Effects of Action Video Game on Spatial Attention Distribution in Low and High Perceptual Load Task*

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***Abstract* - As video game playing is gaining great popularity in today's society, some researchers have done great researches about its cognitive effects. They found that the experience of video game playing could enhance a number of cognitive abilities of people such as reaction speed, attentional capability and the efficiency of the spatial attention distribution, which made the target search from distractors faster with better accuracy. Based on the previous researches, the present study explored the attention distribution of action video game players and non-players at different perceptual loads under focused attention condition. The results showed that, at low perceptual load, action video game players tried to focus their attention on the task at-hand whereas the non-players tried to explore the adjacent locations with the left-over resources from the research task; however, at high perceptual load, the players would process the visual information at the adjacent locations of the target with the left-over resources, whereas the non-players focused their attention on the target locations to finish the search task. Furthermore, the training study indicated that the two video games applied could enhance the reaction speed of the participants and that limited training could not alter the way of the spatial attention distribution.**

***Index Terms* - Action video game, Distractor compatibility, Game training, Perceptual load, Attention distribution**

I. Introduction

Traditional attention theory suggested capacity of attentional resource was limited. The most important functions of our visual system was to search for and select the relevant information to present task, and ignore the interference from the irrelevant stimuli at the same time (e.g., Castel, Pratt & Drummond, 2005; Lavie, 2005). Researches (Eriksen & Hoffman, 1974; Hoffman, 1975; Jonides, 1980; Lavie, 1995; Finch & Lavie, 2007) found that attention distribution would be affected by factors like spatial cue, visual information distribution, task difficulty and perceptual load. Furthermore, recent studies have found the effects of video-game play on visual attention and visual search.

Many researches found that video games have series of requirements on the players' cognitive abilities (e.g., response speed, hand-eye coordination, attentional capacity, attention distribution, and visual tracking, etc). Video game played an important role on players' cognitive processing (Achtman, Green & Bavelier, 2008; Dye, Green, & Bavelier, 2009). Dorval and Pepin (1986) trained 70 undergraduates without video playing experience, and the results showed that video game training could improve participants' visual searching ability. Some related studies found that game training could improve players' hand-eye coordination and response speed (Gopher & Bareket, 1994; Griffith，Voloschin, Gibb & Bailey, 1983；Orosy-Fildes & Allan，1989). Li and his colleague (2004) found that the cognitive ability of the preschoolers with video game experience was better than those without such experience. McClurg and Chaille (1987) found video game had positive effect on visual spatial cognition. Yuji's (1996) study indicated that video game experience help people improving their cognitive strategies on problem-solving. In recent 10 years, video game has been developed rapidly with more virtual reality and human-computer interaction. The more recent studies indicated that video game play could improve players' efficiency of spatial attention distribution in time progress (Green & Bavelier，2003). VGPs (video-game players) also performed better on multiple-object tracking task (Green & Bavelier, 2006b; Boot, Kramer, Simons, Fabiani & Gratton, 2008)

Lavie (1995) suggested perceptual load as an important factor affecting people's attention distribution. Greenfield and colleagues (1994) investigated divided attention of expert and novice VGPs. The results indicated that the experts could divide and allocate their attention more efficiently than novices. Green & Bavelier (2003，2006a) did further studies on how video game experience affected palyers' attention capacity. They used the flanker compatibility effect paradigm and found VGPs had a bigger attention capacity than NVGPs (non-video-game players). Even in high perceptual load task, VGPs had extra attention resources to process peripheral stimuli. In general, in random visual search task (target presented randomly in spatial locations), VGPs had high efficiency to allocate their attention

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resources in different spatial locations, and their searching performance was better than NVGPs. Based on these studies, video game have a significant effect on players' different cognitive ability. And the feature of video game also reflected the basic cognitive ability is necessary during game play. Furthermore, as discussed above, a hypothesis was proposed that action video game experience may influence the spatial attention distribution of the players' attention resource in different levels difficulty perceptual load tasks. Therefore, the present study would explore the effects of action video game training on players' attention distribution in focused attention condition.

