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ATTENTIONAL SHIFTING DIFFERENCES IN AUTISM: DOMAIN GENERAL, DOMAIN SPECIFIC, OR BOTH?

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Abstract

Atypical attention is considered to have an important role in the development of autism. Yet, it remains unclear whether these attentional difficulties are specific to the social domain. The study aimed to examine attentional orienting in autistic (A) and non-autistic (NA) adults from and to non-social and social stimuli. We utilized a modified gap-overlap task with schematic images (Experiment 1: A=27, NA=26) and photographs (Experiment 2: A=18, NA=17). Eye-tracking data (i.e., saccadic latencies) were then compared across condition and type of stimulus (social or non-social) using multi-level modelling. Autistic adults exhibited mostly typical gap and overlap effects, as well as a bias towards social stimuli. Yet, autistic participants benefited from exogenous disengagement when orienting to social information more than non-autistic participants. Neither a domain general nor social domain specific account for attentional atypicalities in autism was supported separately. Yet, subtle combined domain differences were revealed in the gap condition.

Lay abstract

Previous research has shown that autistic individuals look at other people less and orient to them more slowly than others. Yet, it is still unclear if this represents general visual differences (e.g., slower looking at any new information, social or not) or a uniquely social difference (e.g., only slower looking to humans but not objects). Here we aimed to examine how quickly autistic and non-autistic adults look to and away from social (i.e., faces) and non-social information (i.e., squares and houses). We used an attentional shifting task with two images where sometimes the first image disappears before the new image appears (makes it easier to notice the new image) and other times it stays on the screen when the new image appears. In Experiment 1 we showed schematic faces and squares to 27 autistic and 26 non-autistic adults and in Experiment 2 we showed photographs of faces and houses to 18 autistic and 17 non-autistic adults. In general, autistic adults looked at the new non-social or social images similarly to non-autistic adults. Yet, only autistic adults looked at new social information faster when the first image disappeared before the new image appeared. This shows that autistic individuals may find it easier to notice new social information if their attention is not already occupied.

Keywords: autism, adults, gap-overlap, eye tracking, saccadic latencies

Introduction

Although not a diagnostic characteristic, atypical attention is considered to have an important role in the development of autism (e.g. Mottron, Dawson, Soulières, Hubert, & Burack, 2006). Attentional atypicalities, especially in relation to social contexts, are likely to have an impact on the development of other social and cognitive skills (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008), such as joint attention (Mundy & Newell, 2007) or Theory of Mind (Baron-Cohen, 2000). According to social motivation theory, reduced social attention may limit attention to social cues, which then may diminish social learning opportunities (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). Research findings are relatively inconsistent on whether these attentional differences in autism are domain general or social domain specific (e.g. Chawarska, Volkmar, & Klin, 2010; J. Fischer, Koldewyn, Jiang, & Kanwisher, 2014; Kawakubo et al., 2007; Kikuchi et al., 2010; Landry & Bryson, 2004; van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2001).

Attentional orienting, resulting in preferential selection of social information, is fundamental in the social domain (Ames & Fletcher-Watson, 2010). Research to date shows that autistic (A) individuals orientate to social stimuli less than non-autistic (NA) individuals (e.g. Klin, Jones, Schultz, & Volkmar, 2003; Riby & Hancock, 2008; Swettenham et al., 1998). Yet, autistic individuals may have atypical general attention mechanisms resulting in difficulty shifting attention between a range of social or non-social stimuli (Courchesne, Townsend, Akshoomoff, & Saitoh, 1994). If so, social orienting difficulties may not reflect atypical social attention, but may instead be caused by domain general abnormalities in visual attention (van der Geest et al., 2001). Alternatively, it is possible that both domain general and social domain specific differences are present in autistic individuals. In other words, there may be general delays disengaging and shifting attention that are more evident for social stimuli (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998).

To distinguish domain general and social specific attention atypicalities from one another and from contextual effects, it is crucial to investigate social and non-social components of attention in controlled experimental studies (Ames & Fletcher-Watson, 2010). The examination of saccadic eye movements in gap-overlap tasks allows us to measure such attention processes. Attention orienting is thought to act in three steps: disengagement from its current focus, capture by a target (i.e. shift), and engagement of the target (Posner, Walker, Friedrich, & Rafal, 1984). It is further proposed to be controlled by two mechanisms: exogenous (e.g. reacting to a sudden change in luminance), which is a relatively reflexive response to the external stimulus; and endogenous (e.g. reporting the colour of the presented word), which depends on internal, volitional, or central executive control (Posner, 1980). In gap-overlap tasks participants are shown a central fixation point, or other stimulus, which precedes the appearance of a stimulus presented to either side of the screen (B. Fischer, Gezeck, & Hartnegg, 1997). Manipulation of the interval between the central and peripheral stimulus presentation allows for the observation of both types of disengagement when contrasted to the baseline condition. In the baseline condition the central fixation point disappears at the same time as the peripheral stimulus appears. In the gap condition the central fixation point is removed before the peripheral stimulus appears (exogenous disengagement). In the overlap condition the central fixation point remains on the display when the peripheral stimulus is presented; thus, attention has to be disengaged intentionally (endogenous disengagement).

Saccadic reaction time tends to be faster in the gap condition and slower in the overlap condition, because attention is already disengaged when the peripheral stimulus is presented in the former condition, but still engaged in the latter one (B. Fischer & Weber, 1993; Saslow, 1967). When combined with social and non-social stimuli, it can provide an insight into domain general and social specific processing by revealing whether attentional shifting atypicalities in autism differ based on stimulus type.

Gap-overlap tasks have often been used to investigate attention shifting from and to non-social stimuli and show that attentional atypicalities in autism might be independent of social contexts. For example, Landry and Bryson (2004) found that autistic children were less likely to disengage their attention in overlap trials in comparison to children with Down's syndrome or typically developing children. This effect has further been shown to apply to motor responses in autistic children (Todd, Mills, Wilson, Plumb, & Mon-Williams, 2009), and has been observed in autistic adults (Kawakubo et al., 2007), as well as infant siblings of autistic children (Elsabbagh et al., 2009). Not all research utilizing the gap-overlap task with non-social stimuli has produced similar findings, however. For instance, van der Geest et al. (2001) claimed that atypical attentional engagement, but not disengagement, took place in their sample of autistic children. Other researchers using the gap-overlap task have not found attentional differences between autistic and control groups when examining children (Crippa et al., 2013; Mosconi et al., 2009), adolescents (Goldberg et al., 2002) or adults of below average cognitive ability (Kawakubo, Maekawa, Itoh, Hashimoto, & Iwanami, 2004). These findings, across different ages, challenge studies finding group differences and suggest that domain general attentional difficulties may not be universal in autism.

