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The effects of video game play on the characteristics of saccadic eye movements

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ABSTRACT

Video game play has become a common leisure activity all around the world. To reveal possible effects of playing video games, we measured saccades elicited by video game players (VGPs) and non-players (NVGPs) in two oculomotor tasks. First, our subjects performed a double-step task. Second, we asked our subjects to move their gaze opposite to the appearance of a visual target, i.e. to perform anti-saccades. As expected on the basis of previous studies, VGPs had significantly shorter saccadic reaction times (SRTs) than NVGPs for all saccade types. However, the error rates in the anti-saccade task did not reveal any significant differences. In fact, the error rates of VGPs were actually slightly lower compared to NVGPs (34% versus 40%, respectively). In addition, VGPs showed significantly higher saccadic peak velocities in every saccade type compared to NVGP. Our results suggest that faster SRTs in VGPs were associated with a more efficient motor drive for saccades. Taken together, our results are in excellent agreement with earlier reports of beneficial video game effects through the general reduction in SRTs. Our data clearly provides additional experimental evidence for an higher efficiency of the VGPs on the one hand and refutes the notion of a reduced impulse control in VGPs on the other.

1. Introduction

Nowadays, playing video games is a widespread leisure activity. A recent survey (Rideout, Foehr, & Roberts, 2010) indicates that 60% of young people between the ages of 8 and 18 years in the U.S. play video games at least 1 h per day. Despite this general dissemination, the consequences of video game play are still heavily debated. On the one hand, negative effects like decreased pro-social and increased aggressive behavior were reported (Anderson et al., 2010). However, if parental involvement was assured, pro-social behavior and civic engagement of subjects increased – which was explained by the team-oriented multiplayer options in action video games (Ferguson, 2011).

On the other hand, playing video games is associated with multiple enhancing effects: amongst others, a better control of the negative effects of bottom-up attentional capture (Chisholm et al., 2010), improved working memory (Colzato et al., 2012), a superior contrast sensitivity function (Li et al., 2009), better signal detection (West et al., 2008), more precise multisensory temporal processing (Donohue, Woldorff, & Mitroff, 2010), enhanced change detection (Clark, Fleck, & Mitroff, 2011) and even better laparoscopic surgical skills (Rosser et al., 2007). Even an increase of grey brain matter after 2 months of video game playing (30 min per day) was recently reported (Kuhn et al., 2013).

Besides documenting a correlation between beneficial effects on performance and video game play, some studies have also established a causal relationship by comparing the performance of subjects before and after training periods (Green & Bavelier, 2003; Li et al., 2009). However, extensive video game practice did not always improve the performance of subjects, for example in an enumeration task (Boot et al., 2008). In summary, video game players (VGPs) react faster than non-video game players (NVGPs) in a variety of tasks (Dye, Green, & Bavelier, 2009).

Despite this large body of evidence, reasons for the short reaction times of VGPs are still unknown. This reduction is most likely of attentional nature, since VGPs are faster in tasks ranging from spatial cueing over n-Back to visual search. Indeed, a recent study showed an altered attentional network in VGPs compared to NVGPs (Bavelier et al., 2012), especially an increased activation of the fronto-parietal network.

Interestingly, most of the above mentioned studies used rather indirect measures of the attentional mechanisms based on costs or benefits in perceptual tasks. It has been shown that subjects express perceptual benefits at the location of the target of subsequently executed saccadic eye movements (Deubel & Schneider,

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1996; Hoffman & Subramaniam, 1995; Kowler et al., 1995). These findings suggest that even without explicitly measuring perceptual thresholds there might exit a possibility to monitor the shifts of attention directly by simply measuring the saccadic eye movements. The above mentioned studies allow the conclusion that these fast jerky eye movements are always preceded by a shift of the spotlight of attention towards the future landing point of the eyes (Posner, 1980). In addition to the possibility of observing the shift of attention directly, it is feasible to monitor the competing attentional control systems in a special saccade paradigm: the anti-saccade task (Hallett, 1978). In this task, subjects are asked to perform a saccade in the opposite direction to the presentation of a visual target (the "*anti-saccade*"). However, since the appearance of the visual target itself attracts attention (Posner, 1980), subjects sometimes fail to suppress the reflexive saccade towards the target (the "*pro-saccade*").

The execution of saccades is controlled by circuits involving the superior colliculus, the parietal eye field, the frontal eye field and, ultimately, the two saccade generators in the brain stem responsible for horizontal and vertical saccades, respectively. These generators cause a fixed linear relationship between the saccade amplitude and its duration and peak velocity – known as the main sequence (Bahill, Clark, & Stark, 1975; Sparks, 2002). Data from animal experiments suggest that the correct execution of anti-saccades depends critically on the frontal cortex: single-unit activity in the supplementary and frontal eye fields of rhesus monkeys is increased during anti-saccades compared to pro-saccades (Munoz & Everling, 2004). Analogously, patients with frontal lobe lesions show an increased frequency of pro-saccades (Guitton, Buchtel, & Douglas, 1985). Therefore, the frequency of pro-saccades ("*error rate*") can be used as a measure for the efficiency of the impulse control mediated by the frontal cortex. In normal subjects, saccadic reaction times (SRTs) are negatively correlated with the error rate: subjects with shorter SRTs show higher error rates (Evdokimidis et al., 2002). The contrary is shown in a study about the effects of ethanol: ethanol caused longer SRTs hand in hand with decreased error rates (Khan et al., 2003).