To explore the difference of the spatial distribution of attentional resources between VGPs and NVGPs, we applied the flanker compatibility effect used by Green & Bavelier (2003) in their study. That is, if the distractor leads to the same response as the target (compatible), the participants will react faster than when the distractor leads to different response from the target (Eriksen, 1974). We also used the perceptual load paradigm to study the distribution of the attentional resources of the VGPs and NVGPs under conditions of high perceptual load and low perceptual load.

In present study, we designed three experiments to investigate the effect of video game on attention distribution. The first and second experiments were contrast study with VGPs and NVGPs. Finally, we used the experiment and control group (received action video game training and non action video game training, e.g. Counter-Strike and Tetris) to attest training effect on different perceptual load (low and high) task.

In the training experiment, we also used the flanker compatibility effect (Green & Bavelier, 2003), and measured the training effect of attention distribution. Flanker compatibility effect means that distracters leading to same response as targets promote participants' reaction speed and, on the contrast, those leading to opposite response impede reaction speed. According to prior studies, we expect when the task is easy one (low perceptual load), the flanker compatibility effect (represented attentional resource distribution) will be larger than difficult task (high perceptual load). The training effect of attention distribution will be different for action video game training group (AVGT) and control group.

II. Experiment 1

Posner, Snyder, and Davidson (1980) suggested that active reallocation of attention is very important to keep it well focused, because habituation of attention to any particular position might result in the exploration of the environment. Therefore, we used a cue with a 100% validity to indicate the position where the target would be presented to make sure that the attention was redirected to a new locus on each trial. Furthermore, many researches (e.g. Jonides, 1980; Posner, 1980; Remington & Pierce, 1984; Eriksen & St. James, 1986) provided evidence that 200ms cue duration was the best for the attentional readiness at the onset of the display and therefore we applied 200ms cue duration in experiment 1.

To explore the difference of the spatial distribution of attentional resources between VGPs and NVGPs, we applied the flanker compatibility effect used by Green & Bavelier (2003) in their study. That is, if the distractor leads to the same response as the target (compatible), the participants will react faster than when the distractor leads to different response from the target (Eriksen & Eriksen, 1974). We also used the perceptual load paradigm to study the distribution of the attentional resources of the VGPs and NVGPs under conditions of high perceptual load and low perceptual load.

A. Method

Participants: Sixteen men with normal or corrected vision, aged between 19 and 26, fell divided into one of two groups, VGP or NVGP. Because it was very difficult to find women who often play action video games, only men participated in this experiment.

Only action video game players participated in this and all subsequent experiments. According to Green & Bavelier (2006b), "action video game are those that have fast motion, require vigilant monitoring of the visual periphery, and often require the simultaneous tracking of multiple targets", with examples as Counter-Strike, Rogue Spear, Medal of Honor, Max Payne and Unreal Tournament. VGPs were those who played action video games at least four days a week for a minimum of one hour per day at least for the previous six months. All eight men fell into the VGP group reported a video game play, at least for the previous six months, of at least five days a week for a minimum of two hours per day. NVGPs were those who played little or none action video games for at least the previous six months. Eight men fell into this category and they reported that they had never played action video games before.

All participants were students from Beijing Normal University and were paid for their participation.

Stimuli and Materials: All stimuli were identical to those used in Green & Bavelier (2006b). They fell into three categories which were target, filler and distractor (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 and were presented peripherally (4.2°to the right or left of fixation). According to cortical magnification factor (Rovamo & Virsu, 1979), the distractors subtended 0.9°vertically and 0.5°horizontally.

Throughout 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 the ring 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 was low and seven fillers were presented inside the other seven circular frames when perceptual load was high.

The design was completely intermixed with all combinations of perceptual load (high or low), target (square or diamond), distractor-shape compatibility (compatible, incompatible or neutral) and distractor-location compatibility (same or opposite).

