low threat" (no enemy would pop up) and "high threat" (more than one enemies were usually expected to pop up) situations respectively. Therefore, under low perceptual load ("low threat" situation), VGPs did not need to pay attention to other locations and would prefer to focus their attention on the task at-hand with a smaller size of distractor compatibility; however, under high perceptual load ("high threat" situation), VGPs would try to focus their attention on the pre-cued locations and paid enough awareness to the adjacent locations where enemies would probably pop up, thus they showed a bigger size of distractor compatibility.

Therefore, we thought that there were some differences on the spatial distribution of attention resource between the VGPs and NVGPs. Both VGPs and NVGPs would try to focus their attention on the task at-hand. However, NVGPs would also allocate some attention to adjacent position of pre-cued position while VGPs would allocate less attention to these positions under low perceptual load. The condition was opposite when the load was high, for limited attention resource cause NVGPs to focus on target, but to VGPs, high load meant high threat, so they would pay more attention to adjacent areas to avoid enemies popping up, keeping the search task results not being affected. Compared with the pre-cued locations, the adjacent-cued locations should also be considered adjacent locations and therefore the VGPs and NVGPs should show some differences on their performance at the adjacent-cued locations. However, we did not find such difference in the analysis. For example, VGPs were expected to focus their attention on the pre-cued locations under low perceptual load and perform not so well as NVGPs at the adjacent-cued locations, but they did not show such difference. Therefore, we suggested that the adjacent-cued locations corresponding to low threatening position of the game be considered to be different from the adjacent locations corresponding to the safe position of the game by the VGPs and they still distributed some, although maybe a very small portion of attention at the adjacent-cued location under low perceptual load. And that was why they did not show any differences from the NVGPs.

In conclusion, the present study found that action video-game-play could not only enhance the attention capacity but also cause a different way of attention distribution under different perceptual load situations. Under low perceptual load, VGPs tried to focus their attention on the task at-hand whereas NVGPs tried to explore the adjacent locations with the left-over resource from the research task; however, under high perceptual load, the players would process the visual information at the adjacent locations of the target with the left-over resource, because they had a comparatively greater attention capability, whereas the non-players focused their attention on the target locations to finish the search task.

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