Do people with autistic spectrum disorder show normal selection for attention? Evidence from change blindness

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People in the general population are typically very poor at detecting changes in pictures of complex scenes. The degree of this ‘change blindness’, however, varies with the content of the scene: when an object is semantically important or contextually inappropriate, people may be more effective at detecting changes. Two experiments investigated change blindness in people with autism, who are known from previous research to be efficient in detecting features yet poor at processing stimuli for meaning and context. The first experiment measured the effect of semantic information while the second investigated the role of context in directing attention. In each task, participants detected the dissimilarity between pairs of images. Both groups showed a main effect of image type in both experimental tasks, showing that their attention was directed to semantically meaningful and contextually inappropriate items. However, the autistic group also showed a greater difficulty detecting changes to semantically marginal items in the first experiment. Conclusions point to a normal selection of items for attention in people with autism spectrum disorders, although this may be combined with difficulty switching or disengaging attention.

Autistic spectrum disorder (ASD) is a developmental disorder with symptoms divided into a central triad of problems with social interaction, imagination and communication. In recent years there has been increasing interest in the proposal that people with ASD visually attend to the world in an unusual way. From the evidence currently available, however, it is not clear which attentional processes are specifically impaired (see Allen & Courchesne, 2001, and Burack, Enns, Stauder, Mottron, & Randolph, 1997, for a review). For example, while some studies have shown that individuals with autism have enhanced visual search ability (Plaisted, O’Riordan, Driver, & Baron-Cohen, 2001), impaired attention shifting (Casey, Gordon, Mannheim, & Rumsey, 1993; Courchesne et al., 1994; Leekam & Moore, 2001; Wainwright-Sharp & Bryson, 1993) or disengaging (Hughes & Russell, 1993; Landry & Bryson, 2004) and difficulties with visually

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processing global figures (Happe´, 1996), other research has not found these differences (respectively, Neely, 2001; Iarocci & Burack, 2004; Leekam, Lopez, & Moore, 2000 Ropar & Mitchell, 1999). A generally accepted view, however, is that individuals with autism are good at featural processing and they are particularly able to detect detailed features in a visual array (Mottron & Burack, 2001; Mottron, Burack, Iarocci, Belleville, & Enns, 2003).

One way in which the attention of people with autism might be distinctively different from that of other people is in the way they use semantic or contextual information to select objects for attention out of the visual array. For the purposes of this study, semantic information is the meaning or role attributed to an item in the visual array, and context information refers to the relationship between an object and its surroundings. To date, there has been limited research examining the influence of semantics or context on the direction of attention in people with ASD. Previous research attempting to study the use of semantic information using a paradigm such as the Navon task (Navon, 1977) has led to mixed results (Plaisted, Swettenham, & Rees, 1999; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000), while research examining the facilitating effects of context has not required subjects to select items from a background context. A new paradigm that can be used to study the influence of semantic and contextual properties is the ‘change blindness’ paradigm (Simons & Levin, 1997).

The current study reports two change blindness experiments that aim to investigate the selection of objects from a complex scene for focused attention, and specifically the effects of semantic and contextual information on this selection process in people with ASD. Change blindness is the phenomenon whereby an individual finds it very difficult to detect changes in scenes that occur during some kind of interruption (Simons & Levin, 1997). These interruptions could be a natural saccadic eye-movement (Grimes, 1996), a blank screen (Rensink, O’Regan, & Clark, 1997; Simons, 1996), a series of ‘mud splashes’ occluding parts of a scene (O’Regan, Rensink, & Clark, 1999), a real world interruption (Simons & Levin, 1998) or a film cut (Levin & Simons, 1997). Change blindness occurs in all the situations described above because the motion cues that normally draw attention to changes are masked by an interruption. Participants often expect to be able to spot the changes (e.g. Simons & Levin, 1998) but take on average 20 seconds to do so under standard conditions (Shapiro, 2000), even when the changes made to the scene are large and significant.

Change blindness occurs because ‘attention is required to explicitly perceive a stimulus in the visual field’ (Rensink et al., 1997, p. 372). Attentional resources are limited, giving us the opportunity to attend to only about five items as we look about our environment (Pashler, 1988). Within a change blindness task, if a change occurs on any stimulus which is not attended to, it will not be detected: changes to the myriad items not attended to are overlooked until attention falls upon them. Therefore, there is a direct relationship between how quickly we detect a change and how early we directed our attention to the object that changed.