Only studies directly comparing both social and non-social attention can offer an insight into whether attentional shifting differences in autism, if present at all, are domain general or specific to the social domain. Only a few studies (Chawarska et al., 2010; J. Fischer et al., 2014; Kikuchi et al., 2010; Mo, Liang, Bardikoff, & Sabbagh, 2019) have applied a gap-overlap task to directly investigate both social and non-social attention differences in autism. Chawarska et al. (2010) utilized the overlap condition with face and non-face central stimuli to investigate attentional disengagement from faces in autistic toddlers. They found that whilst autistic children disengaged from non-face stimuli similarly to typically developing or developmentally delayed toddlers, they disengaged slower from central face stimuli. Kikuchi et al. (2010) compared disengagement from social and non-social stimuli in autistic and typically developing children in both gap and overlap conditions. They found that typically developing children responded slower in the overlap condition when the central stimulus was a face compared to when it was a house. However, slowed disengagement from the social stimulus was not present in the autistic group. They did not find any differences between groups or type of central stimulus in the gap condition. This atypical social attention by disengaging from social stimuli faster than typically developing children may indicate a weaker engagement with social stimuli in autism. More recently Mo et al. (2019) looked at attentional shifting to social and non-social peripheral stimuli in autistic children and found generally slower attentional shifting, unless the object displayed fell under circumscribed interests. J. Fischer et al. (2014) included social stimuli for both the central and the peripheral target, when investigating disengagement and social capture in autistic children and found no differences in comparison with the typically developing children. In their study, autistic children disengaged from the central social stimulus similarly to typically developing children. They also shifted their attention towards social peripheral stimuli faster than non-social stimuli as did typically developing children. This indicates a lack of impairment in both domain general and social domain specific attention in autism. Therefore, the findings comparing general or social domain specific disengagement or engagement issues in autism are inconsistent.

The present study, firstly, aimed to investigate domain general and social domain specific attentional atypicalities in autism by using both non-social and social stimuli to examine attentional engagement and disengagement in autistic adults. The inclusion of trials where both stimuli are non-social to those involving social stimuli allowed us to determine the presence of domain general (i.e. differences in all trials) or social domain specific (i.e. differences in social trials) atypicalities in autism. In contrast, combined atypicalities in general and the social domain would be supported if autistic participants experienced different attentional shifting with all stimulus conditions, but more so with social stimuli. Secondly, the current study also aimed to evaluate whether attentional differences in autism persist, or possibly emerge, when the ecological validity of the stimuli used is increased. If attentional disengagement issues are a pervasive characteristic of autism, differences should occur independent of stimulus complexity. Thus, Experiment 1 was conducted using relatively simple monochrome shapes as stimuli (i.e. a rectangle and a schematic face). Previous research indicates that autistic individuals may respond to, for example, static graphical representations of social stimuli differently than to more socially realistic images (Riby & Hancock, 2008). Experiment 2 addressed the possibility that attentional atypicalities in autism may be dependent on the ecological validity by including colour photographs of houses (non-social) and faces (social) stimuli.

For NA individuals, it was expected that attention capture and disengagement would be, respectively, faster towards and slower from the social stimulus when compared to the non-social stimulus (Hypothesis 1). Further moderation effects were also predicted in light of findings by Chawarska et al. (2010) and Kikutchi et al. (2010). It was expected that for NA individuals the social central stimuli would result in slower response rates than the non-social central stimulus in the overlap, but not gap, condition (Hypothesis 2). Based on previous research suggesting atypical attentional orienting in autistic individuals, three possible outcomes were hypothesised: (a) domain general deficit hypothesis - longer disengagement in the overlap condition irrespective of whether the central stimulus was social or non-social (Hypothesis 3a); (b) social domain specific hypothesis - faster disengaging from and slower attentional capture by a social stimulus, but responding similarly to NA participants when disengaging from a non-social to a non-social stimulus (Hypothesis 3b); or (c) combined domain general and social domain specific deficit hypothesis - potentially taking longer to disengage in the overlap condition, but especially in case of attentional capture by a new social stimulus (Hypothesis 3c).

Experiment 1

Methods

Participants

Participants were recruited through online advertisement, previous participation in authors' studies, and word-of-mouth. Participants were reimbursed for their time (£8 per hour). Informed consent was obtained from all participants included in the study and all procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration. All the participants were living without direct support and were able to travel independently and had normal or corrected to normal vision. For the autistic group, only participants with a pre-existing autism diagnosis were invited to partake in the study and their autism presentation was confirmed using ADOS-2 Module 4 (Lord et al., 2012). Regarding the NA group, only those scoring under the cut-off point of 32 on the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) were included in the study.

The final sample consisted of 27 adults with a pre-existing diagnosis of autism (M_{Age}=38.22, SD_{Age}=13.87; 14 females) and 26 NA adults (M_{Age}=37.23, SD_{Age}=13.93; 13 females). Groups were comparable in terms of gender ($\chi^2(1)<=0.02$, p=.893), age ($t(51)=-0.26$, p=.797), and full scale IQ (A: M=110.33, SD=14.44; NA: M=110.39, SD=11.07; $t(51)=0.01$, p=.989) as measured by the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), but not their AQ (A: M=34.93, SD=6.72, Range 21:48 ; NA: M=18.62, SD=5.83, Range 5:29; $t(51)=-9.42$, $p<.001$) scores.

Stimuli and Apparatus

Monochrome stimuli were presented on a 40 x 30 cm (1024 x 768 px) CRT monitor with a white background. The stimuli measured 1.33 by 1.88 cm (0.95^{o} by 1.34^{o} of visual angle). Stimuli were either non-social (rectangle), or social (schematic face; Figure 1). Therefore, two types of stimuli were used to create four engagement/disengagement conditions based on stimulus pairs: social to non-social, non-social to non-social, social to social, and non-social to social. E-prime stimulus presentation package (Psychology Software Tools Inc., 2012) and a Tobii x120 eye-tracker (Tobii Technology AB, 2010) were used to present the stimuli and record the data.

(Figure 1)

Procedure

The task was presented in a 3x2x2 within-subject design, where one variable was the condition (gap, baseline, or overlap), the other was the type of the central stimulus (social or non-social), and the third was the peripheral stimulus type (social or non-social). The experiment encompassed 72 trials in total (6 trials per combination). Trial order was fully randomised to prevent subjects from predicting the upcoming stimulus. The task took around 15 minutes to complete.

