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Video game players show higher performance but no difference in speed of attention shifts

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ABSTRACT

Video games have become both a widespread leisure activity and a substantial field of research. In a variety of tasks, video game players (VGPs) perform better than non-video game players (NVGPs). This difference is most likely explained by an alteration of the basic mechanisms underlying visuospatial attention. More specifically, the present study hypothesizes that VGPs are able to shift attention faster than NVGPs. Such alterations in attention cannot be disentangled from changes in stimulus-response mappings in reaction time based measurements. Therefore, we used a spatial cueing task with varying cue lead times (CLTs) to investigate the speed of covert attention shifts of 98 male participants divided into 36 NVGPs and 62 VGPs based on their weekly gaming time. VGPs exhibited higher peak and mean performance than NVGPs. However, we did not find any differences in the speed of covert attention shifts as measured by the CLT needed to achieve peak performance. Thus, our results clearly rule out faster stimulus-response mappings as an explanation for the higher performance of VGPs in line with previous studies. More importantly, our data do not support the notion of faster attention shifts in VGPs as another possible explanation.

1. Introduction

Video games have been a research topic in science for the last three decades (Latham, Patston, & Tippett, 2013). Despite their high prevalence – 60% of juveniles in the U.S. play at least 1 h a day (Rideout, Foehr, & Roberts, 2010) – we still have no consistent evidence about the consequences of playing video games. Some studies have shown detrimental effects like increased aggression (Anderson et al., 2010), or addiction symptoms (Gentile et al., 2011). However, it remains unclear whether or not violence in video games can be blamed for aggressive behavior (Ferguson, San Miguel, Garza, & Jerabeck, 2012), or if being "bad" in a video game improves moral sensitivity in the real world (Grizzard, Tamborini, Lewis, Wang, & Prabhu, 2014). But video game play has also been causally linked to positive effects like superior contrast sensitivity (Li, Polat, Makous, & Bavelier, 2009), enhanced control over selective attention (Green & Bavelier, 2003), improved multitasking (Chiappe, Conger, Liao, Caldwell, & Vu, 2013; Strobach, Frensch, & Schubert, 2012), increased visual working memory capacity (Blacker & Curby, 2013) and encoding speed (Wilms, Petersen, & Vangkilde, 2013), faster information integration (Green, Pouget, & Bavelier, 2010) and even real-life ameliorations such as better surgical skills (Schlickum, Hedman, Enochsson, Kjellin, & Fellander-Tsai, 2009), or improved reading abilities in dyslexic children (Franceschini et al., 2013).

In addition, correlational studies found more precise temporal processing (Donohue, Woldorff, & Mitroff, 2010; Rivero, Covre, Reyes, & Bueno, 2013) and better selective attention abilities (Cain, Prinzmetal, Shimamura, & Landau, 2014; Chisholm & Kingstone, 2012; Green & Bavelier, 2003) in video game players (VGPs) compared to non-video game players (NVGPs). In general, VGPs show shorter reaction times than NVGPs in a multiplicity of tasks (Dye, Green, & Bavelier, 2009). We have shown that VGPs have shorter reaction times but do not produce more errors in an anti-saccade task (Mack & Ilg, 2014). Our results indicate that inhibitory control is not altered in VGPs. Paralleling our results, a similar study using saccade targets and distractors also found shorter saccadic reaction times in VGPs (Heimler, Pavani, Donk, & van Zoest, 2014). However, this study found a slight increase in error rates of VGPs.

Recently, it was proposed that VGPs exhibit an enhanced ability in "learning to learn" (Bavelier, Green, Pouget, & Schrater, 2012), that is, the ability to adapt swiftly to new tasks. More specifically, allocation of attentional resources is increased, thereby enhancing the signal in question for the task. It is debated whether these attentional improvements are related to exogenous, bottom-up control (Cain et al., 2014), or to early distractor inhibition (Bavelier, Achtman, Mani, & Focker, 2012; Mishra, Zinni, Bavelier, & Hillyard, 2011) and other, later components of endogenous, top-down control of attention (Chisholm, Hickey, Theeuwes, & Kingstone, 2010; Chisholm & Kingstone, 2012; Clark, Fleck,

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& Mitroff, 2011; Wu et al., 2012). Based on our eye movement results, we wanted to explore a third alternative: faster allocation of attentional resources in VGPs, as suggested by Bavelier, Green, et al. (2012). We hypothesized that, in the framework of visuospatial attention, not just the allocation, but the mere attentional orienting response is faster in VGPs. Within the famous "spotlight of attention" metaphor, this orienting is achieved through a covert attention shift (Posner, 1980; Posner, Snyder, & Davidson, 1980). This shift can be driven in a bottom-up manner through exogenous signals like sudden onset cues, or by top-down control through endogenous signals like symbolic cues. It has been argued that bottom-up processes precede top-down control of attention (Theeuwes, 2010) and that feature-based attention is closely related to bottom-up priming (Theeuwes, 2013). In our own study (Mack & Ilg, 2014), we found faster reaction times in VGPs for exogenously as well as endogenously driven saccadic eye movements that are believed to be preceded by covert attention shifts (Shepherd, Findlay, & Hockey, 1986). Since both saccade types were similarly affected, a faster covert shift of attention might be the best explanation for these results. In addition, this would account for the shorter reaction times of VGPs in any task which involves some form of spatial attention.