A number of theoretical descriptions of how attention is allocated have been put forward. Rensink’s coherence theory (Rensink, 2000a, 2001; not to be confused with the weak central coherence theory of autism, which is unrelated) suggests that we form volatile and limited representations of many proto-objects in a scene but select and build solid representations of only a few of these for focused attention. Henderson and Hollingworth (2000) suggest that attention is allocated to one item in the site of foveal fixation and to an additional four items represented semantically in visual short-term
memory (VSTM). These items represented in VSTM can also be transferred into long-term memory, accounting for our excellent memory for previously viewed scenes (e.g. Sperling, 1960) and our simultaneous difficulty in detecting small changes to present scenes (Simons & Levin, 1997).

While considerable research has been conducted using the change blindness paradigm with normal adults, to date there has been little theoretical detail on the influence of higher-level information on the selection of objects for attention: how do we choose the five items to which we direct attention? Findings suggest that semantic information (Hollingworth & Henderson, 2000; Rensink et al., 1997) plays a role by prioritizing the most informative stimuli that need to be attended to. Individual differences can also direct attentional focus; experts on American football are more able than novices to the sport to detect changes to a photograph from a game which alter the meaning of the scene (Werner & Thies, 2000). Thus changes to items which catch an individual’s attention are perceived rapidly. The speed of an individual’s response to a change blindness trial is therefore a measure of the extent to which the area of change captures that individual’s attention. Consequently, it is possible to use the change blindness paradigm as a tool ‘to infer the individually meaningful parts of an image from the change detection latencies of a specific subject’ (Werner & Thies, 2000, p. 172).

This principle will be used to investigate how autistic selection of items for focused attention compares with TD attention. Participants will be introduced to a standard change blindness task in Experiment 1, which will establish whether people with ASD respond in a typical or atypical way to the change blindness paradigm. In addition, this experiment will address the effect of an item’s semantic role in a scene on selection for attention. This is followed by Experiment 2, which uses the change blindness paradigm to address specifically the issue of the appreciation of context in ASD.

**EXPERIMENT 1**

This experiment closely replicates a task developed by Rensink and colleagues (Rensink et al., 1997) using the flicker paradigm. Exactly the same stimuli were used in the current study as in Rensink’s task. In Rensink’s task, participants viewed alternating images of a tourist scene in which a single inanimate object changed in one of three ways: its colour changed, it moved horizontally or vertically in the scene or it disappeared and reappeared. In addition, the image set was divided into two categories: central and marginal. Rensink et al. manipulated the images to create two kinds of change that they defined as being ‘central’ or ‘marginal’ to the scene. It is important to note that the measure of centrality and marginality is not defined by an item’s location within the borders of the image, but by the importance or semantic role of an item within a scene.

These categories were devised by Rensink and colleagues (1997) as follows: before changes were introduced, five naïve observers were asked to view the original images and describe what they could see. Those items mentioned by at least three of the five observers were categorized as central. Those items mentioned by none of the observers were categorised as marginal.

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1 For examples of this paradigm, visit [http://www.psych.ubc.ca/~rensink/flicker/](http://www.psych.ubc.ca/~rensink/flicker/)
The current study examined whether people with autistic spectrum disorder showed normal selection for attention by investigating the responses of ASD and TD participants to Rensink’s two categories of image (central and marginal). If people with autism give attentional priority to the same items as most people, then ASD and TD people alike should show an advantage for changes to central over marginal items. If people with ASD do not show this pattern of response, this could indicate differences in attentional selection.

In addition to examining the performance of people with autism using Rensink’s method, we were also able to investigate whether people with ASD would exhibit faster response times than their TD peers, regardless of whether or not they prioritize central over marginal items. Certain visual search tasks (Plaisted et al., 2001) provide evidence of enhanced performance by people with ASD. Rensink (2000b) has emphasized that there are systematic similarities between the change blindness task and visual search tasks and suggests that both tasks rely on the same underlying mechanisms. If the change blindness task uses the same system as the visual search tasks in which people with ASD excel, a group difference would be predicted, with autistic response times being quicker than TD ones overall. This potential for enhanced performance in the ASD group is also supported by anecdotal and clinical evidence, which notes that people with ASD often display highly enhanced attention to detail and abilities to detect minute changes in their environment (Howlin & Asgharian, 1999).

Method

Participants

The autism group comprised 19 high-functioning adolescents and young adults (aged 17–26 years) with ASD. There were 2 females and 17 males. All had been diagnosed with either high-functioning autism or Asperger syndrome (AS) using the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 1999) and/or the Autism Diagnostic Interview (ADI) (Lord, Rutter, & LeCouteur, 1994) and all attended a European Society for People with Autism (ESPA) specialist college for people with high-functioning ASD.

