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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 34(34)

ISSN

1069-7977

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Publication Date

2012

Peer reviewed

State effects of action video-game playing on visuospatial processing efficiency and attention among experienced action video-game players

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Abstract

Although researchers have speculated action video gaming might induce the state of “flow experience”, most previous experimental studies have focused primarily on the long-term (trait) effects of action video gaming, while overlooking possible short-term (state) effects characterizing the “flow” state. The goal of the current research was to investigate the state effects of action video games on visual-spatial processing efficiency and visual-spatial attention. We compared the baseline performance of experienced action video game players on two visual-spatial tasks and Attention Network Test with their performance on these tasks immediately after action video-gaming. The findings indicate half an hour of action video-game playing temporarily boosted participants’ performances on tasks that require visual memory, spatial transformations (mental rotation), and executive network of attention. The existence of such enhanced cognitive states implies the possibility of consciously accessing the latent resources of our brain and boosting our attentional and visual capacity upon demand.

Keywords: enhanced cognitive states, visual-spatial processing efficiency, attention, action video game

Introduction

Phenomenological research suggests the existence of mental states in which overall mental functioning, as well as specific cognitive processes (e.g., attention, perception) can be enhanced for limited durations (Csikszentmihalyi, 1990; James & Marty, 1982; Maslow, 1999). Csikszentmihalyi (1997) termed such experiences “flow experiences” (p. 29), which are characterized by “complete focus” (p. 31) where “attention becomes ordered and fully invested” in the activity (p. 31). Despite the wealth of phenomenological evidence, these enhanced mental states are largely neglected in cognitive psychology research. Kozhevnikov, Louchakova, Josipovic, & Motes (2009) were the first to report experimental evidence on the existence of enhanced cognitive states as an aftereffect of focused meditation. In particular, they found that meditation that required holding the focus of attention on an internally generated image of a religious deity temporarily boosted participants’ performance in a number of visual-spatial working memory tasks. Kozhevnikov et al. (2009) suggested that a key characteristic of the induction of enhanced cognitive states, at least in the visual domain, is the intense voluntary focus of visual attention on a chosen object, which activates prefrontal-temporal and prefrontal-parietal connections in the brain, thus facilitating an enhancement of visual-spatial working memory.

A number of researchers have speculated that action video gaming might also induce the state of “flow experience”

(Chiang, Lin, Cheng, & Liu, 2011; Klasen, Weber, Kircher, Mathiak, & Mathiak, 2011; Sherry, 2004; Weber, Tamborini, Westcott-Baker, & Kantor, 2009) due to “cognitive absorption”, deep immersion, intense focus, and merging action with awareness (whereby awareness is only focused on activity) required during video-game play. Experimental studies, however, have thus far focused primarily on the trait effects that result from action video gaming (Bavelier & Green, 2003; Castel, Pratt, & Drummond, 2005; Dye, Green, & Bavelier, 2009; Green & Bavelier, 2006a, 2006b; Li, Polat, Makous, & Bavelier, 2009).

What characteristics of FPS enable these changes in cognitive performances to occur has been discussed in detail (Spence & Feng, 2010). However, despite its abundance in literature, playing FPS is seldom seen as a source of intense visual focus. While playing FPS might leave a lasting change in cognitive performances, the nature of cognitive states induced by intense visual focus remains to be unstudied. In the current study, action video game playing is seen as one way of inducing sustained intense visual focus. The aim of this study is to investigate the nature of cognitive states induced by intense visual focus by utilizing various psychological measurements.

Among the different cognitive processes affected by meditation which might be temporarily enhanced as a result of intense visual focus are different components of visual-spatial cognitive processing (Kozhevnikov, et al., 2009) as well as attentional components (Tang et al., 2007). In the present study we compared the baseline performance of experienced action video game players on two visual-spatial tasks (Mental Rotation Task and Visual Memory Task) as well as on the Attention Network Test measuring executive, orienting, and alerting components of attention with their performance on these tasks immediately after FPS video gaming.

Method

Twenty-eight action video-game players (24 males) who have 4 to 20 years of experiences (Mean = 10), aged from 20 to 27 (Mean age = 23) were recruited for the study by advertising in National University of Singapore. One participant’s data was deleted due to procedural error. Two participants’ data were treated as outliers.

