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Video game experience and its influence on visual attention parameters: An investigation using the framework of the Theory of Visual Attention (TVA)

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ABSTRACT

Experts with video game experience, in contrast to non-experienced persons, are superior in multiple domains of visual attention. However, it is an open question which basic aspects of attention underlie this superiority. We approached this question using the framework of Theory of Visual Attention (TVA) with tools that allowed us to assess various parameters that are related to different visual attention aspects (e.g., perception threshold, processing speed, visual short-term memory storage capacity, top-down control, spatial distribution of attention) and that are measurable on the same experimental basis. In Experiment 1, we found advantages of video game experts in perception threshold and visual processing speed; the latter being restricted to the lower positions of the used computer display. The observed advantages were not significantly moderated by general person-related characteristics such as personality traits, sensation seeking, intelligence, social anxiety, or health status. Experiment 2 tested a potential causal link between the expert advantages and video game practice with an intervention protocol. It found no effects of action video gaming on perception threshold, visual short-term memory storage capacity, iconic memory storage, top-down control, and spatial distribution of attention after 15 days of training. However, observations of a selected improvement of processing speed at the lower positions of the computer screen after video game training and of retest effects are suggestive for limited possibilities to improve basic aspects of visual attention (TVA) with practice.

1. Visual attention and video game expertise

An interesting research question is to which extent different aspects of visual attention can be improved with excessive and intensive playing of action video games. Several studies have suggested that persons with strong expertise in video game playing are superior in a variety of attention tasks compared to video game non-experts (e.g., Bavelier, Green, Pouget, & Schrater, 2012; Dye, Green, & Bavelier, 2009; Green & Bavelier, 2003), with some of them providing even evidence for a causal relation between video game expertise and the superior attention performance (e.g., Green & Bavelier, 2003, 2006; for a critical perspective, see Boot, Kramer, Simons, Fabiani, & Gratton, 2008).

However, still these existing findings do not allow us to determine the basic mechanisms which might differ between groups differing in their amount of video game expertise. Critically, investigations reporting video-game related differences often rely on incomparable experimental paradigms and theoretical frameworks, which make a clear-cut identification of those mechanisms across studies difficult that might be at the basics of the superior attention performance in the video game experts. The current study aims at specifying such basic mechanisms in visual attention that are related to video game expertise.

Possible candidates for differences in basic mechanisms are, for example, the capacity of visual short-term memory storage (e.g. Achtman, Green, & Bavelier, 2008; Boot et al., 2008; Green & Bavelier, 2003, 2006; Spence & Feng, 2010; Tahiroglu et al., 2010; Trick, Jaspers-Fayer, & Sethi, 2005), the processing speed of visual information (Appelbaum, Cain, Darling, & Mitroff, 2013; Cohen, Green, & Bavelier, 2007; Dye et al., 2009; Green & Bavelier, 2003), the spatial resolution/distribution of attention (Castel, Pratt, & Drummond, 2005; Dye et al., 2009; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003, 2006, 2007; Riesenhuber, 2004), and the efficiency of attention top-down control (Cain, Prinzmetal, Shimamura, & Landau, 2014; Hubert-Wallander, Green, Sugarman, & Bavelier, 2011). Typically, existing studies on

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these mechanisms in video game experts use paradigms targeting different aspects of attention in a highly selective manner but with heterogeneous theoretical and methodological backgrounds. For example, evidence for increased capacity of visual short-term memory storage was demonstrated with the enumeration task (Trick & Pylyshyn, 1994). In this experimental paradigm, participants are asked to do a fast estimation of the number of items flashed briefly on a computer screen. Participants are usually able to estimate the number of items correctly within one single focus of attention if no more than 3–4 items are presented, while increasing the visual load above 3 or 4 items (i.e., the number of items shown) gradually decreases the accuracy and/or the time for their estimates. The first observation is usually said to reflect the subitizing span while the observation of a decreasing performance with increasing visual load of more than 3–4 items is assumed to reflect the counting range. The subitizing range is increased in video gamers in contrast to non-video gamers (e.g., Green & Bavelier, 2003, 2006). This has been interpreted to indicate that video gamers can maintain more items in their visual short-term memory and, therefore, have an increased capacity of this storage type.

Video gamers also outperformed non-video gamers in the attentional blink paradigm, requiring the identification of sequentially presented targets in a rapid visual stream (Green & Bavelier, 2003). The correct identification of a second target briefly presented after a first target was improved in video gamers compared to non-video gamers, and this observation is interpreted as reflecting higher visual processing speed. Furthermore, improved spatial distribution of attention in video gamers is often demonstrated with the paradigm of the useful field of view task (Feng et al., 2007; Green & Bavelier, 2003; Wu et al., 2012). In this paradigm stimuli have to be detected at different visual angles (e.g., at 5°, 10°, to 30°) under short presentation time conditions and video gamers show superior performance compared to non-gamers at larger visual angles indicating a larger spatial distribution of attention across the visual field. Interestingly, the resulting visual field in video gamers extends up to 30°, which covers a spatial region larger than most of the computer displays used by video gamers during gaming (Green & Bavelier, 2003).