The typically developing (TD) comparison group comprised 19 students from a community college and a sixth form college (aged 17–32 years: 2 females and 17 males). The Weschler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999) was used to measure IQ. Age and IQ data for each group are illustrated in Table 1. The groups were group-wise matched on the basis of chronological age, $t_{36} = 1.768, p = .086$; full-scale

<table>
<thead>
<tr>
<th></th>
<th>ASD</th>
<th>SD</th>
<th>TD</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2.59</td>
<td>18.21</td>
<td>3.41</td>
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<tr>
<td>Overall IQ</td>
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<td>9.45</td>
<td>97.32</td>
<td>12.29</td>
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<td>82.16</td>
<td>11.15</td>
<td>98.21</td>
<td>11.90</td>
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</tbody>
</table>
IQ (FSIQ), $t_{(36)} = -1.036, p = .307$; verbal IQ, $t_{(36)} = .079, p = .938$; and performance IQ, $t_{(36)} = -1.618, p = .114$.

**Design**

The experiment used a mixed design with group (ASD and TD) as between-subjects factor and image-type as a within-subjects factor with two levels: central and marginal.

**Materials**

The images were standard change blindness images, first used by Rensink *et al.* (1997) and provided for use in this study by the author. These images are photographs of holiday scenes from around the world and all changes were to inanimate objects. The difference between each pair consists of either a change to the colour of an object, the location of an object or the presence/absence of an object. The differences were introduced by manipulating the original photographs using a computer graphics package.

This set of images was subdivided into two conditions. In half the images, the change was located on an item defined as being of central interest and in the other half the change was marginal. We adopted the category definitions produced by Rensink *et al.* (1997) for our replication of the task.

The task assessed how the centrality of an object in a scene affects the time taken to spot a difference between two images. Eighteen trials were presented, preceded by three practice trials. There were nine central trials and nine marginal trials, in random order. The trials were also counterbalanced so that in half the photographic manipulation was in the first image and in half the manipulation had occurred in the second image.

**Program**

The images were incorporated into a computer program developed for this study and run on a Sony Vaio PC laptop with a 15-inch screen. An adaptation was made to Rensink’s original flicker paradigm to make the pace of the image presentation more suitable for people with autism. Since this adapted ‘switch’ method contains all the essential elements leading to change blindness (Simons, 2000; Simons & Levin, 1997) – namely, successive presentations of stimuli separated by brief interruptions – there was reason to expect the method to produce the usual change blindness effects. The ‘switch’ method is described below (and see Figure 1):

1. Presentation of a screen, labelled with the trial number, for 500 milliseconds.
2. Presentation of the first image in the trial pair.
3. Upon pressing the SPACE BAR the participant is confronted with a blank white screen for 300 ms, automatically followed by the second image.
4. The participant may continue to press the SPACE BAR as often as he wishes. Each time he will be presented with the same blank screen for 300 milliseconds followed by the other image in the trial.
5. When the participant has noticed the change (whichever image in the pair he is currently looking at) he may press the ENTER KEY.
6. The image remains on the screen so that the participant can point to the location of the difference and verbally describe how it has changed.
7. Then the participant can move on to the next trial by pressing N.
Figure 1. A sample set of images, illustrating the sequence of displays within a trial.
**Procedure**

Participants were tested in a quiet room in their college. They were given an information sheet designed to be comprehensible to all involved and were then asked to fill in a consent form. The WASI was then administered.

Participants were introduced to the computer program by a set of instructions on the screen. The instructions were read out and explained if necessary by the investigator and the participant then carried out three practice trials. Following the practice trials there was a brief reminder of the keys to press and another opportunity to ask questions if required. Finally, each participant completed all 18 trials and was de-briefed at the end of the session.

**Scoring**

Participants could make four possible responses to a trial. They could end the trial by pressing the Enter key by accident, known as a ‘mistake’ response. They could end the trial but then incorrectly guess the location of the difference, known as a ‘wrong’ response. They could also give up and choose to move on to the next trial without finding the difference, known as a ‘pass’ response. Combined, these three types of responses are known as ‘incorrect’ responses. Finally, participants could end the trial and correctly guess the location of the difference, known as a ‘correct’ response. Tests showed that there were no significant differences in the number of incorrect responses made by each group ($t_{(36)} = 1.21, p = .234$; ASD mean = 3.26, $SD = 2.6$; TD mean = 2.26, $SD = 2.49$).