Each participant received on-screen and verbal instructions to look at the central stimulus and shift gaze to the peripheral stimulus as soon as it appeared. At the beginning of each trial a social or non-social central stimulus was presented in the middle of the screen. The peripheral social or non-social stimulus was then presented to the right or the left of the central stimulus for 1500 ms. In the baseline condition (Figure 1b), the central fixation disappeared at the same time as the peripheral stimulus appeared. In the gap condition (Figure 1a) the peripheral stimulus appeared 200 ms after the central fixation disappeared (exogenous disengagement). Finally, in the overlap condition (Figure 1c) the peripheral stimulus appeared 200 ms before the central fixation disappeared (endogenous disengagement), thus overlapping in time. An inter-stimulus interval of 200 ms was chosen in accordance with the protocol for the gap-overlap paradigm (B. Fischer et al., 1997). The partial overlap design was chosen to avoid data loss due to potential absence of attentional shifting to the peripheral target and thus to better capture a delay in endogenous disengagement (c.f. Wilson & Saldaña, 2019). After each trial the screen went blank for 200 ms before the next trial started. The peripheral stimulus was presented 7.13^{o} (10 cm) away from the central stimulus. In line with previous studies, to minimize the possibility of anticipating the timing of the peripheral stimulus onset, the central stimulus were presented at random (1500, 3000, or 4500 ms) interval.

Data Analysis

The sampled values of eye position were utilized to compute eye velocity, which were subsequently used to determine relevant saccadic latencies (i.e. difference between the appearance of peripheral stimulus and the onset of the saccade) using a custom-built Matlab (The MathWorks Inc., 2013) script. Saccades were detected by a saccadic velocity criterion of 20^{o}/s and duration threshold of 15 ms (B. Fischer et al., 1997; B. Fischer & Weber, 1993). B. Fischer et al. (1997) suggests that in gap-overlap tasks the saccadic response should occur in a range of 80-699 ms. Thus, anticipatory saccades (defined by $RT<80$ ms) and saccades made in the wrong direction (direction errors) were excluded from analysis. Given that only 0.32% of trials across participants fell within a late response (defined by $RT>699$ ms) range, they were also excluded from further analysis (A: M=0.26, SD=0.45; NA: M=0.19, SD=0.40). Trials where participants did not engage with the stimulus or where the number of artefacts, due to blinks or head movements, made it impossible to determine the saccadic responses and so were also eliminated. The amount of overall incorrect or missing responses did not significantly differ between groups, $t(42.87)=-1.21$, $p=.233$. On average autistic participants were missing data on 24% (*M*=17.00, *SD*=22.14, range: 0-67) of trials, whilst NA participants were missing data on 15% (*M*=10.96, *SD*=13.30, range: 0-65) of trials.

As the data deviated from a normal distribution due to negative skewness, the saccadic latency data was log-transformed with the basis of 10. For the ease of interpretation, however, the means and standard deviations throughout this article are reported in their raw form. The data was then analysed using linear mixed-effect (multilevel) modelling with 2x3x2x2 design. Modelling was carried out using the nlme package (Pinheiro, Bates, DebRoy, & Sarkar, 2016) in R (R Development Core Team, 2015). Participant information including their diagnostic details (autistic or NA) was modelled at the third level of analysis. Nested within each participant, trial type with the information of condition (gap, baseline, or overlap) was modelled at the second level. Repeated measures of saccadic latencies for each trial with central (social or non-social) and peripheral (social or non-social) stimulus type as predictors were modelled at the first level.

Community Involvement

None of the community members were directly involved in the development of the research question and outcome measures, the design of the study, its implementation, and/or the interpretation and dissemination of the findings.

Results

The mean saccadic latencies in milliseconds of all three conditions per stimulus combination for both groups are shown in Table 1. Results of the multilevel modelling (see Table 2) revealed that the main effect of diagnosis was not significant. In other words, autistic (*M*=184.63, *SD*=81.27) and NA (*M*=177.37, *SD*=76.37) participants did not differ on average saccadic latencies. There was, however, a significant main effect of condition. Least square pair-wise comparisons based on Tukey HSD (Tabachnick & Fidell, 2007) showed a significant difference between saccadic latencies in the gap (*M*=154.81, *SD*=52.85) and baseline (M=172.82, SD=67.68) conditions, $t(100)=4.79$, $p<.001$, $r=.43$. The overlap condition produced significantly longer saccadic latencies (M=214.32, SD=96.64) than baseline ($t(100)=8.35$, $p<.001$, $r=.64$) or gap trials ($t(100)=13.16$, $p<.001$, $r=.80$). Peripheral stimulus type also had a significant effect on the participants' saccadic latencies. Saccadic latencies towards a social stimulus (M=173.84, SD=72.44) were shorter than towards a non-social stimulus (M=188.13, SD=84.35).

(Table 1)

(Table 2)

The effect of the peripheral stimulus type was further significantly moderated by the condition (Figure 2). Indeed, only in the overlap condition were saccadic latencies towards the social stimuli (M=159.81, SD=55.11) significantly shorter than towards non-social stimuli (M=201.38, SD=87.70), $t(2897)=5.35$, $p<.001$, $r=.10$. Saccadic latencies to social and non-social stimuli in both the gap (social: M=149.87, SD=50.09; non-social: M=159.81, SD=55.11; $t(2897)=2.65$, $p=.086$, $r=.05$) and baseline (social: M=169.37, SD=64.15; non-social: M=176.40, SD=71.05 $t(2897)=1.43$, $p=.706$, $r=.03$) conditions were similar. None of the other interaction effects in the model yielded significance (see Table 2).

(Figure 2)

Summary

Experiment 1 investigated attentional capture by and disengagement from simple non-social and social stimuli in autistic adults in comparison to NA individuals. Contrary to predictions, there was no difference in the pattern of saccadic latency responses between the autistic and NA participants. Instead, both autistic and NA adults responded very similarly: faster in the gap (compared to baseline) condition and slower in the overlap (compared to baseline) condition. This indicates a lack of universal domain general attentional differences in autism, as both exogenous and endogenous disengagement appeared intact in the current experiment. Additionally, no social domain specific attentional differences were observed. Autistic participants responded faster when shifting attention towards faces, just like NA individuals. Therefore, no support was found for either domain general or social domain specific attentional atypicalities in autism when using simple monochrome drawings as stimuli.