Procedure: For each trial, a 1-s fixation point was first presented followed by a 200-ms cue. Then the trial shapes were presented for 100 ms followed by a 2-s blank screen for participants to react. The participants were required to identify which of the two target shapes (square of diamond) appeared in one of four circular frames. They were told to respond as quickly and accurately as possible and to ignore any other stimulus outside the ring of the circular frames (the distractors).

The participants were given a block of practice of 64 trials first and then would start the test if they could finish the practice with an accuracy of at least 85%, or they had to do the practice again until they achieved 85% correct. The test was divided into four blocks, and following each block of 288 trials, participants were given a resting screen that told them to have a rest for at least one minute. The entire experiment lasted about 40 minutes.

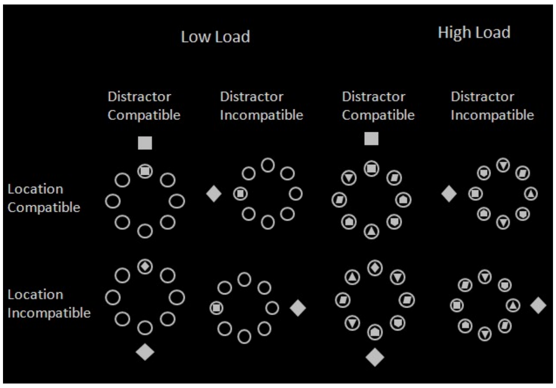

Figure 1. Procedure of Experiment 1

B. Results

In this part, all analysis focused on trials with compatible or incompatible distractors (Proksch & Bavelier, 2002; Green & Bavelier, 2003; Green & Bavelier, 2006b).

The accuracy data were analyzed in a 2x2x2x2 analysis of variance (ANOVA) with VGP (VGPs vs. NVGPs), perceptual load (low vs. high), distractor-location compatibility (same vs. opposite) and distractor compatibility (compatible vs. incompatible) as factors. Only the main effect of distractor compatibility was found (compatible: 95.44%±2.12; incompatible: 94.48±1.98), $F(1,14)=5.49$, $p=0.03$. The lack of interaction between VGP and any other factor suggested that the different level of factors caused the same task difficulty change for the VGPs and NVGPs.

For the RT analysis, the incorrect trials and the trials with RTs greater than 1800 ms or less than 200ms were excluded (VGPs: 5.4%±1.12; NVGPs: 4.7%±0.93). Then the filtered data were analyzed in a 2 x 2 x 2 x 2 analysis of variance (ANOVA) with video-game experience (VGP vs. NVGP), perceptual load (low vs. high), distractor compatibility (compatible vs. incompatible) and distractor-location compatibility (same vs. opposite) as factors.

The analysis revealed main effects of perceptual load (low load: 533ms±85; high load: 544ms±83), $F(1, 14)=27.93$, $p<0.001$, indicating that the task difficulty increased with perceptual load increasing, and distractor compatibility (compatible: 536ms±84; incompatible: 541ms±85), $F(1,14)=8.93$, $p<0.01$, reflecting that the compatible distractor facilitated the participants' responses and the incompatible distractor interfered with their response. An interaction between distractor compatibility and distractor-location compatibility was observed, $F(1,14)=13.90$, $p=0.002$, with a large distractor compatibility effect when the distractor appeared on the same side as the target and a minimum distractor compatibility effect when the two were presented on different sides.

Some studies (Lavie et al., 2004; Lavie, 2005) suggested that the left-over attentional resources of the participants, if the task was not very difficult and did not occupy all resources, were distributed at the adjacent locations. Therefore, to better assess the distribution of the attentional resources of the VGPs and NVGPs in the experiment, the data in distractor-location-same and opposite were separated and analyzed in a 2 x 2 analysis of variance (ANOVA) with VGP (VGPs vs. NVGPs) and perceptual load (low vs. high) as factors. When the distractor was presented at the same location with that of the target, no main effect or interaction was found. However, no main effect was found when the distractor was presented on the opposite side with the target, but the interaction between VGP and perceptual load revealed that the compatibility effect of the NVGPs decreased more quickly than the VGPs with the increasing of perceptual load, $F(1,14)=5.42$, $p=0.04$ (Figure 2).