Likewise, there were no significant differences in the number of incorrect responses to central trials ($t_{(36)} = 0.73, p = .47$; ASD mean = 0.74, $SD = 1.24$; TD mean = 0.47, $SD = 0.96$) and the number to marginal trials ($t_{(36)} = 1.26, p = .218$; ASD mean = 2.53, $SD = 1.77$; TD mean = 1.79, $SD = 1.84$) made by each group. There were also no significant differences between groups when the different types of incorrect responses (mistake, wrong or pass) were analysed separately.

**Results**

**Response time data**

Response times for correct trials only are reported: since ASD and TD participants could vary in the length of time at which they decided to give up and pass the trial (i.e. their persistence at the task), inclusion of incorrect trials could reveal a spurious group difference. A total of 105 incorrect trials were removed out of 684 trials completed.

Response times were measured in milliseconds as the time from the presentation of the first image to the time that the participant found the difference and duly pressed the correct key. Examination of the data revealed no outliers nor was there any skew or kurtosis in the data (central RT skew = 1.12, kurtosis = 0.46; marginal RT skew = 1.08, kurtosis = 1.23). Therefore, all correct trials from all participants were included in the final analysis. To adjust for the dependence created by matching, analysis of covariance was used.

A separate mixed ANCOVA (Type I sums of squares) was performed on response time data with image type (central/marginal) as a within-subjects factor, group (ASD/TD) as a between-subjects factor and FSIQ as a covariate. The analysis revealed a significant main effect of image type, $F_{(1:35)} = 60.526, p < .001$. This finding is due to the fact that central changes (mean RT = 12.3 seconds, $SD = 7.4$ seconds) were spotted faster than marginal...
changes (mean RT = 19.9 seconds, SD = 10.9 seconds), as predicted. There was no main effect of group nor any effects of FSIQ (see Table 2).

Table 2. Means and standard deviations of response time, number of switches and switches per second for Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>Central</th>
<th>Marginal</th>
<th>Central</th>
<th>Marginal</th>
<th>Central</th>
<th>Marginal</th>
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</thead>
<tbody>
<tr>
<td>RT (ms)</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
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<tr>
<td>ASD</td>
<td>13,571.38</td>
<td>7,146.33</td>
<td>23,947.46</td>
<td>11,439.64</td>
<td>4.46</td>
<td>1.41</td>
</tr>
<tr>
<td>TD</td>
<td>11,095.24</td>
<td>7,639.88</td>
<td>15,880.03</td>
<td>8,930.95</td>
<td>3.62</td>
<td>1.65</td>
</tr>
<tr>
<td>Switches</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>ASD</td>
<td>4.46</td>
<td>1.41</td>
<td>10.13</td>
<td>3.98</td>
<td>0.42</td>
<td>0.24</td>
</tr>
<tr>
<td>TD</td>
<td>3.62</td>
<td>1.65</td>
<td>6.07</td>
<td>2.78</td>
<td>0.45</td>
<td>0.31</td>
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<tr>
<td>Switches/second</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
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<tr>
<td>ASD</td>
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<td>0.53</td>
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<tr>
<td>TD</td>
<td>0.45</td>
<td>0.31</td>
<td>0.48</td>
<td>0.31</td>
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</tr>
</tbody>
</table>

There was also a significant interaction between group and image-type, $F_{(1,35)} = 8.335$, $p = .007$. Post-hoc $t$ testing revealed that the group difference in response time to central images only was not significant ($p = .309$) but that the group difference in response to marginal items was significant, $t_{(36)} = 2.423$, $p = .021$. In addition, analyses were conducted on each group separately, showing that each individual group displayed a significant difference in their responses to marginal and central changes (ASD group: $t_{(18)} = 6.1$, $p < .001$, TD group: $t_{(18)} = 5.31$, $p < .001$). Therefore this group by image-type interaction reflects the fact that while both groups responded more slowly to marginal than to peripheral trials, the ASD group was also slower than the TD group in detecting marginal changes only (see Figure 2 and Table 2).

Switch data
In addition to the response time for correct trials we also analysed the number of switches made, as participants alternated between the two images for each trial, before deciding the location of the change.