These findings are consistent with some previous research using non-social gap-overlap task on autistic children (Crippa et al., 2013; Mosconi et al., 2009), adolescents (Goldberg et al., 2002), and adults (Kawakubo et al., 2004). Yet, a few of the previous studies that found differences in autism attentional disengagement used more complex stimuli: e.g. dynamic cartoons (Elsabbagh et al., 2009), illustrations (Kawakubo et al., 2007), dynamic patterns (Landry & Bryson, 2004), or photographs (Kikuchi et al., 2010). Thus, Experiment 2 was designed to replicate and further explore the findings of Experiment 1 by improving the ecological validity of the paradigm. This was achieved by utilizing photographs of faces and houses as social and non-social stimuli, respectively.

Experiment 2

Methods

Participants

A smaller sample of participants, who completed Experiment 1, also took part in the Experiment 2 within a year later. This sample consisted of 18 adults with a pre-existing diagnosis of autism (M_{Age}=38.28, SD_{Age}=13.98; 8 females) and 17 NA adults (M_{Age}=36.84, SD_{Age}=13.95; 10 females). Again, groups were comparable on gender ($\chi^2(1)=0.72$, p=.395), age ($t(33)=0.31$, p=.762) and full scale IQ (A: M=110.56, SD=14.64; NA: M=111.77, SD=10.16; $t(33)=-0.28$, p=.780), but not their AQ scores (A: M=33.83, SD=7.07, Range 21:44; NA: M=16.65, SD=5.74, Range 5:24; $t(33)=7.86$, p<.001).

Stimuli and Apparatus

Similarly to Experiment 1, two types of stimuli were used to create four capture/disengagement conditions based on stimulus pairs: social to non-social, non-social to non-social, social to social, and non-social to social. Photographs of two houses and two faces were used as stimuli. In comparison to Experiment 1, the number of stimuli was increased to two in each category to avoid the gender effect (one face was male and one female), but purposefully left small to avoid introduction of a novelty effect. Thus, the stimulus was either non-social (house), or social (face; Figure 3). Photographs of faces with neutral expressions came from the NimStim facial stimulus set (Tottenham et al., 2009). Stimuli were matched on colour scheme and size, measured 2.97 by 2.78 cm (2.13^o by 2.00^o).

(Figure 3)

Procedure

The task was presented in a 3x2x2 within-subject design, where one independent variable was condition (gap, baseline, or overlap), the second one was central stimulus type (social or non-social), and the third one was peripheral stimulus type (social or non-social). Each participant viewed 432 trials in total, presented in three separate blocks (144 trials each)[3]. Experiment 2 followed the previously described procedure albeit, due to the exclusion of late responses in Experiment 1, the peripheral stimulus was presented for 699 ms (Figure 3). Both the order of the blocks and the trials within them were fully randomised to prevent fatigue and prediction effects. Each block took participants around 15 minutes to complete.

[3] Each block was presented with a different background noise. As it was not a variable of interest for the purposes of the current study, the data has been aggregated across the different noise conditions. A model including background noise conditions can be found in Supplementary Materials.

Data Analysis

The same Matlab script and criteria, as in Experiment 1, was used to extract saccadic latencies for each trial in Experiment 2. On average autistic participants were missing saccadic latency data for 39% (*M*=168.50, *SD*=95.27) of trials, whilst NA participants were inaccurate or missing data on 31% (*M*=134.76, *SD*=73.86) of trials. The amount of incorrect or missing responses did not significantly differ between groups, $t(33)=-1.17$, $p=.252$. A multilevel analysis with the same hierarchical structure as Experiment 1 was carried out on the log-transformed (basis of 10) saccadic latency data.

Results

The raw mean saccadic latencies of all three conditions per stimulus combination and diagnosis are shown in Table 3. The multilevel model building, in general, yielded similar results to those of Experiment 1 with a few notable exceptions (see Table 4). Most importantly, the effect of condition on participants' saccadic latencies was moderated by diagnosis and peripheral stimulus type (Figure 4). The gap effect was only significant for autistic participants when shifting attention to social (gap: *M*=150.90, *SD*=59.10; baseline: *M*=167.72, *SD*=57.01; $t(66)=3.84$, $p=.014$, $r=.43$), but not non-social information (gap: *M*=158.73, *SD*=58.53; baseline: *M*=170.27, *SD*=59.90; $t(66)=2.30$, $p=.484$, $r=.27$). For NA participants, however, the gap effect was not significant when shifting attention to either social (gap: *M*=145.34, *SD*=53.27; baseline: *M*=150.86, *SD*=45.20; $t(66)=1.60$, $p=.905$, $r=.19$) or non-social stimuli (gap: *M*=143.87, *SD*=42.96; baseline: *M*=158.69, *SD*=55.61; $t(66)=3.09$, $p=.106$, $r=.36$). The overlap effect, on the other hand, occurred in both groups independently from whether the peripheral stimulus was social (A overlap: *M*=218.74, *SD*=93.25, $t(66)=7.64$, $p<.001$, $r=.68$; NA overlap: *M*=194.92, *SD*=86.68, $t(66)=7.27$, $p<.001$, $r=.67$) or non-social (A overlap: *M*=215.51, *SD*=94.94, $t(66)=6.67$, $p<.001$, $r=.63$; NA overlap: *M*=200.30, *SD*=92.95, $t(66)=6.62$, $p<.001$, $r=.63$).

(Table 3)

(Figure 4)

In addition to effects of peripheral stimulus, in this experiment the central stimulus type also yielded a significant main effect on participants' saccadic latencies. Reactions from a social stimulus (M=176.78, SD=77.37) were slower than from a non-social (M=172.90, SD=73.82) stimulus. There was a further two-way interaction effect between central stimulus type and condition of the trial. Post-hoc comparisons showed a significant difference between saccadic latencies in the overlap condition when disengaging attention from social (M=210.94, SD=94.51) stimuli in comparison to non-social (M=202.87, SD=90.02) stimuli, t(9673)=3.31, p=.012, r=.03. Yet, there were no differences between saccadic latencies from social or non-social stimuli in the gap (social: M=149.47, SD=55.09; non-social: M=149.66, SD=52.96; t(9673)=0.65, p=.987, r=.01) or baseline (social: M=162.32, SD=53.57; non-social: M=160.84, SD=56.38; t(9673)=0.73, p=.978, r=.01) conditions.

