Playing Action Video Games Affects Cognitive Ability

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Abstract. The great growth of the video game industry and the massive increase in the number of video game players has prompted extensive research into video games. The varied impacts of video games gaming on cognitive skills, primarily action video game, are reviewed in the article. Different studies were divided into three types: the speed of processing, perception, and attention, in order to explore the neural mechanism behind action video game play. Action video games' effects on users' cognitive abilities can be mainly divided into the impact on low-level sensory pathways and the impact on attention control. Although behavioral experiments have demonstrated superior perception abilities in action video game players, less evidence when it comes to electrophysiology and brain imaging for the same enhancement. Action Video games are widely proven to enhance top-down attention and working memory but have no significant effect on bottom-up attention.

Keywords: Action video game; Perception; Attentional control.

1. Introduction

Since the 1990s, computer games have developed from a relatively narrow interest to a considerable common and popular form of entertainment in modern life. Video games are now accessible to an increasing number of people. Through the 2016 Global market report, globally, about 2.5 billion individuals enjoy playing video games, using various devices including computers, gaming consoles, and mobile phones [1]. It is expected that in the future, due to the further popularization of internet devices, the number of video game players will continue to increase steadily and significantly. Video games are not only thought of as simple entertainment, but also a new kind of art, which is exhibited in high-level museums. The artistic and cultural value of video games is also widely discussed in the academic field. Additionally, video games have been introduced into the field of education and medicine as a new kind of technology, which helps students learn and practice or reduces patients' pain and is beneficial for recovery. Therefore, playing video games may have a potential but large influence on players' behaviors, emotions, and even brains.

Importantly, different video games have different effects on the brain and cognition. Video games can be divided into enormous genres through a huge diversity of potential experiences which contains considerably slow-moving and hard strategy games (i.e., wherein participants have sufficient time to make a careful plan and decision) and fighting games (i.e., where gamers must always make judgments and respond as quickly as they can). According to earlier studies, playing racing games can encourage participants to engage in unsafe driving practices, and increase players' risk-taking [2]. Another research has shown that aggressive behavior and cognition can be significantly improved through playing violent video games [3]. Similarly, a study report that surgeons who regularly play action video games perform operations faster and experience fewer hand tremors [4]. These effects are significantly different. Therefore, while researching how video games affect brain function, the possible impact of game genres cannot be disregarded.

Most of the articles will be reviewed here interest in one specific genre of video games termed "action video game" (AVG), which contains fighting games and shooting games, were believed to have a variety of effects on players. Numerous studies concentrate on the potential impact of action video game play. Most studies showed that AVG have several significant effects on the cognitive skills of players [5, 6]. Early studies mainly used behavioral experiments in which reaction time (RT) and accuracy were mostly used as a measure of cognitive skills. Consequently, enormous studies reported a faster response of action video games player, which indicate AVG may have a large

positive impact on the speed of processing. Through perception experiments, a specific kind of behavioral experiment, researchers found that the participants' perceptual threshold is improved by training them to play action video games. As research methods improve, more advanced techniques would be used in investigating the distinction between action video game gamers and those who don't play them, including electrophysiological techniques and neuroimaging, which give researchers more direct approaches to find deeper changes in executive function such as cognitive flexibility and cognitive control.

Accordingly, action video games affect brain functions in a variety of ways, and discussing them categorically according to the types of experimental tasks, the measures used, and what abilities they reflect, is an intuitive and clear way to review these effects. These enormous influences will be specified and discussed in three different parts, which are the speed of processing, perception, and attention.

2. The Speed of Processing

Players are frequently expected to make decisions and respond with motor activities in a short amount of time, which is a common element of many video games. Although there isn't much time pressure in certain types of games (e.g., turn-based games such as Sid Meier's Civilization VI), several genres of games, particularly action video games, call for players to make rapid, accurate decisions from a wide range of possibilities. Consequently, gamers especially those who enjoy playing action games, can react more quickly than those who don't play video games. What's more, action video game players (AVGPs), different from NAVGPs (non-action video game players), tend to be more display a faster overall processing speed, even though they play other genres of games [7, 8]. This finding was amply supported by a wide range of response and stimuli techniques such as both visual and auditory responses and vocal, manual, or saccadic stimuli [9-11]. Cross-sectional designs, intervention designs, and many different tasks (e.g., Stroop task and AX-CPT task) were used during the research on AVGPs, and the majority of the results support the stability of the claim that AVGPs had faster processing speed mainly represented by reaction time (RT).

