

# Reduced Visual Disengagement but Intact Phasic Alerting in Young Children with Autism

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Children with autism may have difficulties with visual disengagement—that is, inhibiting current fixations and orienting to new stimuli in the periphery. These difficulties may limit these children's ability to flexibly monitor the environment, regulate their internal states, and interact with others. In typical development, visual disengagement is influenced by a phasic alerting network that increases the processing speed of the visual system after salient events. The role of the phasic alerting effect in the putative atypical disengagement performance in autism spectrum disorder (ASD) is not known. Here, we compared visual disengagement in six-year-old children with autism ( $N = 18$ ) and typically developing children ( $N = 17$ ) matched for age and nonverbal IQ. We manipulated phasic alerting during a visual disengagement task by adding spatially nonpredictive sounds shortly before the onset of the visual peripheral targets. Children with ASD showed evidence of delayed disengagement compared to the control group. Sounds facilitated visual disengagement similarly in both groups, suggesting typical modulation by phasic alerting in ASD in the context of this task. These results support the view that atypical visual disengagement in ASD is related to other factors than atypicalities in the alerting network. *Autism Res* 2017, 10: 539–545. © 2016 The Authors Autism Research published by Wiley Periodicals, Inc. on behalf of International Society for Autism Research.

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Autism spectrum disorder (ASD) has been associated with atypical attention since the first descriptions of the condition [Asperger, 1944]. Current theories acknowledge that ASD is likely to result from multiple interacting factors [Happé, Ronald, & Plomin, 2006]. An inflexibility of basic attentional functions has been suggested to be one of the causal factors behind many of the ASD symptoms [see Keehn, Müller, & Townsend, 2013 for a review]. For example, social interaction typically requires quick shifts of attention to appropriately monitor others' actions. Looking away from aversive stimuli is also an important mechanism for reducing negative emotions (emotional self-regulation). Despite its long history, the notion of atypical attention in ASD remains controversial, as some studies have found no evidence of atypical attention in ASD [e.g., Fischer, Koldewyn, Jiang, & Kanwisher, 2014; Fischer et al., 2015].

Although a number of theories about the nature of attention exist, there is general agreement of a distinction between two fundamental types of attention. One of these is responsible for selecting specific parts of the sensory input for perceptual processing, the other is responsible for regulating the overall level of cortical

arousal. These forms of attention are dissociable on a cognitive and neurophysiological level [Corbetta & Shulman, 2002; Petersen & Posner, 2012; Raz & Buhle, 2006]. In line with Petersen and Posner [2012], we refer to selective attention as *orienting* and regulation of arousal as *alerting*. ASD has been associated with alterations in both orienting and alerting, but less is known about interactions between the two [Keehn et al., 2013]. In the orienting domain, ASD has most consistently been associated with delayed disengagement of attention from spatial locations [Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014]. The aim of the present study was to examine the effect of the alerting network on disengagement of attention.

The alerting network is closely linked to arousal mechanisms of the brain, in particular the noradrenergic system [Petersen & Posner, 2012; Robertson & Caravan, 2004; Robertson, Mattingley, Rorden, & Driver, 1998]. Transient sensory input such as brief sounds or changes in luminance trigger phasic responses in the alerting system and affects behavior and perception, usually by increasing processing speed [Fernandez-Duque & Posner, 1997; Petersen & Posner, 2012]. Phasic alerting is

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a highly influential factor in human attention. For example, task-irrelevant auditory cues presented shortly before (~200 ms) or simultaneously with visual targets greatly influence perception and oculomotor behavior, typically resulting in faster orienting and more adequate detection [Diederich, Schomburg, & Colonius, 2012; Keetels & Vroomen, 2011; Zou, Müller, & Shi, 2012]. This effect is particularly pronounced in populations with reduced tonic alertness such as patients with right hemisphere neglect [Robertson et al., 1998] or healthy participants with pharmacologically attenuated tonic noradrenergic activity [Brown et al., 2015]. Previous research has shown that people with ASD often have highly variable and inconsistent arousal responses to sensory stimuli [Hirstein, Iversen, & Ramachandran, 2001; Schoen, Miller, Brett-Green, & Hepburn, 2008] including human eyes [Kylliäinen & Hietanen, 2006] and unpredictable sounds [van Engeland, 1984]. Inconsistent responding of the alerting network is likely to lead to less adaptive allocation of attention [Orekhova & Stroganova, 2014].

