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Comparison of change detection performance and visual search patterns among children with/without ADHD: Evidence from eye movements

Belgüzar Nilay Türkan [a,*], Sonia Amado [a], Eyüp Sabri Ercan [b], Ipek Perçinel [c]

[a] Ege University, Department of Psychology, 35400 Izmir, Turkey
[b] Ege University, Department of Child and Adolescent Psychiatry, 35100 Izmir, Turkey
[c] Osmaniye Child and Adolescent Psychiatry Clinic, Osmaniye, Turkey

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ABSTRACT

Background: ADHD participants showed poorer change detection performance compared to participants without any diagnosis. The difficulty to detect changes in ADHD children might be due to their voluntary eye movement control and attentional deficits.
Aims: To evaluate change detection performance and visual search patterns of children with ADHD and compare their performances with typically developing (TD) children.
Methods and procedures: 48 children ($n_{ADHD} = 24$, $n_{TD} = 24$) participated ($M_{age} = 8$ years, 10 months). Flicker paradigm was used to evaluate change detection performance, while eye movements were recorded during the experiment.
Results: Change detection accuracies of TD children were higher compared to ADHD children. TD groups made longer fixations on the changed area and their first fixation duration was also longer than ADHD children which showed that TD children had longer fixation maintenance than ADHD children.
Conclusions: The change detection performance, which is associated with visual attention and memory, was found to be worse in ADHD children than TD children and these children made shorter fixations on the changed area than TD children. The findings were found to be in line with the difficulty to sustain attention in ADHD children that is necessary for encoding the scene properties and goal-oriented behavior.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) associated with problems in developmental, social, academic and cognitive fields as well as inattention, impulsiveness and hyperactivity symptoms (i.e. Barkley, 1997, 2006; Nigg, 2010). It was demonstrated in the previous studies, that children with ADHD have weakened cognitive control and difficulty in suppressing an elicited motor or oculomotor response compared to typically developing ones (Engelhardt, Nigg, Carr, & Ferreira, 2008; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Nigg, 2006). Apart from cognitive control, some empirical evidence (Alloway, Rajendran, & Archibald, 2009; Alloway, Elliott, & Place, 2010) suggested that visual–spatial working memory impairments that emerge in ADHD lead to impairments in tasks, requiring ADHD children to memorize task instructions and accomplish simultaneous processes accordingly (Alloway et al., 2010; Karatekin & Asarnow, 1998;

* Corresponding author at: Ege University, Faculty of Letters, Department of Psychology, 35400 Bornova-Izmir, Turkey.
E-mail address: turkan.nilay@gmail.com (B.N. Türkan).

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Karatekin, 2007). In conjunction with visual working memory, it is also important to investigate visual attention performances of ADHD children who are basically associated with attentional difficulties.

Research carried out on visual memory revealed that observers do not often detect the large and repeated changes in a scene from one viewpoint to the next. In common real world situations, a change in a scene creates a signal and it provides an automatic and internal cue for the subject, however, when the change occurs during an eye movement or an eye blink, people almost never notice the change. This inability to detect changes of an object or a scene is known as *change blindness* and this phenomenon is commonly related to attentional mechanisms, visual perception and visual working memory (Levin & Simons, 1997; Rensink, O'Regan, & Clark, 1997). It is emphasized that focused attention is necessary in order to detect changes (Mitroff & Simons, 2002; O'Regan, Deubel, Clark, & Rensink, 2000; Rensink et al., 1997). Furthermore, attention is basically directed by high level of interest without the presence of a change signal; thus, changes in the central objects (central interest) with regard to the context of the scene are detected faster than the secondary (marginal interest) changes. Rensink et al. (1997) referred to the terms "central" and "marginal" in the flicker paradigm to indicate the *level of interest* according to the theme of the scene. In addition to high-level and contextual related level of interest variable, Rensink et al. (1997) manipulated the properties of changing objects and change type variable and according to that there were three types of change that might occur on a scene: color, presence/absence and location.