However, in reaction time based experiments, faster responses can be explained alternatively by more efficient stimulus-response mappings (Castel, Pratt, & Drummond, 2005). An examination of purely attentional effects must therefore use a paradigm without any motor involvement. Although there have been perceptual studies using performance based signal detection tasks (Bejjanki et al., 2014; Green & Bavelier, 2003; Schubert et al., 2015; West, Stevens, Pun, & Pratt, 2008; Wilms et al., 2013), none of them looked explicitly at the speed of covert attention shifts. Using the theory of visual attention to model the effects of video game play on various aspects of visual attention, it has been shown that VGPs have a higher processing speed and lower perceptual thresholds compared to NVGPs (Schubert et al., 2015; Wilms et al., 2013).

The spatial cueing task of Nakayama and Mackeben (1989) is an elegant way to measure the speed of attention shifts without any motor involvement. In the "Nakayama task" the shifting speed is derived from discrimination performance. As in other spatial cueing tasks, participants have to detect the presence of an oddball in a search array. The oddball is defined by a feature conjunction of orientation and color (Treisman & Gelade, 1980). In contrast to normal conjunction search tasks, the oddball's location is cued, reducing the conjunction search to a simple neighbor comparison. The crux of the task is the very brief presentation of the search array for only 17 ms. The duration of the cue indicating the upcoming oddball location in the search array ("cue lead time"; CLT), is systematically varied between trials. With increasing CLT, an attentional enhancement of the signal and thus better discrimination performance can be observed until a certain point. For longer CLTs, the attentional enhancement decays and performance drops substantially. At a specific CLT, the attentional enhancement will be strongest, resulting in a performance peak. This CLT for peak performance is a direct measure for the speed of covert attention shifts.

Nakayama and Mackeben (1989) suggested that the time course of performance reflects an early peaking bottom-up part as well as a late plateauing top-down component. At short CLTs, the orientation response is *transient* and bottom-up triggered. At long CLTs, the response is *sustained* and under top-down control. It has been shown that the attentional selection of the signal before the covert attention shift is responsible for the transient component (Wilschut, Theeuwes, & Olivers, 2011). This study also found that task difficulty is echoed in a transition from shorter to longer CLTs for peak performance. The authors proposed that this reflects a shift from a bottom-up defined to a top-down controlled strategy in the participants. In summary, the CLT for peak performance in the Nakayama task reflects differences in subjective task difficulty, as well as type and speed of attention shift.

Very recently, Schubert et al. (2015) showed, that the attentional system of VGPs is especially better in the lower visual field. Processing speed seems to be higher for stimuli in this region. In their experiment, the authors presented five letters arranged in a vertical column to measure visual processing speed on a fine-grained eccentricity level. Since the stimuli in our Nakayama task are arranged in a circular manner, it is possible to examine effects of retinal position on an isoeccentric level and to elaborate on the effects of eccentricity in a future study.

1.1. Research questions

We used the Nakayama task to pursue four research questions:

(1) Do VGPs perform better in the Nakayama task, thereby lending further support against a faster stimulus-response mapping?
(2) Do potential attentional differences in VGPs result from faster attention shifts?
(3) Do VGPs and NVGPs differ in the balance between top-down and bottom-up control of attention?
(4) Are differences in performance between VGPs and NVGPs especially pronounced in the lower visual field?

It is important to note that our study is a correlational study. Obviously, it is impossible to infer any causal relationship between differences in performance and video game play from our results. In contrast, we intended to explore the nature of these differences as precisely as possible.

2. Methods

2.1. Experimental setup

The experiments were performed with a PC (Compaq dc5750) running under Windows XP with extended desktop settings for two monitors. The stimulus screen (HP L1950; screen diagonal: 19″, refresh rate: 60 Hz, resolution: 1280 × 1024 pixels) was connected via the VGA-port of the graphics adapter (ATI Radeon Xpress 1150). Stimuli were presented using the Psychophysics Toolbox Version 3 (Brainard, 1997; Pelli, 1997) and MATLAB R2008a (The Mathworks, Natick, MA). Viewing distance of the participants was kept constant at 57 cm through use of a head rest.

2.2. Task

Fig. 1 shows the sequence of events in our version of the Nakayama task (i.e. "Experiment 5: effect of retinal eccentricity" in Nakayama & Mackeben, 1989). Participants had to indicate if the bar at the cued location matched the other bars in its feature combination. These features were 'orientation' (horizontal/vertical) and 'color' (black: luminance ≤ 1 cd/m^2; white: 125 cd/m^2). Stimuli were presented on a gray background (30 cd/m^2). Each trial started with a white fixation cross (size: 19 × 19 arcmin, line width: 2 arcmin) at the center of the screen. After a random fixation time (250–500 ms), a red square (size: 44 × 44 arcmin, line width: 4 arcmin) cued the oddball location. The CLT was parametrically chosen from 14 values (0, 17, 33, 50, 67, 83, 100, 117, 133, 150, 200, 300, 400 and 600 ms). Subsequently, the search array, consisting of 12 bars (each sized 30 × 16 arcmin) in a circular arrangement of 4° radius, was shown for 17 ms. Bar centers were equally spaced at the 12 clock positions with a center-to-center distance of 2.1° of visual angle. Six bars were randomly assigned to one feature combination (e.g. "horizontal-black") and the remaining six to the opposite feature combination (e.g. "vertical-white"). Thus, the two groups of bars were always different in both feature dimensions. The bar at the cued location (aka the oddball) either differed in its orientation from the rest (e.g. "vertical-black" or "horizontal-white") or not at all (e.g. "horizontal-black" or "vertical-white"). All other bars were randomly assigned to any of the 11 remaining positions. The cue stayed on the