#### *Visual Disengagement and the Gap Paradigm*

Claims of atypical disengagement of attention in ASD are to a large extent based on experimental findings from variants of the gap paradigm (for reviews, see [Keehn et al., 2013; Sacrey et al., 2014]). In this paradigm, participants initially fixate on a central stimulus and then make a gaze shift (or manual response) to a target that appears at one of two possible positions in the visual periphery. The saccade latency (SL) to the peripheral target is reduced if the central stimulus disappears just before or simultaneously with the appearance of the target [Csibra, Johnson, & Tucker, 1997; Pratt, Bekkering, Abrams, & Adam, 1999]. The relatively longer response latencies on trials with a remaining central stimulus (overlap trials) reflect the additional oculomotor or cognitive processes needed to disengage from the remaining stimulus. In line with previous research, we refer to this phenomenon as *visual disengagement*. Note that this term is silent with regards to the exact contribution of attentional versus oculomotor processes, which a topic of ongoing debate, as noted below. Performance in overlap trials are often compared to *baseline or (zero gap) trials* where the central stimulus disappears at the same time as the peripheral appears, or *gap trials* where a short temporal gap (typically <500 ms) is introduced between these two events.

#### *Disentangling Visual Disengagement*

Although the gap paradigm may seem easy to interpret, research in nonclinical samples have demonstrated that performance in the paradigm captures a number of processes in addition to disengagement of spatial attention

[Csibra et al., 1997; Kingstone & Klein, 1993; Pratt, Lajonchere, & Abrams, 2006; Reuter-Lorenz, Oonk, Barnes, & Hughes, 1995]. First, visual disengagement is partly accomplished by oculomotor mechanisms relatively independent of higher attentional processes. These include release of visual fixation due to reduced activity of fixation cells in the rostral pole of the superior colliculus [Dorris, Pare, & Munoz, 1997]. Second, and more important in the present context, successful visual disengagement is also highly influenced by phasic alerting. When spatially nonpredictive cues are added to overlap trials, saccadic reactions are facilitated [Pratt, Bekkering, & Leung, 2000]. Since these sounds do not provide information about where the target will appear, they are likely to affect visuospatial attention through phasic alerting. Similarly, the disappearance of the central stimulus in the gap condition is as a spatially nonspecific alerting cue [Jin & Reeves, 2009; Kingstone & Klein, 1993; Reuter-Lorenz et al., 1995]. In the overlap trials, there are no alerting cues preceding the appearance of the peripheral stimulus. Even the appearance of the peripheral stimulus (an event that occurs in gap as well as overlap conditions) is likely to trigger an alerting response. This may be even more pronounced by sudden changes in sound or visual dynamics. So far, alerting has not been manipulated experimentally in the context of a visual disengagement task with children with ASD.

#### *Visual Disengagement in ASD*

The most consistent reports of delayed visual disengagement in ASD come from prospective studies of infants at high risk for ASD by virtue of having an older sibling with the condition. So far, delayed visual disengagement is one of the earliest markers of a future diagnosis of ASD [Elsabbagh & Johnson, 2010; Jones, Gliga, Bedford, Charman, & Johnson, 2014]. Relative to other infants, infants who later develop ASD have been found to show longer SL during overlap trials with atypicalities appearing in the first or second year of life [Elsabbagh et al., 2013; Sacrey et al., 2014; Zwaigenbaum et al., 2005]. Similarly, Elison et al. [2013] reported that longer saccadic latencies during overlap trials at 7 months predicted an ASD diagnosis at 24 months. Bedford et al. [2014] further showed that reduced performance on the gap task predicts ASD outcome independently from a social orienting response (gaze following). Results from children with a diagnosis of ASD are less consistent. Although a number of studies have found clear evidence of slower disengagement in children with ASD [Goldberg et al., 2002; Kawakubo et al., 2007; Kawakubo, Maekawa, Itoh, Hashimoto, & Iwanami, 2004; Landry & Bryson, 2004], other studies have found no group differences [Fischer et al., 2013;

Kikuchi et al., 2011] or even faster disengagement [van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2001].