The participants of the current study played the action video-game *Unreal Tournament 2004* (referred to as FPS henceforth) by Atari. The video-game uses first-person point of view and require monitoring of the entire visual field (extent from fixation about 16° height × 29° width).

The participants were administered two computerized tasks assessing different aspects of visual processing: a visual memory task (VMT, MM Virtual Design, 2004) that assessed their ability to maintain images of complex static objects in visual working memory and a mental rotation task (MRT, Shepard & Metzler, 1971) that assessed their ability to dynamically transform and compare two spatial objects.

The VMT (MM Virtual Design, 2004) consisted of two parts. There were six test trials in the first part of the VMT. On each trial, participants were exposed to a single image (see Figure 1a) that appeared for 5 seconds. This display was replaced by an array of six images: five distractors and the previously shown image. Participants were asked to determine which image in the array was the previously shown image. There were 18 test trials in the second part of the VMT. On each trial, participants viewed an array of seven images (see Figure 1b) that appeared for 8 seconds. This array was replaced by another array of seven images: six of the previously studied images and one novel image. Participants were asked to judge which image in the second array was not present in the first.

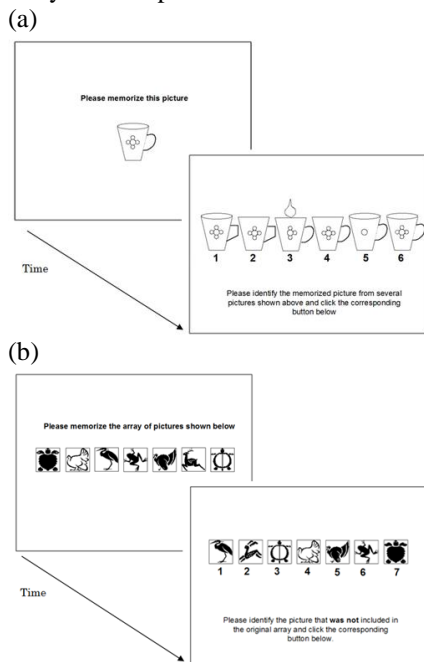


Figure 1: Examples of items from the visual memory test.

On each trial of the MRT, participants viewed a pair of two-dimensional pictures of three-dimensional forms (see Figure 2). The forms in each pair were rotated relative to each other around the x-, y-, or z-axis. Across trials, the amount of rotation ranged from 40° to 180°, in 20° increments. Participants judged whether the forms in the pair were the same or mirror-reversed. There were 36 test trials.

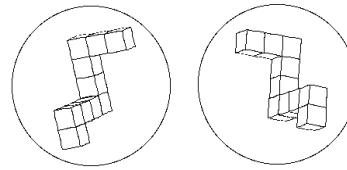


Figure 2: Example of a test trial from the Shepard & Metzler mental rotation task.

The Attention Network Test (ANT) was designed by Fan et al. (2002) to evaluate three attention networks: alerting, orienting and executive attention (see Figure 3). First, the alerting attention signifies the ability to make use of the presented cue. It represents individual's vigilance or alert state of preparedness to respond to the cue while attention is prompted to be diffused. Second, orienting attention is measured by the use of spatial cue. It signifies individual's ability to direct attention to specific location. Third, executive attention represents individual's ability to selectively attend to the significant stimuli while filtering out the distracting stimuli. It is measured by the incongruent targets.

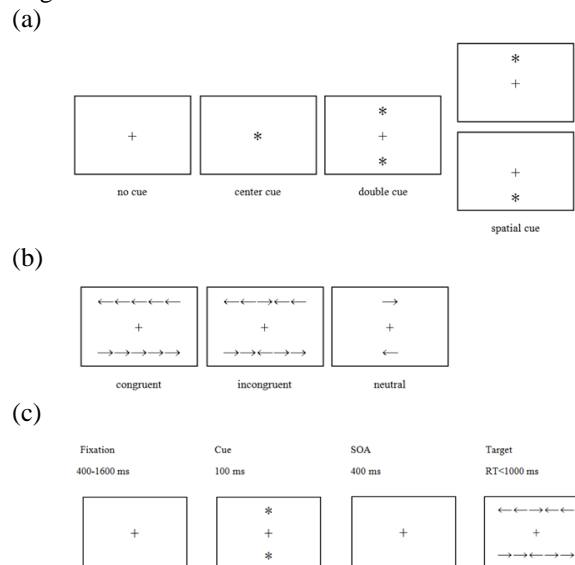


Figure 3: Attention Network Test (ANT). (a) The four cue conditions; (b) The three target conditions; and (c) an example of stimulus presentation sequence.