(Table 4)

Summary

The aim of Experiment 2 was to replicate and expand on the findings of Experiment 1 by utilizing more ecologically valid stimuli. This yielded some subtle domain general and social domain specific atypicalities in autistic adults. To be precise, autistic individuals exhibited a facilitating gap effect (i.e. faster saccadic latencies in gap than baseline condition) when shifting attention to social stimuli, whilst NA participants did not. This differed from Hypothesis 3c, which predicted that autistic individuals would take longer to disengage in the overlap condition, but especially so when shifting attention to a social stimulus. The diagnostic differences in the current study occurred in the exogenous disengagement condition, instead. Regarding capture by non-social information, the pattern was similar for autistic and NA adults as neither benefited from the gap between stimuli presentation. The stimulus type had a similar effect on both autistic and NA participants. Partially in line with Hypothesis 1, the appearance of a social rather than non-social stimulus as a new target, overall, facilitated attentional capture. Responses in both groups were slower if attention had to be shifted from a social, rather than non-social, stimulus. This was especially true if that stimulus was still present on the screen when the new target stimulus appeared, as proposed in Hypothesis 2.

General Discussion

This is the first study using a modified gap-overlap task to examine both attentional capture by and disengagement from both social and non-social stimuli in autistic adults. It investigated whether domain general or social domain specific attentional shifting atypicalities are present in autistic adults. Moreover, the current study aimed to evaluate whether attentional differences in autism persist to, or possibly emerge, when the ecological validity of stimuli is increased. This was achieved by examining individuals' saccadic latencies to relatively simple schematic stimuli (Experiment 1) and more ecologically valid photographic stimuli (Experiment 2).

Attentional Shifting Differences Between Autistic and Non-Autistic Adults

Both attentional disengagement and social capture have previously been implicated in autism (e.g. Courchesne et al., 1994; Dawson et al., 1998; van der Geest et al., 2001). However, in the current research, autistic adults, for the most part, performed very similarly to age and IQ matched NA adults. They responded slower in the overlap than baseline condition and faster in the gap than baseline condition across the stimulus types. This indicates a lack of pervasive domain general attentional differences in autism, as in general both exogenous and endogenous disengagement appeared intact. Pervasive social domain specific attentional difficulties also did not occur. Autistic participants responded faster when shifting attention towards faces than non-social stimuli, just like matched controls. They also exhibited slower endogenous disengagement from photographs of faces rather than houses just like NA peers. These findings are consistent with some previous research using non-social gap-overlap task on autistic individuals (e.g. Crippa et al., 2013; Goldberg et al., 2002; Kawakubo et al., 2004). More importantly, they are also consistent with previous research using a gap-overlap task to examine both social disengagement and social capture as was done in the current study (J. Fischer et al., 2014).

Although neither the domain general, nor the social domain specific perspective were exclusively supported, the current findings indicated more subtle differences in exogenous disengagement of autistic individuals compared to NA individuals. Only autistic, and not NA , adults benefited from exogenous disengagement when shifting attention towards social information. In other words, attentional capture was facilitated by the gap before social stimulus presentation, when more realistic photographs were used, only for autistic individuals. One could speculate that NA individuals already experience a social bias when shifting attention towards a social stimulus that appears at the same time as the currently engaged information disappears, thus diminishing the facilitation effect of the increased inter-stimulus interval. Given that the difference between reaction times in gap and baseline conditions (the gap effect) is usually not as large as the difference between overlap and baseline (the overlap effect) conditions (e.g. Goldberg et al., 2002); faster attentional shifting in the baseline condition could diminish the said gap effect. In turn, this social bias may not be as strong in autistic adults, especially if attention is engaged elsewhere, and thus exogenous disengagement is required to facilitate attentional capture. These findings suggest that a combination of subtle domain general and social domain specific atypicalities in attentional shifting of autistic adults occurred when using more ecologically valid stimuli, albeit during exogenous and not endogenous disengagement.

In practical terms, this indicates that autistic individuals may benefit from more explicit prompts or instructions in guiding their attention towards relevant social information. Indeed, it has previously been observed that susceptibility to illusions in autism depends on the instructions given (Brosnan, Scott, Fox, & Pye, 2004). Furthermore, previous intervention research has also shown that participating in training for joint attention bid use resulted not only in improved joint attention, but extended to expressive language and other social characteristics in autistic children (Jones, Carr, & Feeley, 2006). Therefore, in combination with previous research, current findings further emphasise the importance of attentional bids and opportunity to disengage from the current when developing efficient interventions to improve the quality of life for autistic individuals.

Social Bias

The overall bias towards social rather than non-social information occurred in autistic and NA individuals alike. It is not surprising that NA individuals responded faster when orienting towards faces rather than rectangles or houses. Fitting with previous literature (e.g. Botzel & Grusser, 1989), this confirms that socially salient stimuli draw one's attention more than non-social stimuli. Yet, autistic adults also shifted attention to faces faster than houses. This partially contradicts the general view and previous research indicating that autistic individuals orientate less to social stimuli (Klin et al., 2003; Riby & Hancock, 2008; Swettenham et al., 1998). In contrast to these previous studies, the present research did not measure the length of attentional engagement by social targets in general, but rather how quickly attention was captured by it. Furthermore, to our knowledge, none of the studies to date explicitly compared exogenous disengagement from social and non-social stimuli in autistic and NA individuals. Thus, it is possible that even though autistic individuals orient to novel social stimuli faster than non-social stimuli, they end up engaging with the social stimulus less.

Disengagement

In contrast to NA individuals, autistic adults benefited from forcefully disengaged attention when shifting attention to social information. Yet, they exhibited typical endogenous orienting taking longer to disengage from photographs of faces than houses and shorter to orient to schematic faces than rectangles, just like NA adults. This counters some previous studies in autistic children (Landry & Bryson, 2004; Todd et al., 2009) and adults (Kawakubo et al., 2007) claiming that atypical orienting occurs due to delayed endogenous disengagement. Yet, it should be noted that these studies excluded participants' baseline disengagement, defining the gap effect as a difference in reaction time between the gap and overlap conditions. The lack of comparison to a baseline condition makes it difficult to distinguish whether the group differences are occurring due to facilitation by exogenous disengagement or the lag in endogenous disengagement. The current findings, including the comparison to a baseline condition, consequently suggest that atypical attentional orienting in autism may actually be better observed during exogenous disengagement.

Limitations and Future Directions

The current study has several strengths such as the inclusion of a baseline condition to control for participants' typical responses, careful data screening with removal of various artefacts (e.g. anticipatory saccades and directional errors), and a balanced gender distribution. It does, however, have limitations. For instance, the sample used was relatively small, but comparable to or even larger than previous studies finding atypcal attentional capture or disengagement (see Sacrey et al., 2014) . Kreft and de Leeuw (1998) suggest that at least 20 cases at the highest level are necessary for sufficient power, which is the case for both of the experiments in this study. Yet, lower power could at least partially explain the lack of significance in some post-hoc tests.