In summary, longitudinal studies suggest that delayed visual disengagement may be an early marker of ASD, and could thus be an important factor in the developmental trajectory of the condition. At the same time, the findings from children with a confirmed diagnosis of ASD are much less consistent. This stresses the need for a better understanding of the mechanisms underlying the putative altered visual disengagement in ASD.

### The Current Study

The aim of the study was twofold. First, in light of the conflicting evidence so far we wanted to re-assess the reduced visual disengagement hypothesis of ASD, stating that children with ASD would show evidence of delayed visual disengagement compared to typically developing children. Second, we aimed to compare the influence of phasic alerting on visual disengagement in the two groups. In line with previous findings of atypical alerting and arousal in ASD, we expected a differential effect. Although the second hypothesis was undirected, we reasoned that this analysis could potentially shed new light on one important mechanism involved in the gap task and in visual disengagement in general. In line with previous studies [Kingstone & Klein, 1993; Pratt, Bekkering, & Leung, 2000], we manipulated alerting by adding a brief spatially nonpredictive sound before the offset of a subset of the overlap trials. In general, one would expect latencies to decrease with increases in alerting cues, which induce a state of readiness to respond.

## Methods

### Participants

Children with ASD were recruited from a habilitation center in the Stockholm area. Data was collected from 18 children. In addition, five children with ASD participated in the experiment but were excluded from the main analysis because they had a diagnosis of learning disability (LD) according to medical records or clinical assessments. Diagnosis was independently confirmed by assessment with the ADOS-2 (17 children) or by records from medical assessment including the ADOS-2 (one child). An initial group of TD participants ( $N = 24$ ) was recruited from a database of families volunteering to participate in developmental research. All participants were assessed with either the WISC-IV [ $N = 9$ ; Wechsler, 2003] or the WPPSI-III [ $N = 27$ ; Wechsler, 2002]. A nonverbal IQ measure was calculated using a method suggested by Black et al. [Black et al., 2009] and used for further analyses. For each child with ASD, we selected the child with TD of the same gender that was

**Table 1. Demographic Information and Clinical Measures**

Measure	ASD ( $N = 18$ )	TD ( $N = 17$ )
Age (years)	6.5 (1.75)	6.5 (1)
Number of females	4	4
Non-verbal IQ	105 (26)	117 (19)
SRS total T-score	79 (16)	44 (6)
ADOS-2 total score	13.65 (5.25) <sup>a</sup>	—

<sup>a</sup>Based on 17 children.

closest in NVIQ as a matched control. After this, no significant group differences were found for age ( $P > .30$ ) or nonverbal IQ ( $P = .09$ ), see Table 1. Our main analysis concerned these NVIQ- and age matched groups. However, all analyses were also run in the full sample (i.e. with children who were not included in the NVIQ-matched groups, see Results). This did not change any of the results. Children with TD had no psychiatric or medical diagnosis, according to parent report, and did not show clinical signs of ASD as assessed by the Social Responsiveness Scale [Constantino & Gruber, 2002; all  $T$ -scores  $< 60$ ]. One child in the TD group was excluded because of low data quality (see *Data analysis*). In sum, data from 18 children with ASD and 17 children with TD was analyzed.