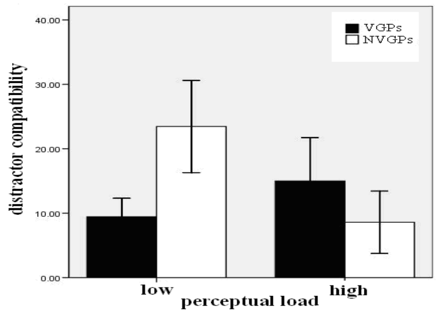

Figure 2. Compatibility Effect of VGPs and NVGPs

Furthermore, the main effect of VGP on the RTs was not significant (VGPs: 510±99; NVGPs: 567±59), $F(1,14)=2.02$, $p=0.18$. It suggested that the difference of the compatibility effect between VGPs and NVGPs was not caused by the response speed of the two groups.

C. Discussion

The main effect of perceptual load indicated that participants performed better when the perceptual load was low, which suggested that perceptual load could also influence the performance of the participants even when their attention was directed to a fixed location.

Moreover, Green and Bavelier (2003, 2006a, 2006b) found that VGPs held a larger attentional resource capability and therefore they could still have attentional resources left over even when the perceptual load was very high. Therefore, we proposed a hypothesis that the left-over attentional resources of the VGPs would split to the adjacent locations to the pre-cued ones where the targets were presented, causing the compatibility effect. And the results of experiment 1 provided evidence for this hypothesis.

That the main effect of the distractor-location compatibility did not approach significance whereas the interaction with the distractor compatibility was significant indicated that the distractors could interfere with the performance of the participants when presented on the same side with the targets but not at the opposite side. The results proved the studies by Lavie and colleagues (Lavie et al., 2004; Lavie, 2005) that the left-over attentional resources from the task were not simply turned off but were instead distributed at the adjacent locations (such as the locations on the same side with the targets in this experiment). From Figure 2, it could be found that, with the increasing of the perceptual load (the fillers increased from 1 to 7), the NVGPs showed a larger decrement in the size of compatibility effect than VGPs, suggesting that the VGPs still had resources left over even when the task was very difficult and that the left-over resources was still directed to explore the adjacent locations even though the targets were presented at pre-cued locations.

One more thing we would like to discuss was that the VGPs showed a smaller size of compatibility effect than the NVGPs at low perceptual load (not significant, but $p<0.1$) whereas a larger one at high perceptual load ($p<0.1$). Green and Bavelier (2006b) found the same phenomenon ($p=0.1$) where the VGPs showed a smaller size of compatibility effect than the NVGPs when perceptual load was very low (one filler). We know that the VGPs, with a larger attentional resource capability, should have more resources left at low perceptual load and therefore should show a bigger size of compatibility effect. However, the results were not in the accordance with the inference, and therefore we proposed a new hypothesis that, on low perceptual load condition, VGPs, with more attentional resources left over although, tried to focus their attention on the pre-cued locations whereas the NVGPs would like to explore the adjacent locations with their attentional resources left over; however, on high perceptual load condition, VGPs, with a bigger attentional resource capability, still processed the distractors with their attentional resources left over, whereas the NVGPs had to focus their attention on the task at-hand to finish the task successfully because of their comparatively smaller attentional resource capability. And we would explore this phenomenon in the following experiments.

In experiment 1, we noted that, although the targets were presented randomly at one of the four locations (up, down, to the left or to the right of the fixation), the 100% valid cue made it more likely a discrimination task instead of a search task. Moreover, since the targets were presented at the pre-cued locations, the task difficulty was not very high even when seven fillers were presented. Therefore, to better explore the attention distribution of the VGPs and NVGPs, we made improvements in following experiments.

To make the experiment more likely a search instead of a discrimination task, we used exactly the same stimuli as experiment 1 with exceptions as follows: 1).In the baseline study, no distractor was presented; but in experiment 3, distractors were presented just at the adjacent locations with the target but not at the opposite ones; 2).The targets were presented just to the left or to the right of the fixation; 3). The validity of the cue was modified to 70%.