All the participants were tested individually, in a testing session lasting from 2.5 to 3 hours. First, as a pretest, all the participants completed the ANT, MRT, and VMT, the order of which was counterbalanced across participants.

After completing the pretest, all the participants were playing a video-game for 30 mins. Then, we randomly assigned the participants to the two following groups (see Figure 4).

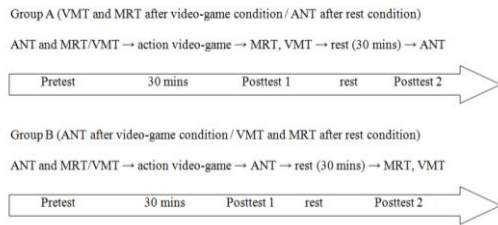


Figure 4: The time sequences of the different groups.

Above are the experimental procedures for group A (N=13) and B (N=12). In the beginning of the whole procedure, ANT, MRT, and VMT were given to all participants as pretests. The order of MRT and VMT was counterbalanced across participants. After the pretests, participants were asked to play FPS for 30 minutes. Right after that, the posttests 1 were administered. When participants are done with their posttests, 30 minutes of rest periods were given. After 30 minutes have elapsed, the whole sequence ended with posttests 2.

The informal interviews were conducted during the rest period. Participants were asked how they generally felt right after playing the FPS.

Posttest 1 was given to the participants to investigate the changes in their performance right after playing the action video-game that is to measure whether they exhibited enhanced cognitive state or to see if the action video-game has enhancing effect in short term. Posttest 2 was administered to the participants in order to see whether the state dissipates with time.

If to assume that the enhanced states do exist, they are of limited duration. The states dissipate quickly (about 20-25 min, according to the reports of meditators from Kozhevnikov et al. (2009) so it was impossible to give to the same participants all the visual and attentional tests in one session (overall time to complete all tests is more than 30 minutes) that is why some participants received only MRT and VMT (total duration; 10 to 15 minutes) after playing the videogame while others received only ANT (total duration; 25 to 30 minutes).

Second, we did not want to give to the same participants the same test three times (there is a possibility that they will remember some of the responses by the third time) in a row, due to a large practice effects. Thus for posttest 2 we used test(s) which was(were) not given in posttest 1.

Results

First, we analyzed participants' descriptions of how they felt right after 30 mins of playing FPS by using the simplified version of phenomenological method (Giorgi, 1985). The recurring themes were "better focus", "faster reaction", "being more alert", and "heightened arousal level". Equally used description was feeling "tired" (7/28). Number of participants reported that playing FPS makes them psychologically alert but physically tired (6/28). It was reported that the state of alertness after playing FPS eventually dissipates in time. One participant who was very

observant to his inner state, reported he was able to react to ANT task much faster and more accurately right after playing FPS, but he could feel this state disappear upon finishing the first block of ANT (after 10 min). Thus, the state might be of short duration, approximately 10 min for 30 mins of FPS playing.

Second, we analyzed performance on the VMT and MRT. In order to avoid confounds arising from speed accuracy trade-offs, a measure of visuospatial processing efficiency for each imagery test was computed for mental rotation and visual memory tasks, similar to the previous literature (Kozhevnikov, Louchakova, Josipovic, & Motes, 2009).