### Stimuli and Equipment

Stimuli were presented on a Tobii TX120 eye tracker (Tobii Inc, Danderyd, Sweden) using the Tobii Studio software and recorded with a sample rate of 60 Hz. All participants completed a 5-point calibration procedure before the onset of the experiment. We used a modified gap paradigm with three main conditions. On silent overlap trials, a peripheral stimulus appeared while the central fixation stimulus remained on the screen. On auditory overlap trials, a brief spatially nonpredictive sound preceded the peripheral stimulus. We interpret the difference between these two conditions as reflecting the influence of phasic alerting on visual disengagement. We also included a baseline or zero-gap condition on which the central stimulus disappeared at the same time as the peripheral stimulus disappeared. In contrast to the more widely used gap trials, such baseline trials evoke less alerting. In contrast to overlap trials, orienting during baseline trials require less visual disengagement to be effectively executed. We used baseline trials as a control condition for inter-individual variability in low-level oculomotor processes. The visual stimuli were a range of animated images depicting everyday objects such as houses, toys, tools and kitchen utensils and geometric forms. Animation effects (tilting, expanding and contracting or brief changes in luminance) were applied to increase participants' attention. Central and peripheral stimuli had an approximate extension of  $4.6^\circ$  of the visual field in horizontal dimension.

## Procedure

All trials started with a central fixation target. This stimulus remained on screen during an interval varying from 1000–2800 ms before the peripheral stimulus appeared. Peripheral stimuli could appear at one of two locations (right or left) at 13° eccentricity from the center of the screen. On overlap trials, the central stimulus remained visible when the peripheral stimulus was shown. On baseline trials, the central stimulus was extinguished simultaneously with the appearance of the peripheral stimulus. The peripheral stimulus remained visible for 1000 ms.

Trials could be either silent or combined with a brief sound lasting 160–480 ms and with a variable offset between 200 and 400 ms before the appearance of the peripheral stimulus. Previous studies have shown that alerting cues during this interval produces a reliable reduction of SLs in people with TD [Kingstone & Klein, 1993].

In total, 72 trials were presented (48 overlap trials and 24 baseline trials). Half of the trials of each type were presented with sound. Silent baseline trials were included as a measure of overall oculomotor speed (see below). Auditory cues were added to 50% of the baseline trials in order to prevent anticipatory learning (ie., that auditory cues would predict overlap trials). Trials were presented in pseudorandom order in 12 separate blocks with six individual trials in each block. The order of the blocks was randomized. Children watched the stimuli in three separate sessions interleaved with short breaks. The order of these sessions was counterbalanced across participants. The participants were asked to watch the screen closely, but were given no further instructions.

### Data Analysis

Fixations were identified using the Tobii Fixation Filter with velocity and distance threshold set to 35 pixels. Data was further analyzed using scripts written in Matlab (Mathworks Inc., CA, USA) by the first author. Trials were discarded if the child did not have a valid fixation at the area of the central stimulus at the onset of the peripheral stimulus, or if the child failed to fixate the peripheral stimulus within a 100–1000 ms time window after its onset (saccades with latencies <100 ms after the onset of the peripheral stimulus were defined as anticipatory, and were not included). Trials were also rejected if 1) the participant failed to fixate the central stimulus during at least 50% of the period before the peripheral stimulus appeared, or if 2) more than 33% of the raw samples were invalid. In addition, all data from one child in the TD group was rejected because of low data quality, likely resulting from technical failure. No group differences were found for the percentage of lost trials (due to failure to orient towards the peripheral stimulus or low data quality) in the ASD group (5.7%)

**Table 2. Saccadic latencies (Raw Values) and Proportion of Rejected Trials by Condition (Means and Standard Deviations)**

	ASD	TD
Baseline		
Saccadic latency	263 (38)	268(44)
% Rejected trials	6.4(7.3)	6.21(9.0)
Overlap (silent)		
Saccadic latency	361 (72)	330(64)
% Rejected trials	6.3 (6.5)	6.4(7.0)
Overlap (cued)		
Saccadic latency	341(85)	303(63)
% Rejected trials	5.7(7.6)	7.5(7.3)

and the TD group (4.8%),  $P = .60$ . Number of included trials and raw saccadic latencies are shown in Table 2.

For each condition, we computed the median saccadic latency in milliseconds to orient to the peripheral stimulus, defined as the onset of the peripheral stimulus subtracted by the first time point when a valid fixation was detected at the peripheral stimulus. The choice of the median rather than the mean as central value was determined based on visual inspection of the overall distribution of SLs, which indicated positively skewed data. To control for individual differences in overall oculomotor speed, we subtracted the median latency in the overlap conditions from that in the silent baseline condition. As expected, no group difference was found in the silent baseline condition ( $P > .5$ ). Baseline corrected SLs to the peripheral stimulus was used as dependent variable in the main analysis. All variables conformed to the assumption of normality according to the Kolmogorov-Smirnov test (all  $P > .08$ ).