Secondly, it is possible that the current findings would have been different if broader range of individuals was included. The majority of previous studies examined younger individuals (Elsabbagh et al., 2009; Goldberg et al., 2002; Kikuchi et al., 2010; Landry & Bryson, 2004; Todd et al., 2009; van der Geest et al., 2001), whilst the current sample included only adults with above average scores on cognitive tests. Autistic characteristics have been found to increase in some autistic individuals as they grow older and decrease in others depending on their cognitive ability (see Levy & Perry, 2011). Thus, higher cogitive ability may allow some autistic individuals to deal with increasingly higher cognitive load as they mature and, subsequently, in some conditions shift attention faster (Mayer, Hannent, & Heaton, 2016). Yet, given that autism is described as a pervasive developmental disorder, its core differences should, to some degree, persist across development and symptom severity.

Whilst the current findings show that there were no sigificant differences between the autistic and NA individuals at the group level, it does not provide information on individual differences within the sample. Other individual characteristics, rather than autism diagnosis, might be a better indicator of attention shifting variability in autistic, and potentially NA , adults. For instance, previous research suggest that alexithymia may be a better predictor of other atypicalities that have been related to autism (e.g., Bird, Press, & Richardson, 2011) Moreover, the NA group in the current sample was not screened for other neurodevelopmental conditions or diagnoses.Were the individuals in both groups in this study, for example, highly socially anxious, differences may have been masked due to in delayed social disengagement associated with social anxiety (Kleberg, Högström, Sundström, Frick, & Serlachius, 2021). Whilst out of the scope for the current study, it is important to further investigate what other individual characteristics maybe be better suited to predict atypical social attention.

Conclusion

This is the first study using a modified gap-overlap task to comprehensively examine attentional capture by, and disengagement from, social and non-social stimuli in autistic adults. Autistic participants exhibited mostly intact exogenous and endogenous disengagement, as well as showed slower disengagement from faces and faster social capture similarly to NA participants. Thus, results of the current study could not be explained by either a domain general or social domain specific account only. Instead, evidence for a combination of subtle domain general and social domain specific impairments emerged, albeit in the gap rather than the overlap condition. Specifically, exogenous disengagement of attention in gap condition facilitated social capture only in autistic adults, but not NA individuals. Yet, this occurred only when more ecologically valid stimuli were used. Therefore, the current findings partially support disengagement differences by showing that autistic individuals benefit from external disengagement when orienting to social information. However, they challenge the belief that either a domain general or social domain specific view can solely account for attentional disengagement differences in autism. They also weaken the prevailing notion that attentional difficulties are pervasive by showing their dependence on ecological validity of the stimuli used.

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Figure Caption

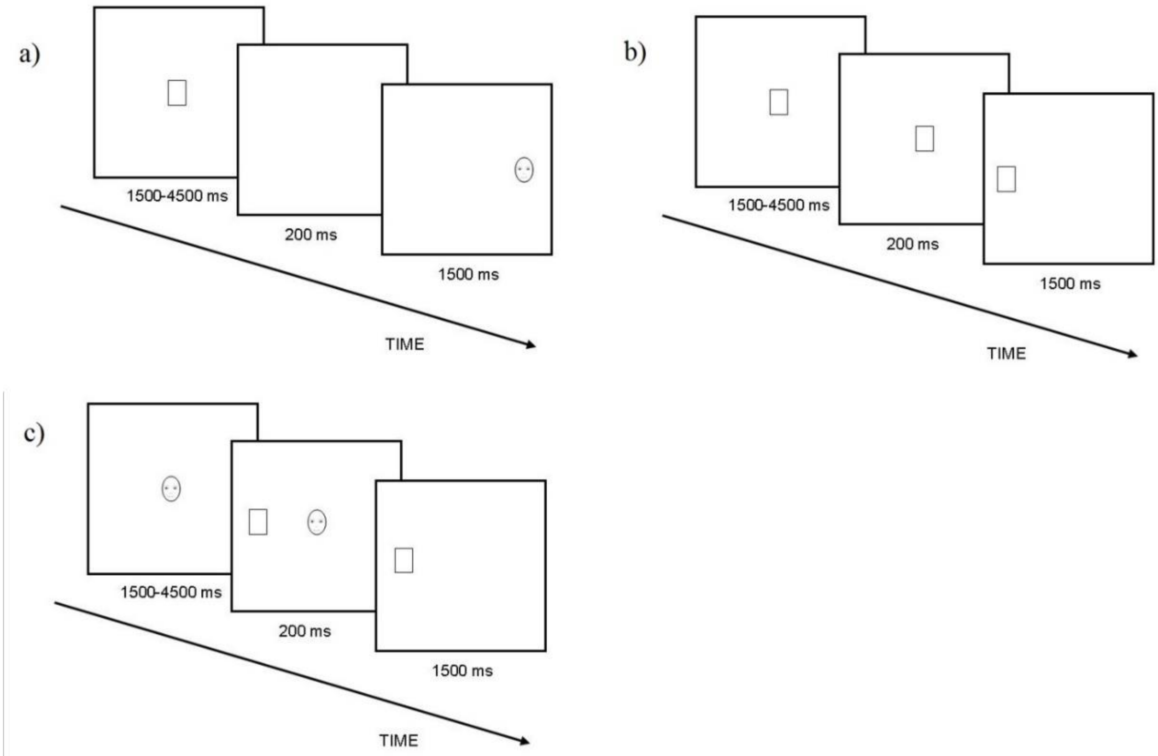
Figure 1. Schematic presentation of the sample stimulus sequence in Experiment 1: a) gap condition for disengagement from non-social to social stimulus; b) baseline condition for disengagement from non-social to non-social stimulus; and c) overlap condition for disengagement from social to non-social stimulus.

Figure 2. Mean saccadic latencies for each condition and peripheral stimulus type in Experiment 1. Error bars represent 95% CI.

Figure 3. Schematic presentation of the sample stimulus sequence in Experiment 2: a) gap condition for disengagement from non-social to social stimulus; b) baseline condition for disengagement from non-social to non-social stimulus; and c) overlap condition for disengagement from social to non-social stimulus.

Figure 4. Mean saccadic latencies for each condition, peripheral stimulus type, and diagnosis in Experiment 2. Error bars represent 95% CI.