Figure 5 presents the results for visual memory processing efficiency. A 2 (time: pretest vs. posttest) × 2 (Condition: after video-game vs. after rest) mixed-model ANOVA yielded a significant main effect of time, $F(1, 25)=8.43$, $p<.001$, suggesting that there was a significant improvement in performance from pretest to posttest for all participants. The main effect of group was also significant, $F(1, 25)=6.22$, $p<.05$, indicating that participants who took the VMT posttest after the videogame (VMT after video-game) performed significantly better than the ones who took posttest after the rest period (VMT after rest). The interaction between time and group was also significant, $F(1, 25)=8.43$, $p<.01$. A follow-up ANOVA revealed a significant increase in efficiency from the pretest to the posttest for VMT after video-game, $F(1, 13)=35.00$, $p<.001$, and a no significant increase for VMT after rest, $F(1, 12)=2.52$, $p=.14$. These results indicate that there is an improvement in visual memory task performance, in posttest compared to pretest, only right after playing videogame. However, this improvement is no longer observable if the posttest is taken about half an hour after playing videogame.

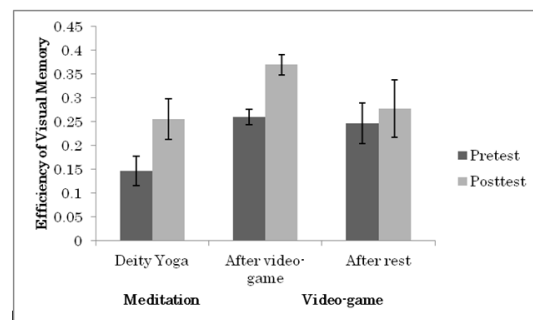


Figure 5: Processing of efficiency on the visual memory pre- and posttests as a function of group. Error bars show ± 1 SEM.

For comparison, on Figure 5 we also plotted the results for deity meditation group from Kozhevnikov (2009) study, where VMT was also given using pre-post test paradigm to different groups of meditators. Among all the groups of meditators, only *deity yoga* meditators (DY) showed the significant increase in VMT efficiency from pretest to posttest ($F(1, 14)=26.41$, $p<.001$). The comparison of effect size reveals participants in VMT after video-game ($\eta^2=.73$) and DY ($\eta^2=.65$) group are quite similar. Although the contents of focused objects are different, both playing FPS and DY involves the acts of intense visual focus.

Figure 6 presents the results for MRT efficiency. A 2 (time: pretest vs. posttest) \times 2 (group: after video-game vs. after rest) mixed-model ANOVA yielded a significant main effect of time, $F(1, 24)=16.54$, $p<.01$ suggesting that there was a significant improvement in performance from pretest to posttest for all participants. However, main effect of group was not significant, $F(1, 24)=.01$, $p=.91$. The interaction between time and group was marginally significant, $F(1, 24)=3.23$, $p=.085$. A follow-up ANOVA revealed a significant increase in efficiency from the pretest to the posttest for MRT after video-game, $F(1, 12)=13.87$, $p<.01$, and only marginal increase for MRT after rest, $F(1, 12)=3.39$, $p=.09$. These results indicate that there is an improvement in mental rotation task performance, in posttest compared to pretest, only right after playing video-game. However, this improvement is no longer observable if the posttest is taken about half an hour after playing video-game.

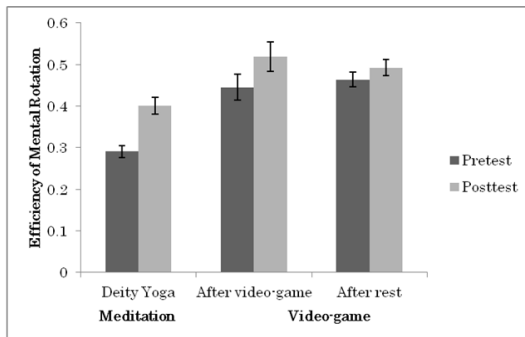


Figure 6: Processing of efficiency on the mental rotation pre- and posttests as a function of group. Error bars show ± 1 SEM.

For comparison, on Figure 6 we also plotted the results for deity meditation group from Kozhevnikov (2009) study, where MRT was also given using pre-post test paradigm to different groups of meditators. Among all the groups of meditators, only deity yoga meditators (DY) showed the significant increase in MRT efficiency from pretest to posttest ($F(1, 14)=19.36$, $p<.001$). The comparison of effect size again reveals participants in MRT after video-game ($\eta^2=.54$) and DY group ($\eta^2=.58$) are quite similar.