However, to examine whether there was difference for participants' attention distribution between cues of 70% validity and 100% validity, we did a baseline study in experiment 2.

III. EXPERIMENT 2

A. Method

Participants: Participants were 18 students from Beijing Normal University, aged between 18 and 23, with normal or corrected-normal visual acuity, and were paid for their participation.

Stimuli and Materials: The stimuli were identical to those used in experiment 1 except that a) no distractor was presented; b) The targets were presented just to the left or to the right of the fixation; c) The validity of the cue was modified to 70%. That is, the targets were presented at the pre-cued locations in 70% of all the trials and such locations were called the "cued-locations"; the targets were presented at one of the two most adjacent locations to the cued-location respectively in 10% of all the trials and such locations were called the "adjacent-cued locations" (it was clearly that the targets were presented in adjacent-cued locations in 20% of the trials in total); the targets were presented at the locations which were exactly on the opposite side from the cued-location in 10% of all the trials and such locations were called the "opposite-locations" (Figure 3).

Procedure: The procedure was also identical to that in experiment 1. For each trial, a 1000ms fixation point was first presented followed by a 200ms cue. Then the trial shapes were presented for 100 ms followed by a 2000ms blank screen for participants to react. The participants were required to identify which of the two target shapes (square of diamond) appeared in one of the circular frames. They were told to respond as quickly and accurately as possible.

The participants were given a block of practice of 64 trials first and then would start the test if they could finish the practice with an accuracy of at least 85%, or they had to do the practice again until they achieved 85% correct. The test was divided into four blocks, and following each block of 160 trials, participants were given a resting screen that told them to have a rest for at least one minute. The entire experiment lasted about 30 minutes.

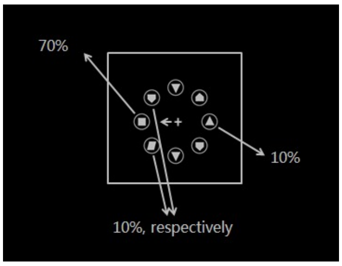

Figure 3. Procedure of Experiment 2

B. Results

The accuracy data were analyzed in a 2x2 analysis of variance (ANOVA) with cue validity (70% vs. 100%) and perceptual load (low vs. high) as factors. The main effect of perceptual load (low load: 95.40%±4.10; high load: 93.60±5.02), F(1,16)=35.62, p<0.001, was found, with a better performance for the participants at low load than at high load. The main effect of cue validity and the interaction between the two factors did not approach significance.

The incorrect trials and the trials with RTs greater than 1800 ms or less than 200ms were removed first (100% validity group: 4.5%±0.03; 70% validity group: 6.3%±0.06). Then the filtered data were analyzed in a 2 x 2 analysis of variance (ANOVA) with cue validity (100% vs. 70%) and perceptual load (low vs. high) as factors.

Results revealed a main effect of perceptual load (low load: 489ms±42; high load: 528ms±56), F(1,16)=77.09, p<0.001, indicating that it was effective to increase the task difficulty by adding fillers and that the participants responded faster at low load than at high load. The main effect of the cue validity did not reach significance (100% group: 501ms±35; 70% group: 516ms±59), F(1,16)=0.40, p=0.54.

We put the data of the 70% validity group into a 2x3 analysis of variance (ANOVA) with perceptual load (low vs. high) and target location (pre-cued location, adjacent-location and opposite-location) as factors. Main effects of perceptual load (low load: 523ms±54; high load: 675ms±84), F(1,48)=32.01, p<0.001, indicating participants' faster response at low load than at high load, and target location (pre-cued location: 516ms±58; adjacent-location: 633ms±99; opposite-location: 648ms±79), F(2,48)=9.82, p<0.001. Further analysis revealed that participants responded faster when targets were presented at pre-cued locations than at adjacent-locations or opposite-locations (p<0.001) whereas there was no difference on the RTs between adjacent-locations or opposite-locations (p=1.000).