Figure 1 top


a)
1500-4500 ms
200 ms
1500 ms
TIME
b)
1500-4500 ms
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TIME
c)
1500-4500 ms
200 ms
1500 ms
TIME

Figure 2 top

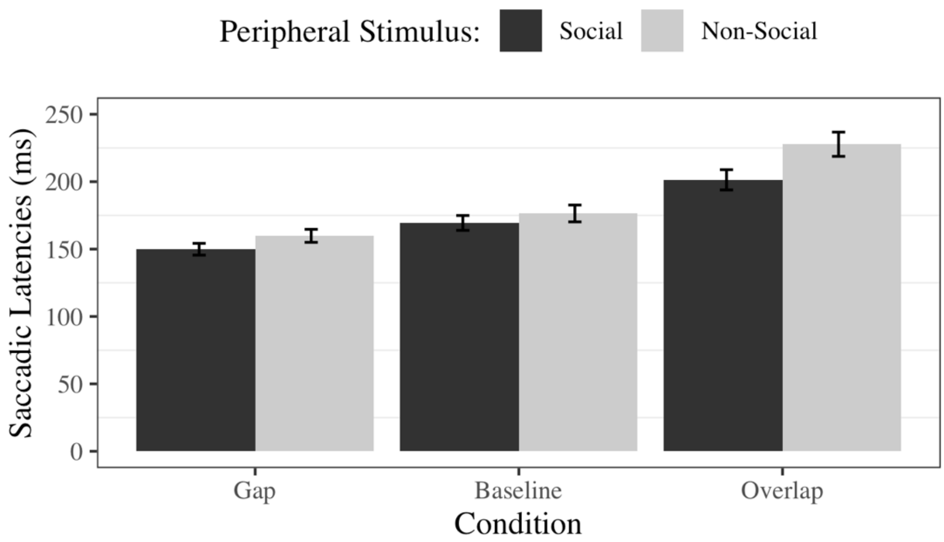
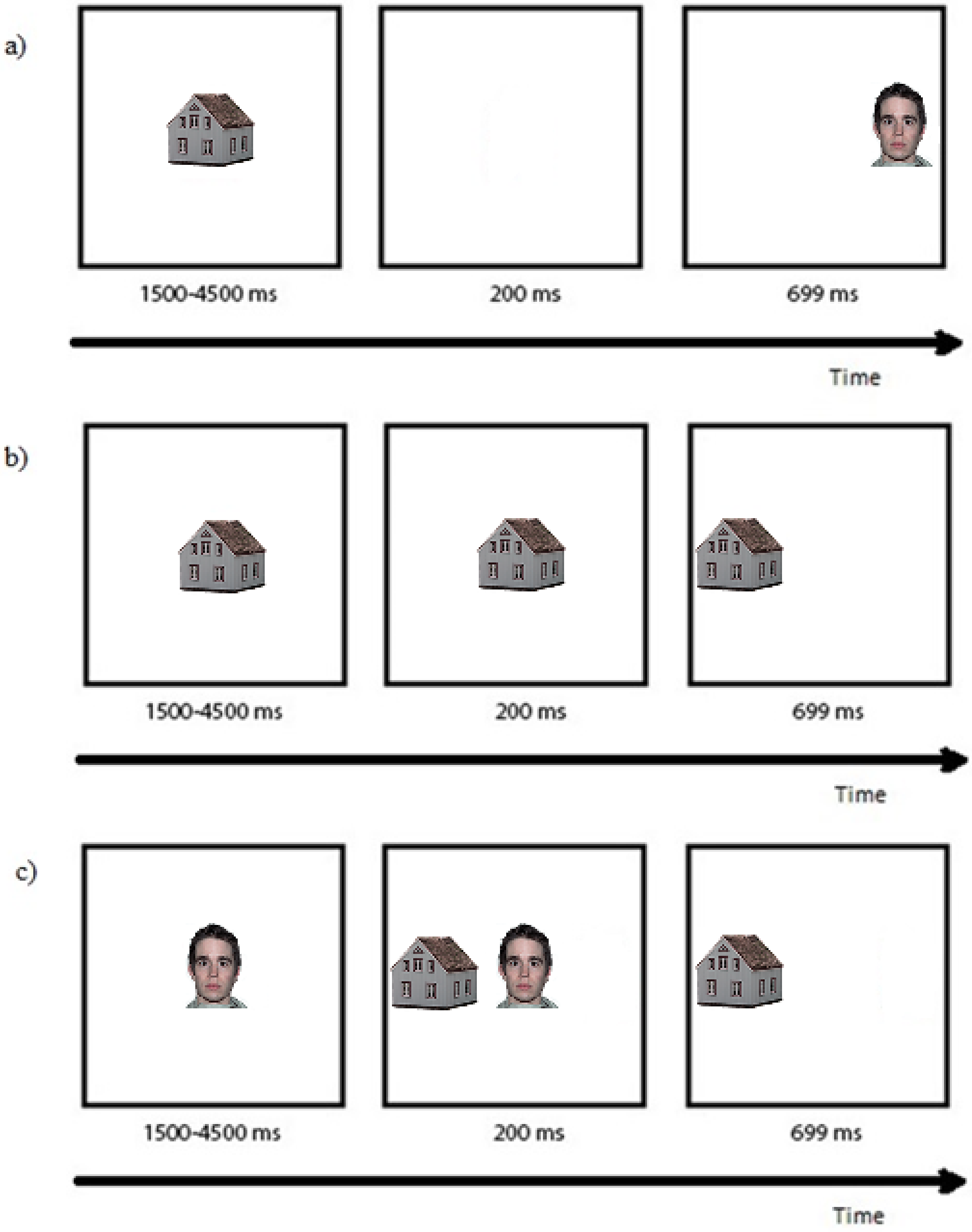

Peripheral Stimulus:
Social
Non-Social
Saccadic Latencies (ms)
250
200
150
100
50
0
Gap
Baseline
Overlap
Condition

Figure 3 top


a)
1500-4500 ms
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b)
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200 ms
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Time
c)
1500-4500 ms
200 ms
699 ms
Time