However, it is worth noting that causal inferences which specifically is concluding that playing action video games is responsible for the changes in AVGPs' speed of processing can't be inferred through research that used a cross-sectional design. A possible explanation is that some people who are naturally faster at the speed of process are more likely to have a better performance in playing action video games the first time and gain good feedback easier. Therefore, it promotes them to play the games, again and again, making it a habit of playing action video games and eventually becoming AVGPs. Therefore, a more thorough discussion of the research's findings using a cross-sectional approach is necessary.

Besides, several studies that used an intervention design also show that participants' speed of processing can be improved by training which is playing action video games in the laboratory. For instance, in a previous study, all NVGPs were trained on Medal of Honor: Allied Assault (a first-shooter game) for 10 days, one hour per day. They were evaluated using UFOV tasks, attentional-blink, and enumeration tasks to measure their ability both before and after training. In all available measures of enhancement, participants' performance significantly improved after training, both in reaction time and accuracy [12].

Importantly, there are three possible reasons to reach faster RTs: faster motor execution, quicker reaction times in making decisions, and a speed-accuracy trade-off. While both faster motor execution and change in speed-accuracy trade-off are possibly and theoretically happened in action video game players, quicker decision-making reaction times are the best explanation for the overall improvement in AVGPs according to study, rather than faster motor execution or change in speed-accuracy trade-off [13].

3. Perception

Playing action video games also enhances perception, which includes lots of different abilities measured by the tremendous variety of tasks, including flanker compatibility tasks, visual search tasks, mental rotation, change detecting tasks, folding tasks and useful field of view (UFOV) tasks. Indeed, visual perception is specifically interested by the most of existing literature, only a few pieces of research focus on other perception pathway such as multi-modal or auditory. Action video game training has been found to improve thresholds on the tasks of perception by numerous studies. For example, participants have a better performance in a task that required identifying small letters or low contrast targets in crowded visual fields after training. It is noticeable that this improvement can only be observed when participants spend long enough time to train, at least 20 hours. [14]. Compared to other successful perception training which usually uses studying durations of 30 to 50 hours, it was more likely to observe steady and obvious changes in perception as the duration of video game training increased.

Interestingly, these wide and enormous improvements which are examined through several kinds of tasks are attributed to enhancements in perception (e.g., improvements of lower-level perceptual channels) or reflecting changes in attentional control (e.g., reducing distraction by irrelevant to the target) is an area of ongoing research and debate. A better attentional control, including keeping attention to the stimulus which relevant to the goal, such as the diamond shape (the target of the flanker compatibility task which needs participants to identify whether it appears and react as fast as possible) in the flanker compatibility task and enemies in a real first-shooter game. Additionally, avoiding being distracted by other stimuli which irrelevant to the target, can enhance the participants' performances in such tasks, which the improvement of perception can promote as well. Thus, it is hard to identify which one is the real reason for the improvement in the several tasks. An event-related potential study suggested that compared to NAVGPs, the anterior N1 component of the AVGPs indicates a more likely association between the task performance and parietal mechanism that depends on attention, and the P2 component indicates a more likely association between the task performance and improved high-level perceptual processing. Accordingly, both improvements in perception and better attentional control led to AVGP's better performances in tasks [15]. However, it is still needing more research using an intervention design to investigate which dominates the changes of participants in a training study.

4. Attention

4.1 Attentional Control

In previous studies, attention is often supposed to be affected by two different orientations: Bottom-up and Top-down. Bottom-up means that attention is attracted by exogenous stimuli (e.g., orientating reflex, a sudden noise). Top-down is also called goal-directed attention, which means attention is controlled by endogenous stimulation (e.g., the ink color that is required to be noticed in the classic Stroop task). Action video game gaming has an impact on attentional control, a crucial component of cognition. Playing action video games considerably improves certain top-down attention-related abilities. Cross-sectional as well as intervention research both show this impact. These changes in attentional control were firstly reported as selective attention, instead of the prior point offering a better explanation and process behind it, it may be best understood as shifts in attentional control [12].