To study the effects of a cue with 70% validity on the distribution of attentional resources, we compared the RT data of the 100% validity group and those at pre-cued locations from the 70% validity group at low load and high load respectively. Results indicated that there was no difference for the RTs of the two groups either at low load or at high load (low load: t(16)=-0.36, p=0.72; high load: t(16)=-1.40， p=0.18).

C. Discussion

We noted that participants from the 70% validity group responded faster to targets presented at pre-cued locations than other locations. Therefore, it should be considered that the participants distributed a larger portion of their attentional resources at the pre-cued locations and little at other locations.

Furthermore, the comparison on the RTs at the pre-cued locations of the two groups revealed that there was no difference for the response of the participants either at low load or at high load. Therefore, it was reasonable to suggest that an arrow with 70% validity could well direct the attention of the participants to the pre-cued locations where they responded as fast as those from the 100% validity group, at least on conditions of our experiments. And the result was in the accordance with that of Eriksen (Eriksen & Yeh, 1985).

Therefore, with the results of experiment 2, we did experiment 3 with a 70% valid cue.

IV. EXPERIMENT 3

The present study was intended to investigate effect of video game training on participants' attention distribution. The flanker compatibility paradigm with 70% validity cue was used to indicate the position where the target presented. The design was an experiment and control group mixed factors design (with pre-test, training, mid-test, training, post-test), to explore the performance of training effect. Furthermore, the training effect on attention distribution was discussed.

A. Method

Participants: Eighteen university students without experience of action video game at least in the past two years were recruited in the experiment. Participants, aged between 19-25 years old, were divided into two groups. Nine, 5 females and 4 males, were placed into action video game training group (AVGT Group) and nine, 5 females and 4 males, were placed into control group. Participants got payment after completing the game training program.

Stimuli and Materials: The stimuli were identical to those used in Green & Bavelier (2006b). There were three categories including targets, fillers and distractors (see Figure 4).

Design and Procedure: The design was completely intermixed with all combinations of perceptual load (high or low), target shape (square or diamond), distractor compatibility (compatible, incompatible or neutral) and target location ("pre-cued location", meaning the location pointed by the cue in 70% of the trials; "adjacent-cued locations", the two most adjacent locations to the cued-location in 20% of the trials; "opposite-cued location", the location exactly on the opposite side from the cued-location in 10% of all the trials). The neutral distractor was only used to control the participants' response bias, not included in the final data analysis.

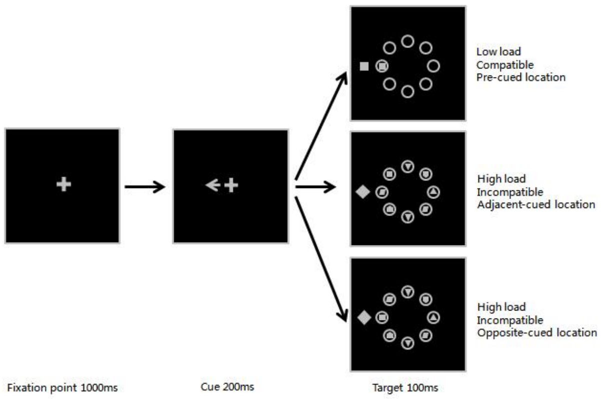

Figure 4. Sample stimuli and trial presentation procedure

Pre-test: For each trial, a 1000ms fixation point was first presented followed by a 200ms cue. Then the trial shapes were presented for 100ms followed by a 2000ms blank screen. The participants were required to press "F" or "J" to identify which of the two target shapes (square of diamond) appeared in one of the circular frames. They were told to respond as quickly and accurately as possible. The participants were first given a block of practice of 48 trials and 720 formal trials in three within factors, which lasted about 50 minutes.

The training game for AVGT group was Counter-Terrorist and control group were trained in the game Tetris which had great requirements for the reaction speed and hand-eye coordination rather than visual attention resources and its distribution. See table 1.