Figure 4 top

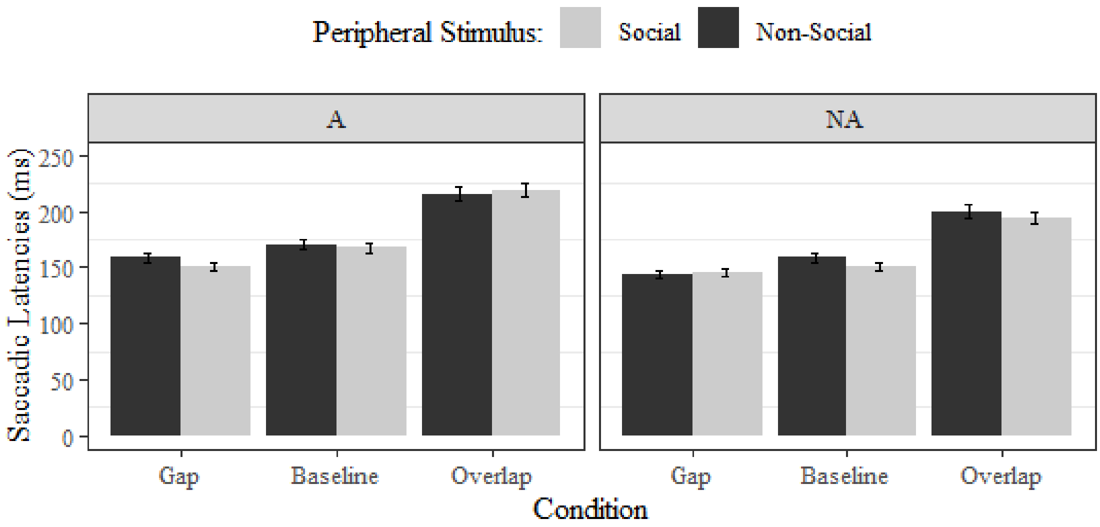
Peripheral Stimulus:
Social
Non-Social
A
NA
Saccadic Latencies (ms)
250
200
150
100
50
0
Gap
Baseline
Overlap
Gap
Baseline
Overlap
Condition

Table 1

Means (M) and Standard Deviations (SD) of Saccadic Latencies (ms) per Diagnosis and Condition in Experiment 1

	A (n=27)			NA (n=26)		
	Gap	Baseline	Overlap	Gap	Baseline	Overlap
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Social to Social	150.44 (49.55)	174.85 (79.98)	204.47 (85.86)	143.77 (44.23)	165.22 (54.64)	204.24 (88.46)
Social to Non-Social	162.71 (56.61)	183.84 (90.51)	235.76 (103.21)	161.34 (57.56)	171.89 (66.52)	222.15 (99.59)
Non-Social to Social	152.15 (41.33)	172.98 (61.35)	204.26 (88.80)	153.49 (62.17)	165.09 (59.27)	192.29 (87.98)
Non-Social to Non-Social	158.90 (48.67)	177.15 (62.64)	232.02 (108.62)	156.28 (56.92)	173.25 (60.88)	221.20 (102.82)

Note. The average scores for each condition are presented here. For subsequent analyses, log-transformed data were used.

Table 2

Saccadic Latency Model Summary of the Main Effects and Interactions in Experiment 1

	df	df_{error}	*F*	*p*	η^2_p
Condition	2	100	88.38	<.001	.64
Central stimulus	1	100	0.06	.810	<.01
Peripheral stimulus	1	2897	29.52	<.001	.01
Diagnosis	1	2897	0.75	.391	.01
Condition * Central stimulus	2	51	0.75	.474	<.01
Condition * Peripheral stimulus	2	2897	3.91	.020	<.01
Condition * Diagnosis	2	2897	0.21	.808	<.01
Central stimulus * Peripheral stimulus	1	100	0.10	.747	<.01
Central stimulus * Diagnosis	1	2897	0.02	.891	<.01
Peripheral stimulus * Diagnosis	1	2897	<0.01	.945	<.01
Condition * Central stimulus * Peripheral stimulus	2	2897	1.32	.268	<.01
Condition * Central stimulus * Diagnosis	2	2897	0.14	.870	<.01
Condition * Peripheral stimulus * Diagnosis	2	2897	0.14	.868	<.01
Central stimulus * Peripheral stimulus * Diagnosis	1	2897	0.34	.559	<.01
Condition * Central stimulus * Peripheral stimulus * Diagnosis	2	2897	0.50	.607	<.01

Note. Condition=gap, baseline, or overlap; Central stimulus=social or non-social; Peripheral stimulus=social or non-social; Diagnosis=A or NA.

Table 3

Means (M) and Standard Deviations (SD) of Saccadic Latencies (ms) per Diagnosis and Condition in Experiment 2

	A (*n*=18)			NA (*n*=17)		
	Gap	Baseline	Overlap	Gap	Baseline	Overlap
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Social to Social	152.96 (63.39)	166.65 (51.28)	226.22 (91.17)	143.87 (51.56)	152.15 (45.59)	197.70 (89.75)
Social to Non-Social	157.03 (55.95)	172.55 (58.63)	221.02 (100.49)	144.84 (47.79)	159.17 (56.76)	200.43 (93.52)
Non-Social to Social	148.81 (54.39)	168.82 (62.44)	211.09 (94.84)	146.80 (54.94)	149.56 (44.82)	192.10 (83.44)
Non-Social to Non-Social	160.31 (60.86)	168.08 (61.08)	209.67 (88.42)	142.90 (37.59)	158.24 (54.56)	200.17 (92.48)

Note. The average scores for each condition are presented here. For subsequent analyses, log transformed data were used.

Table 4

Saccadic Latency Model Summary of the Main Effects and Interactions in Experiment 2

	df	df_{error}	*F*	*p*	η^2_p
Condition	2	66	123.58	<.001	.79
Central stimulus	1	9673	3.85	.050	<.01
Peripheral stimulus	1	9673	6.89	.009	<.01
Diagnosis	1	33	2.75	.107	.08
Condition * Diagnosis	2	66	0.29	.751	.01
Central stimulus * Diagnosis	1	9673	3.49	.062	<.01
Peripheral stimulus * Diagnosis	1	9673	0.77	.379	<.01
Condition * Central stimulus	2	9673	3.70	.025	<.01
Condition * Peripheral stimulus	2	9673	1.20	.300	<.01
Central stimulus * Peripheral stimulus	1	9673	1.20	.273	<.01
Condition * Central stimulus * Diagnosis	2	9673	2.23	.108	<.01
Condition * Peripheral stimulus * Diagnosis	2	9673	5.85	.003	<.01
Central stimulus * Peripheral stimulus * Diagnosis	1	9673	0.61	.435	<.01
Condition * Central stimulus * Peripheral stimulus	2	9673	0.83	.437	<.01
Condition * Central stimulus * Peripheral stimulus * Diagnosis	2	9673	0.66	.518	<.01

Note. Condition=gap, baseline, or overlap; Central stimulus=social or non-social; Peripheral stimulus=social or non-social; Diagnosis=A or NA.