Finally, studies that investigate the impact of distractors on the processing of pre-defined target stimuli suggest superior control of attention selection in video gamers. In these studies, the presence of a task-irrelevant distractor was found to interfere with target stimulus processing to a smaller degree in video gamers in contrast to non-gamers. This smaller degree of interference is suggestive for video gamers' improved focussing on the relevant visual information in sceneries with high visual load (Chisholm, Hickey, Theeuwes, & Kingstone, 2010; however, see also studies with an increased distractor interference effect on video gamers because of a larger attention focus under conditions of increased visual load, Green & Bavelier, 2003).

While the paradigms used in the studies mentioned above are well suited for targeting individual aspects of visual attention according to selected theoretical frameworks, they are highly diverse with respect to several factors. For example, they require processing of different types of stimuli (i.e. letters, digits, geometric figures, etc.), different basic attention mechanisms, different attention domains, and they often differ in the response demands. Therefore, it is difficult to draw firm conclusions whether extensive action video gaming is associated with a general and broad improvement of visual attention or whether some specific, and if so then, which specific aspects of visual attention are improved in video gamers compared to non-gamers.

2. Theory of visual attention and video game expertise

In the current study, we applied a methodological approach that allowed us to assess several aspects of perception and attention processes within one uniform experimental context that is built upon a cohesive theoretical framework of visual attention. We applied psychophysical assessment tools that are based on the theory of visual attention (TVA, Bundesen, 1990; Bundesen, Habekost, & Kyllingsbæk, 2005; Kyllingsbæk, 2006). These tools deliver, from the same set of trials, a variety of perceptual and attentional parameters that characterize several basic aspects of the individual visual attention performance of participants in a way that is free of possible influences from the motor response system.The latter is important because differences in motor response speed may also obscure differences in attention processes between video gamers and non-gamers (e.g., Castel et al., 2005; Dye et al., 2009).

Visual attention is assessed by several visual attention parameters: perception threshold (t_0), processing speed (C), iconic memory buffer (μ), visual short-term memory storage capacity (K), top-down control (α), and spatial distribution of attention (w_{lat} and w_{vert}). Quantitative estimates of these parameters are derived from modeling participants' performance in two different types of attention tasks, the whole and partial report tasks. In the whole report task participants are presented with 5 letters that are listed in columns either at the left or right side of the display for very short duration (see Fig. 1 for more details). A reproduction function can be obtained individually for each participant and the function exponentially approaches a maximum number of reported letters with increasing time of presentation (see Fig. 2). In the partial report condition participants only need to reproduce the letters of a predefined color that can be accompanied by a distractor letter of an alternative color. The parameters of visual attention can be obtained by applying an independent mathematical fitting procedure to the individual reproduction functions (Bundesen et al., 2005; Kyllingsbæk, 2006).

Using the theoretical framework of TVA has the advantage of a proven and widely accepted theory on attention mechanisms, which can explain obtained differences in the performance between video gamers and non-gamers by referring to basic characteristics of the visual attention system. In detail, TVA has a close relation to the biased-competition view of visual attention (e.g., Desimone & Duncan, 1995). According to this view, visual objects are processed in parallel and compete for selection, i.e. conscious representation. The race between objects can be biased in such a way that some objects are favored for selection, based either on automatic, “bottom-up” or on intentional, “top-down” factors. The selection of an object is synonymous with its encoding into a visual short-term memory storage with limited capacity. The selection probability is determined (a) by an object's processing rate, which in turn depends on its attentional weight, and (b) by the capacity of the short-term memory store. Different TVA parameters model the general processing efficiency of the information processing system (visual perceptual processing rate and visual short-term memory storage capacity), and specific aspects of attentional weighting, namely top-down-control (filtering), and spatial distribution of attention. The validity of TVA and the related assessment tools have already been proved in various contexts. Thus, they were applied in a number of studies to systematically characterize specific groups of younger and older adult patients (e.g., Bublak et al., 2005, 2011; Bublak, Redel, & Finke, 2006; Duncan et al., 1999; Finke et al., 2011; Finke, Bublak, Dose, Müller, & Schneider, 2006; Habekost & Bundesen, 2003; Habekost & Starrfelt, 2009; Redel et al., 2012). Furthermore, it has been shown that the TVA attention capacity parameters react differently to enhancing manipulations, such as alertness cueing (Finke et al., 2012; Matthias et al., 2009), increase of temporal expectancy (Vangkilde, Coull, & Bundesen, 2012) and stimulating pharmacological interventions (Finke et al., 2011).

An initial application of TVA-based assessment tools in the context of video gaming was realized in a study of Wilms, Petersen, and Vangkilde (2013). The authors showed larger visual processing speed in video gamers compared to non-gamers with a certain type of TVA-based assessment tools (see below for more details). As a result the authors suggested that, e.g. superior performance in other attention paradigm such as the attentional blink paradigm (Green & Bavelier, 2003) may result from the fact that video gamers process visual information at a higher rate and therefore encode visual information faster into short-term memory.