Table 1 Train procedure and perceptual-attention task

Group	Pre-test	Training 1	Mid-test	Training 2	Post-test
AVGs	Y_{11}	10 h	Y_{12}	10 h	Y_{13}
NAVGs	Y_{21}	10 h	Y_{22}	10 h	Y_{23}

Participants were trained for 10 hours at this stage, with at least five days and at most 8 hours a week with a minimum of 1 hour and a maximum of 2 hours per day.

Mid-test: After 10 hours' training, all participants were re-tested on the same experiment as the pre-test.

Training: 10 hours' training which was identical with that at the first stage.

Post-test: After 10 hours' training, all participants were tested for the third time on the same experiment as pre-test.

The totally time lasted 20 days.

B. Results

a). Game play performance

For the AVGT group, the mean score of kill-death ratio was used to assess game improvement. The kill-death ratio was improved by 290% in the training of the first 10 hours and 33% of the second 10 hours.For the control group, the highest score was used to assess the game improvement. The mean score was improved by 226% in the first 10 hours and 80% in the second 10 hours. These results demonstrated that the participants of both two groups showed great improvements on the training task.

b). Accuracy

Accuracy of experiment and control group pre-test and post-test was 95%. The experiment control was valid.

c). Search task performance

A 2x2x2x3 repeated measure analysis of variance (ANOVA) was conducted. The results showed that, main effects of perceptual load (high load: 597ms±65; low load: 540ms±51), $F_{(1,16)}=139.58$, $p<0.001$, with faster reaction speed at low than high perceptual load, distractor compatibility (compatible: 567ms±56; incompatible: 577ms±57), $F_{(1,16)}=11.68$, p=<0.01, demonstrating compatible distractors making the search task easier, and test (pre-test: 627ms±97; mid-test: 556ms±65; post-test: 525ms±52), $F_{(2,32)}=17.23$, $p<0.001$, showing both training games used in the experiment improved the reaction speed of the participants.

d). Distractor compatibility Effect

A 2x2x3 analysis of variance (ANOVA) of the compatibility data was conducted, the interaction between the three factors was found, $F_{(2,32)}=6.88$, $p<0.01$, demonstrating that, after game training, the two group showed difference on the attention distribution at different perceptual loads in focused attention condition. Further analysis revealed that the compatibility effect reached significance between pre- and post-tests, $F_{(1,16)}=10.88$, $p=0.005$, and mid- and post-tests, $F_{(1,16)}=7.87$, $p<0.05$, whereas did not reach significance between pre- and mid-test, $F_{(1,16)}=1.64$, $p>0.05$, meaning that 10 hours' game training was not enough to influence the way the participants distributed their attention in spatial locations.

Therefore, to better assess the effects of action video game experience, we did further analysis to the data of the pre- and post- tests. At high perceptual load, the interaction between training group and test was found, $F_{(1,16)}=8.74$, $p<0.01$, demonstrating a greater increment of the size of the compatibility effect for the AVGT group. The two groups did not show difference of compatibility effect on the pre-test, $F_{(1,16)}=0.28$, $p>0.05$, but the AVGT group than the control group showed a bigger size of compatibility effect on the post-test (AVGT group: 12.64ms±2.74; control group: -0.33ms±2.53), $F_{(1,16)}=11.23$, $p<0.01$; however, at low perceptual load, training group did not interact with test ($p>0.05$) and the two group did not show difference either on the pre-test ($p>0.05$) or on the post-test ($p>0.05$).

C. Discussion

The results suggested a different way of attention distribution in low and high perceptual loads between participants of AVGT group and control group. For participants of AVGT group, they would focus their attention on the target location even though they had more resources left-over at low perceptual load; whereas they tried to process the visual information presented at peripheral locations with the attention resources left-over at high perceptual load. However, for participants of control group, they would process the peripheral information as long as they got attention resources left at low load; at high load, they would focus attention on the target locations to finish the search task first because of their smaller attention capacity.