Change detection performance was previously investigated in different clinical groups such as ADHD, autism and dyslexia (Burack et al., 2009; Cohen & Shapiro, 2007; Fletcher-Watson, Leekam, Turner, & Moxon, 2006; Rutkowski, Crewther, & Crewther, 2003). Cohen and Shapiro (2007) demonstrated that change detection accuracy of adults with ADHD was lower and the variability of detection performance was higher when compared to control groups. Change blindness phenomenon was studied with adults as well as children (Cohen, 2009; Fletcher-Watson, Collis, Findlay, & Leekam, 2009; Rutkowski et al., 2003; Shore, Burack, Miller, Joseph, & Enns, 2006). Cohen (2009), for instance, indicated in the flicker task that children with ADHD showed faster but less accurate change detection performances and had more commission errors compared to TD children. Even though Cohen (2009) argued that the failure in complicated visual tasks like flicker is due to the weakness in the control of the eye movement, unsystematic and disorganized visual scanning strategies, previous studies did not measure eye movement properties of these children during flicker tasks which indicate that there might be further information on the subject.

Seeing is an active process, which requires searching and finding visual information (Liversedge & Findlay, 2000) whereas eye movements are behavioral indicators of attentional direction (Deubel & Schneider, 1996; Henderson, 2003). It was argued that attention can be directed without eye movements, however, directing attention to a specific place in a scene frequently accompanies the direction of eye movements to that place (Duchowski, 2007; Feifel, Farber, Clementz, Perry, & Anllo-Vento, 2004; Liversedge & Findlay, 2000). Findings from previous studies carried out through eye tracking methodology (i.e. Droll, Gigone, & Hayhoe, 2007; Henderson & Hollingworth, 1999; Hollingworth, Schrock, & Henderson, 2001), indicated that change detection performance was influenced by fixation (eye) position and fixation latency directed to the changing area. Observers were likely to make their first fixations on the informative and high-level interest area of the scene which resulted in a rapid change detection performance (Henderson, 2003; Hollingworth & Henderson, 2000).

Several studies using eye tracking methodology (i.e. Pauc, 2010; Rommelse, Stigchel, & Sergeant, 2008; Stigchel et al., 2007) to investigate inhibition control in ADHD asserted that ADHD children tend to show deficits in voluntary eye movement control and poor inhibition of saccades (Sweeney, Takarae, Macmillan, Luna, & Minshew, 2004). Recent neuroimaging studies claimed that there is a strong relationship between the oculomotor and attentional brain systems, and impairments in saccadic control were expected to result in visual attentional deficits (Feifel et al., 2004). Therefore, when a task requires shifting the attention from the high-level interest area (central interest region) to the low-level interest (marginal interest region), ADHD children might have more difficulty due to their voluntary eye movement control and attention shifting mechanisms while detecting changes in the marginal interest regions which might result in higher accuracy differences between central and marginal changes. The results of the interactions between cognitive processes and oculomotor behavior suggested that it is important to investigate the visual scan paths of ADHD children with eye tracking equipment during visual discrimination tasks that require systematic search strategies like change detection (Cohen, 2009; Sonuga-Barke, Elgie, & Hall, 2005). Despite the relevance of eye movements on both cognitive processes of ADHD and change blindness phenomenon, eye tracking methodology was not included in the previous studies.

The main purpose of this study is to evaluate change detection performance and visual search patterns of children with ADHD and to compare their performances with typically developing (TD) children. For this purpose four questions are addressed in the present study: (a) Will children with ADHD have a lower change detection performance compared to TD children? (b) Will there be any interaction between groups and levels of interest (central/marginal)? (c) Will change detection performance differ across different types of change? And (d) Could this expected discrepancy of change detection performance between children be explained by visual scanning strategies?

2. Method

2.1. Participants

The sample included 53 children, with an age range of 8–11 years. Five children were left out of the sample, due to technical difficulties during the recording of the eye movements.