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# Differential development of visual attention skills in school-age children

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ABSTRACT

Children aged 7–17 years and adults aged 18–22 years were tested on three aspects of visual attention: the ability to distribute visual attention across the field to search for a target, the time required for attention to recover from being directed towards a target, and the number of objects to which attention can be simultaneously allocated. The data suggested different developmental trajectories for these components of visual attention within the same set of participants. This suggests that, to some extent, spatial, temporal and object-based attentional processes are subserved by different neural resources which develop at different rate. In addition, participants who played action games showed enhanced performance on all aspects of attention tested as compared to non-gamers. These findings reveal a potential facilitation of development of attentional skills in children who are avid players of action video games. As these games are predominantly drawing a male audience, young girls are at risk of under-performing on such tests, calling for a careful control of video game usage when assessing gender differences in attentional tasks.

## 1. Introduction

The ability of children to pay attention is quite limited early in development; with increasing age, attentional skills improve, allowing better on-task focus and improved performance (Plude, Enns, & Brodeur, 1994). Little is known, however, about the factors that promote this development and its exact time line. This field of inquiry is complicated by the fact that attention is far from being a homogeneous concept, but rather encompasses several different skills which may or may not mature at the same rate or under the same conditions (Goldberg, Maurer, & Lewis, 2001). In this study we contrast three specific attentional skills – the ability to distribute visual attention spatially, deploy attention over time, and allocate attention to visual objects. Using a cross-sectional design, we compare the rate of development of these skills as well as their sensitivity to an environmental factor: action video game usage.

The rate of maturation of the spatial deployment of attention was tested using an adaptation of the Useful Field of View paradigm (UFOV) in which participants are asked to locate a simple target shape amongst a field of distractors (Ball & Sekuler, 1982). The developmental literature is rich in studies documenting the maturation of such visual search skills. Peak performance is noted as early as 6 years of age for simple feature search paradigms (Hommel, Li, & Li, 2004; Lobaugh, Cole, & Rovet, 1998; Ruskin & Kaye, 1990), but performance is seen to improve during school years when using complex search tasks. For example, reduced response latencies from early childhood to adolescence have been reported in conjunction searches (Hommel et al., 2004; Lobaugh et al., 1998; Ruskin & Kaye, 1990; Trick & Enns, 1998). Similarly, there is some evidence that very young children – aged between 6 and 8 years – are susceptible to the influence of distractors during conjunction searches but not during simple feature search (Hommel et al., 2004). This difference between complex and simple search tasks may reflect a rather rapid maturation of the ability to distribute attention over space, but a slower development of the mechanism that mediates feature binding (Trick & Enns, 1998). As our study focuses on a relatively simple search task, a fast development with peak performance reached by 6 to 7 years of age was expected. The children tested in this study are aged between 7 and 17 years of age, alongside 18–22 year old adults. Thus we anticipated that this paradigm would allow us to assess the impact of action video gaming on an attentional skill that was expected to be mature and stable across the age range tested.

The effect of age on the temporal dynamics of visual attention was studied using the attentional blink (AB) task, which measures how attention recovers over time once it has been allocated to an item (Raymond, Shapiro, & Arnell, 1992). In contrast to visual selective attention across space, the only developmental study available using this task suggests a protracted period of development with improvement still noted during adolescence (Shapiro & Garrad-Cole, 2003). Therefore, attention was expected to recover faster in older than in younger children, allowing older children to process a stream of rapidly presented stimuli more accurately. Developmental studies of the temporal deployment of attention

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typically focus on sustained attention or the ability to maintain attention over a range of minutes, rather than the fast recovery of attention over a few hundreds of milliseconds as measured by the attentional blink. These sustained attention studies report improvement during the primary school ages (Levy, 1980; Lin, Hsiao, & Chen, 1999). It is unknown whether these tests measure similar or distinct aspects of the dynamics of attention. Performance on sustained attention tests and the attentional blink have been shown to correlate, at least in some clinical populations such as people with schizophrenia (Li et al., 2002), suggesting these attentional skills may be under the control of some common dynamical constraints. However the extent to which they overlap remains unknown.

Finally, we used a multiple object tracking (MOT) task to assess the developmental time line of the number of objects to which attention can be simultaneously deployed. The number of objects that can be tracked has been shown to improve across the school-age years. In addition, children who were action gamers displayed increased capacity in the number of objects they could track (Trick, Jaspers-Fayer, & Sethi, 2005). While we employ a different paradigm to that of Trick and colleagues, the present study will provide not only a conceptual replication of the MOT benefit, but will also confirm that the amount and quality of action video game playing behavior in our sample is sufficient to induce observable effects.