The result (interaction) for MRT comparing after video-game vs. after rest group was only marginally significant. This could be caused by the presence of ceiling effect. Since VGPs seem to exhibit exceptionally high spatial abilities from the beginning (Fig 6), the MRT was not able to reflect the effect of action video-game playing.

For ANT, three networks – executive, alerting and orienting – were calculated by subtracting the average RTs of specific condition from other condition (Fan et al., 2002).

ANT is composed of three test blocks, with each block taking approximately 10 minutes to complete. So that overall duration of the test is 30 min. However, as the qualitative data show, the duration of the enhanced states might be limited, and dissipate in 10 min as one of our participants reported. Since ANT took about 2 to 3 times longer compared to VMT or MRT (25 to 30 minutes vs. 10 to 15 minutes respectively), it is possible that by the time participants reached second block of the posttest, the

enhanced state started to dissipate. Thus, for each of the attentional network, we performed two analyses: 1) we compared ANT pretest with participants' performance on the first block on ANT posttest only, and 2) we compared performance on ANT pretest and ANT posttest (including all three blocks for both pretest and posttest).

Figure 7 presents the results for executive network. For better comparisons, the results for each of the three blocks of the ANT posttests are presented separately. A2 (time: pretest vs. posttest block 1) \times 2 (Condition: after video-game vs. after rest) mixed-model ANOVA did not yield a significant main effect of time, $F(1, 25)=0.48$, $p=.50$ suggesting that there was no significant improvement in performance from pretest to posttest block 1 for all participants. The main effect of group was not significant either, $F(1, 25)=1.48$, $p=.24$ indicating that overall performance of participants' executive network did not differ from pretest to posttest block 1. However, the interaction between time and group was significant, $F(1, 25)=9.84$, $p<.01$. A follow-up ANOVA revealed a significant increase in executive network efficiency from the pretest to the posttest block 1 for ANT after video-game, $F(1, 12)=5.38$, $p<.05$, and a marginally significant decrease for ANT posttest block 1 after rest, $F(1, 13)=4.36$, $p=.06$.

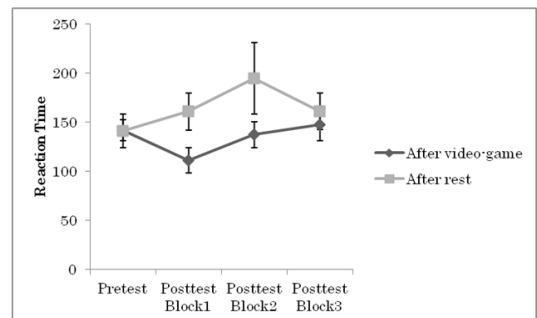


Figure 7: Executive network pre- and posttests as a function of condition. Higher reaction time denotes less efficient executive network. Error bars show ± 1 SEM.

Then, we conducted a 2 (time: pretest vs. posttest all 3 blocks) \times 2 (Condition: after video-game vs. after rest) mixed-model ANOVA did not yield any significant main effects ($p>0.2$). Similar to the previous case, only interaction between time and group was significant, $F(1, 25)=7.73$, $p<.05$. A follow-up ANOVA revealed a significant decrease for ANT 3 blocks after rest, $F(1, 13)=6.65$, $p<.05$, and no significant difference in executive network efficiency from the ANT pretest to the posttest all 3 blocks right after video-game, $F(1, 12)=1.50$, $p<.25$.

These results indicate that there is an improvement in conflict resolution performance, in posttest compared to pretest, only about 10 minutes (during performance on block 1) right after playing video-game, and then the performance starts to degrade for both groups, as it could be seen from Figure 7.

For the orienting network and alerting network, there were no evidences that playing action video-game improved

network efficiency right after playing action video-game compared to after resting ($p > 0.1$).

Taken together, the results of present study show that the enhanced cognitive states do exist. As the results of ANT (executive network) show, this state is transient and it dissipates quickly. The result shows that the residual effect of 30 min of action video-game playing can hold for at least 10 mins when the degree of visual focus intensity is strong enough.