Top-down attention includes the ability to reduce task-irrelevant information distracts attention, and enhance and keep attention on the target relevant to goals. They promote participants to complete the tasks in different ways. Previous research showed that, on the one hand, requiring participants to ignore more and more unimportant distractors in the tasks can lessen distractibility. On the other hand, training subjects focused on only enhancing information relevant to the task, have no the same influence on processing distractors [16]. The above results are consistent with a large literature that

focus on perceptual training, enhancing task-relevant information makes it easier for conceptual or perceptual representations to form that correspond to information about the target. The developments in representations possibly hard to improve attentional control when participants face a new task. However, training distraction suppression can transfer enhancement of attentional control from a specific task to a lot of different types of tasks, which is a more feasible way of training attentional control. What's more, some studies have failed to show AVGPs have a better performance in Bottom-up attention compared to NAVGPs, such as the speed of capturing exogenous stimuli, which may potentially suggest that top-down attention is more adaptable than bottom-up attention in terms of its mechanics [17, 18].

4.2 Other Changes in Attention

Playing action video games can cause various changes in attention besides attentional control, which are not observable through changes in top-down attention. The participants' working memory (WM) was examined by a variety of standard visuospatial working memory tasks including N-back task and complex span tasks. Results show that AVGPs have more storage capacity than NAVGPs in cross-sectional work, the same result also happened in an intervention study. For instance, through an adaptive color-wheel exercise, researchers discovered that AVGPs exhibit more accurate visual WM for colors than NAVGPs in simple spatial memory tasks [19]. Equally, another research shows that performance of participants in an object enumeration task is enhanced after action video game training [20].

Cognitive flexibility is an important ability for AVGPs to complete a game perfectly. Players in an action video game must quickly switch between different attention modes to meet task demands. More specifically, that is distributing the attention on the whole screen to make sure of notice targets when they appear as fast as possible. After that, focus attention on the targets so that they can complete the task (e.g., shoot them in first-shooter games) quickly, efficiently, and flawlessly. When AVGPs complete a task, they will distribute the attention on the whole screen again to detect the next target.

All these processes can happen in a short time. Therefore, the ability to quickly switch between attention modes according to job demands is essential for AVGPs. The spatial or temporal resolution of attention may be affected by this rapid shift, by switching between an allocated attentional state and a state of attentional focus, or between a short time and a long-time scale [21]. In all conditions, greater cognitive flexibility results in an enhanced capacity for task-relevant information focus. Although several studies indicate that it's possible to enhance cognitive flexibility, whether action video games can improve it remains a controversial topic in the field [22, 23].

5. Conclusion

Considerable diverse studies examined the influences of action video games on brain function, through a large different number of tasks and methods. Although the tasks and experimental designs used in the studies are quite different, these influences can be roughly summarized as effects on low-level processing channels (e.g., improvement of the primary visual pathway) and higher-level cognitive processes (e.g., cognitive flexibility and attentional control). Investigating how action video games affect cognitive function is crucial. Although previous studies have found electrophysiological evidence that action video games affect higher-level cognitive processing such as cognitive control, changes in cognitive processes were not sufficient to fully explain the steady and marked improvement in speed of processing. Further research is needed to focus on how action video games influence perceptual processing. Cognitive improvement through training has been a widely discussed research field in recent years. As a possible and efficient method of training, action video games significantly enhance people's cognitive skills. However, whether this improvement can be far transferred, to enhance performance in other domains related to cognitive skills, such as academic performance, remains for further study. Participants' preferences for different game types may also potentially affect the results of training with digital games.

With the expansion of the video game market, the types of video games are gradually increasing, and new game types such as virtual reality games are difficult to be strictly classified by existing taxonomies. How these new kinds of games affect brain function is also a topic worthy of study. More importantly, formulate a new classification method and make the same type of games have similar effects on brain function so that researchers can reasonably distinguish the effects of different genres of games and conduct better research. Building such a mature and successful classification system requires a concerted effort from different disciplines to design, analyze, research, and develop video games.

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