By administering all of these tasks to the same sample of juvenile and adult participants, this study aims to establish whether different components of visual attention share the same developmental profile. If they mature at similar rates, this suggests that they share substantial underlying neural circuitry. On the other hand, differential rates of development would indicate that, at least to some extent, these visual attention processes rely upon differing neural mechanisms that are maturing at different times during the course of development. An important additional feature of this study is that children and adults who play action video games were considered separately from those that do not. Recently, it has been demonstrated that playing action video games changes several aspects of visual selective attention in adults (Green & Bavelier, 2003, 2006a, 2006b), and in particular the three attentional skills tested in this study – the efficiency of attentional allocation over space, over time and to objects. Performance of gamers was better than that of non-gamers on the UFOV search task, the AB task and the MOT task in adults (Green & Bavelier, 2003, 2006b). Importantly, the causal effect of gaming has been established through training studies. Non-gamers trained on a first-person point-of-view action video game showed significant improvement from their pre-training scores on these three measures of attention – UFOV, AB and MOT – indicating that as little as ten hours of video game playing can alter these fundamental aspects of visual attention in young adults (Green & Bavelier, 2003, 2006b).

The present study asks whether children who play action video games exhibit similar enhancement of performance on these tests as that observed in adults. Children were classified as gamers or non-gamers after selection for inclusion and prior to data analysis. Those who reported playing first/third-person 'shooter' games in the 12 months prior to testing were classified as action gamers. Other children, although classified as non-gamers, still played video games. However, these games were not action-based, did not have a first-/third-person point-of-view, and were not as fast-paced. We acknowledge that any differences observed between gamers and non-gamers may reflect pre-existing population differences, i.e. children who have better attentional skills initially may tend to be better at action-based video games, and thus more likely to play them. Although this is certainly a concern, research has shown that training using action video games leads to enhanced performance on the skills tested in adults who have not played such games in the past (Green & Bavelier, 2003, 2006a, 2006b).

Our aim was to first determine the impact of normal maturation upon the development of the ability to deploy attention over space, time and objects. To this effect, a large sample of school-aged children, aged 7–17 years, and 18–22 year old adults were tested on child-friendly versions of the UFOV, AB and MOT tasks. Once the variation due to age had been accounted for, we then assessed the difference between those who played and those who did not play action video games. We predicted that little improvement would be observed on the UFOV task (a simple search task) in non-gamers after the age of 7 years, but that those who played action video games would be able to detect peripheral targets in a field of distractors more easily than those who did not play such games. For the AB task, we predicted that the time needed to recover attentional resources would show a decrease in non-gamers as age increased from 7 to 22 years. We further predicted that resources would recover more rapidly in gamers than in non-gamers. Finally, for the MOT task, we predicted increases in performance across the age range tested in non-gamers, with an additional improvement in the number of objects that could be tracked resulting from action video game experience.

## 2. Methods

### 2.1. General method

#### 2.1.1. Participants

One hundred and fourteen school children were recruited from a suburban school district in Rochester, NY. In addition, 47 adults were recruited at the University of Rochester, Rochester, NY. Recruitment and testing took place between January 2003 and April 2007. Participants were aged between 7 and 22 years, and divided into four age groups according to the level of schooling they were receiving at the time of testing: elementary/primary school (7–10 years), middle school (11–13 years), high school (14–17 years) and university (18–22 years). While seemingly arbitrary, these *a priori* age divisions reflect transitions within the US educational system, with concomitant changes in expectations of a child's maturation and ability to attend to their school environment.

After testing, participants were interviewed about their video game playing habits. The interview aimed to establish the frequency of action video game usage in the 12 months prior to testing. For each video game the participants reported playing, they were asked how often they played that game in the previous 12 months and for how long they played it during a typical session. This approach was motivated by that used in surveys to elicit information that can be hard for interviewees to accurately recall; for example, the method is similar to that used in the UK's General Household Survey to acquire information on alcohol consumption (Office for National Statistics, 2004, chap. 9).Those who reported playing first- or third-person perspective 'shooter' games were classified post-hoc as 'gamers' (VGPs; $N = 58$). Others were designated as 'non-gamers' (NVGPs; $N = 103$). Sample size, gender, and age data for the subjects are reported in Table 1 and lists of which games were reported and how they were classified is reported in an Appendix. It should be noted that because males are more likely to play action video games our sample reflects that bias with the gamer group predominantly made of males and the non-gamer group predominantly female. We will return to this issue in the General Discussion.

#### 2.1.2. Apparatus

Stimuli were presented to participants using Matlab version 5.2.1 software and the Psychophysics Toolbox running on an Apple G4 PowerBook computer. The laptop was connected to a 23 in. Apple Cinema Display via an Apple ADC-DVI adaptor, running with a refresh rate of 60 Hz. The display was adapted to function as a