Conclusions

The findings of this study indicate that half an hour of FPS video game playing temporarily boosted participants' performances on tasks that require visual memory, spatial transformations (mental rotation), and executive network of attention. The effect of enhanced performance disappeared and returned to the baseline level for all the tasks after 30 minutes of rest. Furthermore, based on ANT data and participants' reports, these performance improvements might last no longer than 10 minutes after video-game playing. Thus we suggest that FPS action video game playing can give an access to relatively short temporary cognitive states characterized by drastically enhanced performance on visual-spatial and executive attention tasks.

Although some researchers (e.g., Weber, et al., 2009) speculated that the experience of flow might be related to the functioning of alerting and orienting networks during video-gaming (due to their importance in achievement/maintaining the alert attentional state as well as efficient orienting of attentional resources to spatial locations where the event takes place), our experimental results do not support this suggestion. The only attentional network which significantly improved during the enhanced state is the executive network. It is possible to infer that during enhanced states, attentional focus becomes "sharper" and of greater resolution, and thus, encoding of visual-spatial information as well as discrimination between target and flankers becomes more efficient. Meditation has a similar effect on attentional networks: Tang et al. (2007) showed an improved performance only in executive network as a result of short-term meditation.

The result of experiment 2 confirmed that intense visual focus induced by action video game playing enhances the efficiency of presented visual information processing.

Furthermore, our results show the significant increase in performance on such visual-spatial tasks as mental rotation and visual memory test during the enhanced cognitive state, similar to what has been reported by Kozhevnikov et al (2009) as a result of focused meditation. In our study, playing FPS required intense visual focus on many elements in the display such as "abrupt-onset events" (Spence & Feng, 2010, p. 93) and "significant objects" (p. 93) that must be discriminated and selected. Similar to DY meditation where the subject focuses on imagining himself/herself as a deity, focused visual attention seems to be crucial for inducing enhanced states. Indeed not all video-games seem to have a similar affect on visual attention (Bavelier & Green, 2003;

Feng, Spence, & Pratt, 2007; Green & Bavelier, 2006a, 2006b, 2007; Li, et al., 2009). For example, compared to FPS, puzzle video-games such as Tetris are shown not to have enhancing effect on spatial attention. Similarly, as it was shown by Kozhevnikov et al. (2009), not all types of meditation lead to enhanced cognitive states, but only those that require intense visual focus as DY. Other types of meditation, such as Open Presence which required "evenly distributed attention that is not directed toward any particular object experiences" (p. 646) did not produce an enhanced cognitive state. In addition focused attention, an interesting aspect of both FPS and DY is that both of them require egocentric (first-person perspective) spatial imagery. DY requires egocentric embodiment (visualizing oneself as a deity and not just focusing on an external image) and FPS "provides a natural egocentric compatibility between the visual input and the motor output" (Spence & Feng, 2010, p. 99). It is possible that a combination of focused attention and egocentric spatial imagery processes might be the key to inducing enhanced cognitive states. Future research should address this question by directly comparing the accessing of enhanced cognitive states using visual concentration on egocentric vs. allocentric visual-spatial images.

It should be noted, however, that although both DY meditation and videogaming seem to boost temporarily visual-spatial memory and attention, we should be very cautious to make any conclusions about similarity of enhanced cognitive states induced by meditation vs. videogaming. First, it is known that meditation leads to emotional stability while video-gaming increases aggression and emotional desensitization (Anderson et al., 2010; Bushman & Gibson, 2011). Second, our participants in informal interview reported depletion of their attentional resources right after the enhanced states while monks reported "refreshed feeling" accompanying them long after meditation. Thus, while both focused meditation and action video-gaming playing might both boost visual-spatial cognitive processes, the nature and temporal dynamics of these enhanced states might be very different.

The fact that enhanced cognitive states do exist has significant practical implications for different domains of human performance. Csikszentmihalyi (1990) described the tremendous energy of enhanced cognitive states using a metaphor of atomic energy, which could be used for a variety of purposes. Knowing the means and the mechanisms behind cognitive enhancements would allow us to generalize related findings to help different cognitive problems (e.g. memory loss, attentional problems). Although it is transient, a temporary boost in visuospatial processing efficiency or attention can also greatly enhance the performance during the critical periods of our lives (e.g. training soldiers before going to battlefields). Furthermore, they can help us boost creativity (Csikszentmihalyi, 1996) or could be of particular use for learning.

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