Moreover, we noted that both training games improved the reaction speed or the hand-eye coordination of the participants. However, the flanker compatibility effect showed by the two groups at post-test indicated that 20 hours' action video game training not only improved the reaction speed but also influenced their visual attention distribution at the spatial locations. That is, participants of the AVGT group would more like to explore the adjacent locations with the left-over resources at high perceptual load, whereas to focus their attention on the target location even though they had more resources left at low perceptual load.

V. General Discussion

The experiments in this study indicated that action video game play had great effects on players' visual attention from aspects as follows.

In the experiments, the Flanker Compatibility Effect Paradigm was applied to explore the players' visual attention capacity and spatial distribution. It was noted that participants showed decrement of the size of distractor compatibility effect as perceptual load increasing, demonstrating that more attention resource was required as the increment of task difficulty or perceptual load. However, NVGPs showed a bigger decrement of the size of distractor compatibility effect than VGPs as perceptual load increasing and VGPs other than NVGPs still showed great compatibility effect at high perceptual load (to search the target from other seven fillers). Therefore, we suggested that VGPs possessed a larger attention capacity than NVGPs and they were able to process the visual information presented at the adjacent spaces with their left-over resources from the search task.

Many studies discussed in the above suggested that VGPs could distribute their visual attention on the spatial locations more efficiently. Dye and colleagues (Dye, Green, & Bavelier, 2009) pointed out that spatial attention distribution could better explain the orientating effect and flanker compatibility effect showed by the VGPs. However, Dye and colleagues explored the whether the VGPs could better utilize a spatial cue to direct their attention, whereas the present study focused mainly on the different ways in which the VGPs and NVGPs distribute their visual attention on the spatial locations in the focused attention situation.

In focused attention situation, visual search task of low perceptual load required fewer attention resources and therefore the NVGPs had a comparatively bigger portion of attention left-over with which they would more like to explore the adjacent spaces from the pre-cued location and process the visual information on those spaces; when the perceptual load of the task was high, more attention was required for the target search and therefore the NVGPs were to focus their attention on the target location to finish the search task. However, for the VGPs, the situation was just different. They would more like to focus their attention on the target location when the perceptual load was low whereas explore the adjacent spaces with left-over resources when the perceptual load was high. With the action video game experience, the VGPs would consider the low perceptual load task as low-threat situation of the game and therefore they would focus their attention on the target location without worrying about threats (enemies of the game, for instance) from other spaces. However, the high perceptual load task would be considered as high-threat situation where enemies might pop up from unexpected place anytime and therefore the VGPs would try to pay attention to process the visual information on the other spaces with the left-over resources when focusing most of their attention on the target location.

In the training study, randomly selected NVGPs were trained on two games (Counter-Terrorist as action video game and Tetris as control game). After 20 hours' study, participants of the AVGT group showed a same trend of attention distribution as the expert VGPs whereas those of the control group did not, demonstrating the effects of action video game play on the VGPs' spatial attention distribution and that it took comparatively longer time (at least longer than 10 hours) to show the effects. Another question is how long these effects will last. Li and colleagues (LI, Polat, Makous & Bavelier, 2009) found that action video game play could improve people's visual contrast sensitivity and that the effects could last for a very long time (5 months or even a year), which might be of great meaning and more works should be done on such field.

VI. Conclusions

Based on the previous researches, the present study explored the attention distribution of action video game players and non-players at different perceptual loads under focused attention condition. we found that from the training experiment, at low perceptual load, action video game players tried to focus their attention on the task at-hand whereas the non-players tried to explore the adjacent locations with the left-over resources from the research task; however, at 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 a comparatively larger attentional capability, whereas the non-players focused their attention on the target locations to finish the search task. Furthermore, the training result also showed that 20 to 30 days training (at least one hour in one day) can cause the attentional distribution improvement. This result will be helpful for have important implications on human-computer or human-machine simulating training to improve special cognitive skill or professional expertise, such as driving and flight training, and other related cognitive plasticity training with computer-based training simulator.

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