## Results

Data from the (baseline corrected) overlap condition was analyzed using a  $2 \times 2$  repeated measures analysis of variance (ANOVA) with group (TD, ASD) and type (silent, cued) as factors. This analysis showed a main effect of condition, driven by shorter SLs after auditory cues,  $F(1, 33) = 5.958$ ;  $P = .020$ ;  $\eta^2 = .16$  and a main effect of group, driven by overall longer SLs in the ASD group,  $F(1) = 6.102$ ;  $P = .021$ ;  $\eta^2 = .15$ , but no group x condition interaction effect,  $F(1,31) = 0.003$ ;  $P = .958$ . To examine the generalizability of our results, we reran all analyses, including children with LD and valid data ( $N = 2$ ) and TD children ( $N = 5$ ) who were not selected as matched controls. This did not change any of the results.

## Discussion

As expected, we found slower visual disengagement in children with ASD than in the typically developing



children. This effect of group was not modulated by the presence of auditory alerting cues. In fact, both groups showed the expected facilitation of alerting in terms of disengagement latencies. Together, this study replicates previous findings of delayed visual disengagement in ASD, but does not support the hypothesis that children with ASD benefit differently from phasic alerting during tasks requiring visual disengagement.

To our knowledge, this is the first study to include experimental manipulations of alerting cues in a visual disengagement task with children with ASD. As noted in the introduction, delayed visual disengagement may be one of the earliest markers of ASD, and could be implicated in the development of the condition. A better understanding of the mechanisms underlying visual disengagement in ASD is therefore of great importance. Our results demonstrate that phasic alerting contributes to visual disengagement latencies in children with ASD.

Even with alerting cues present, the ASD group showed longer disengagement latencies than the TD group. Nevertheless, the improved disengagement after alerting cues suggest that strategies targeting the alerting network may be used to help children with ASD achieving more flexible visuo-spatial attention. This adds to a previous literature that found auditory phasic alerting to partly normalize attention and cognitive functioning in other clinical conditions such as ADHD [O'Connell, Bellgrove, Dockree, & Robertson, 2006] and right hemisphere neglect [Robertson et al., 1998]. Since the orienting and alerting mechanisms differ in their neural underlying factors [Raz & Buhle, 2006], this finding could be important for understanding the pathophysiology of ASD.

Given the small sample size, our results await replication in larger samples. The moderating effects of individual differences should also be examined further. A limitation of the study is that the control group had high NVIQ (although not significantly different from the ASD group). Two recent studies by Fischer and colleagues reported typical visual disengagement in toddlers [Fischer et al., 2013] and 9-year olds with ASD [Fischer et al., 2015]. There are some notable differences between these studies and the current one. Most importantly, we used dynamic images as stimuli, whereas Fischer and colleagues used static images. Dynamic and multimodal stimuli may be particularly likely to lead to slow disengagement in children with ASD [Sabatos-DeVito, Schipul, Bulluck, Belger, & Baranek, 2016]. Also, in our study, peripheral stimuli appeared within a variable interstimulus interval after the onset of the central stimulus. In contrast, Fischer and colleagues used a constant interstimulus interval [Fischer et al., 2015] or only two possible intervals [Fischer et al., 2013]. A constant or less variable interstimulus interval

could potentially enable the participants to form expectations about the stimulus onset.

Our results implicate that phasic alerting effects should be experimentally controlled and systematically manipulated in future studies. For example, it is likely that various characteristics of the stimuli during overlap trials such as sound and visual dynamics can have an alerting effect. To sum up, we did not find a differential effect of alerting in children with and without ASD, although we did find evidence of delayed visual disengagement. This suggests that alerting mechanisms may function typically (at least in the context of reorienting from attended stimuli) whereas disengagement of attention is atypical. These results have implications for understanding the nature of atypical attention in children with ASD.

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### Conflict of Interest

The authors do not have any conflict of interest to declare.

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