For these reasons, we addressed the effects of video game play upon eye movements as a handle to the orienting of attention with two different saccade paradigms. The double-step task (Becker & Jurgens, 1979; Lisberger et al., 1975) was used to enforce reflexive saccades with very short reaction times. The anti-saccade task (Hallett, 1978) allowed us to measure the ability to withhold the fast reflexive pro-saccades towards a visual target. We hypothesized that VGPs display shorter SRTs compared to NVGPs in general. This reduction may be caused by an impaired impulse control or alternatively by an increased efficiency of the visuo-motor system of VGPs. Independent of the exact nature of the second possibility, if the first explanation were true, the error rates of VGPs should be increased compared to NVGPs. Identical error rates in VGPs and NVGPs on the other hand would definitively exclude the explanation of impaired impulse control in VGPs. Finally, we asked whether the dynamic properties of the gaze shifts, determined by brainstem circuits, display any differences between VGPs and NVGPs.

2. Material and methods

2.1. Participants

All subjects were classified according to their daily video gaming time. The time was self-reported in a questionnaire before the measurement. Subjects who reported less than 1 h per day were classified as non-video game players (NVGPs), whereas subjects with equal or more than 1 h per day were classified as video game players (VGPs). The subjects were not told to which group they belong before the experiment. This was done to avoid differential motivation effects which could have led to better performance in VGPs, simply because they think that they will perform better due to their expertise.

We measured a total of 67 subjects of whom 46 participated in both tasks. Some subjects completed only one of the two tasks. Therefore, the sample sizes are slightly different. In the anti-saccade task, a total of 56 subjects (26 NGVPs, 30 VGPs) were tested. The mean age of NVGPs was 18.6 ± 0.6 years (mean ± SE) and that of VGPs 19.5 ± 0.6 years. In the double-step task, 57 subjects were measured (27 NVGPs, 30 VPGs). The NVGPs in this task were aged 18.6 ± 0.6 years and the VGPs 19.8 ± 0.7 years. There were no significant group differences regarding age in neither task (1-factorial ANOVA: $p = 0.318$ in the anti-saccade and $p = 0.191$ in the double-step task). All experiments were performed in accordance with the Declaration of Helsinki.

The analysis of the reported daily gaming times showed that there were similar amounts of video game consumption in each task. VGPs in the anti-saccade task played on average 1.3 ± 0.1 h per day (mean ± SE) whereas VGPs in the double-step task played and 1.4 ± 0.1 h per day. All subjects had normal or corrected to normal vision.

2.2. Experimental setup

The experiments were performed on a PC (AMD Athlon 64 X2 4800+, 1 GiB DDR2 RAM, ATI Radeon Xpress 1150) with two 19 in. screens (HP L1950, refresh rate: 60 Hz, resolution: 1280 × 1024 pixels). The main control screen was connected via the DVI-Port and the stimulus screen via the VGA-Port of the graphics adapter. Data analysis and stimulus presentation was done with Matlab 2008a (The Mathworks, Natick, MA) and the Psychophysics Toolbox Version 3 (Brainard, 1997; Pelli, 1997).

Horizontal eye position was recorded with an infrared limbus tracker in front of the subject's left eye. The eye position was sampled at 1 kHz with a spatial resolution of approximately 6 arcmin (Ilg et al., 2006). Viewing distance in all experiments was kept at 57 cm and the stimuli were presented in white (luminance 60 cd/m^2) on a black background.

2.3. Saccade tasks

The duration of the entire experimental session was at most 1 h and consisted of the anti-saccade task and/or the double-step task. In both tasks, a trial began with a random fixation time between 500 and 1000 ms. A white cross with 18 arcmin edge length was presented as the fixation target at the center of the screen. Saccade targets were filled white squares with an edge length of 7 arcmin.

2.3.1. The double-step task

In the double-step task, two consecutive targets were presented with an inter-stimulus interval (ISI) of 50, 100, 250 or 500 ms. Targets could appear at 5 and 10 deg to the left and right of the fixation spot. The second target always appeared at a different position as the first target, resulting in twelve target position combinations. The subjects were asked to perform saccades towards these targets as fast as possible. A measurement consisted of two blocks of 144 trials (three repetitions for each of the four ISIs and the twelve target position combinations). For the evaluation, the datasets from the two blocks were merged. The duration of each trial was fixed to 2000 ms. Saccades towards the first target ("*saccade 1*") were defined as being closer to this target than to the second target. Otherwise they were considered saccades towards the second target ("*saccade 2*"). Corrective saccades towards either target were also detected but not include in this analysis. Entire trials were excluded from analysis if no saccade 2 was found, either saccade