A separate mixed ANCOVA (Type I sums of squares) was performed on switch data with image type as a within-subjects factor (central/marginal), group as a between-subjects factor (ASD/TD) and FSIQ as a covariate. The analysis revealed a significant main effect of image type, $F_{(1,35)} = 53.041$, $p < .001$, produced by the fact that fewer switches were made in central than in marginal trials (central mean = 4.04 switches, SD = 1.6 switches; marginal mean = 8.1 switches, SD = 3.96 switches). In addition, there was a significant effect of group, $F_{(1,35)} = 12.908$, $p = .001$, reflecting a tendency for the ASD group to make more switches per trial than the TD group (see Table 2).

Finally, there was a significant interaction between image-type and group, $F_{(1,35)} = 8.354$, $p = .007$. Post-hoc $t$ testing revealed that the group difference in number of switches on central images was not significant ($p = .1$) but that the group difference in switches on marginal items was significant, $t_{(36)} = 3.645$, $p = .001$. In addition, analyses were conducted on each group separately, showing that each individual group displayed a significant difference in their number of switches on marginal and central changes (ASD group: $t_{(18)} = 5.824$, $p < .001$, TD group: $t_{(18)} = 4.777$, $p < .001$). Therefore, this group by image-type interaction reflects
the fact that both groups made more switches on marginal than on peripheral trials, and the significant group effect was due to the difference for marginal changes only.

An analysis was made of the number of switches made by each group per second. This revealed that both groups made a similar number of switches per second across all trials and there was no significant difference. There were no interactions between rate of switching and either image type or IQ (see Table 2). This shows that the switch data reflected the RT data.

Discussion

The results of Experiment 1 showed that both groups responded with a similar pattern to the images presented: they took longer to detect marginal changes to a scene than they did to detect central changes. In other words, the ASD group showed that they perceived items as semantically central or marginal in the same way as originally defined by a TD sample. However, the pattern was not identical: although people with autism evidently found central changes as easy to detect as did their TD counterparts, the ASD group also found the marginal changes much harder to find. Since both groups were matched on multiple IQ measures as well as age and gender and since FSIQ was also included as a covariate, this difference in responding must be related to the diagnosis of autism held by the ASD group.

It appears that the ASD group were selecting items for attention in a similar way to the TD group, however, the participants with autism were less quick to move their attentional focus to marginal objects. This group difference, specifically in responding to marginal changes, may reflect a difficulty in disengaging attention from those central items initially selected for attention (Casey et al., 1993; Landry & Bryson, 2004) or shifting attention between items (Courchesne et al., 1994).

On the whole, response time and switching data in this study led to the same conclusions: slower responding overall to marginal than central images and evidence that the ASD group showed particularly poor ability to detect marginal changes.
compared with the TD group. In addition, the switching data revealed a main group difference: the ASD group overall made more switches than did their TD peers. Further examination of the switching data showed that this main effect of group was due to a difference in the number of switches made to marginal trials only – both groups made the same number of switches for central trials. This tallies with response time results, which likewise revealed slower responding by the ASD group to the marginal image category only. The correspondence between RT and switching data is further supported by the fact that both groups made a similar number of switches per second on all trials. Therefore, it is likely that the main effect of group found in the switching data is due to the greater sensitivity of this variable, and does not reflect a theoretically important distinction between the two groups.

EXPERIMENT 2

Experiment 2 was a modified replication of a change blindness study testing the effect of context on attention (Gareze & Findlay, 2002). TD participants show a bias towards selecting contextually inappropriate objects for focused attention (Henderson & Hollingworth, 2000; Hollingworth & Henderson, 2000). In this task, contextual information is investigated by comparing changes to common objects which either belong or do not belong in the room in which they are depicted (Gareze & Findlay, 2002). Items which are incongruous with their setting may be subject to the ‘pop-out’ effect (Treisman & Gelade, 1980) which occurs when an item that differs in more than one way from those around it is noticed immediately. An object that is not only unique (e.g. the only football in the room) but is also distinguished by its contextual incongruity (e.g. a football in a kitchen) should be subject to ‘pop-out’. This attention-grabbing effect is enhanced by evidence that contextually inappropriate objects may capture attention because they offer more information about the scene than predictable, appropriate ones (Henderson & Hollingworth, 2000).

Weak central coherence theory has claimed that individuals with autism have a bias for detailed or local processing because of a more general problem in integrating information into a coherent whole. This difficulty shows itself in contextual processing tasks: the person with autism should be unable to take account of the appropriateness of a context. Recent studies have shown that, contrary to the claims of weak central coherence, contextual processing is intact in autism, at least in the visual domain (Kourkouloú, Findlay, & Leekam, 2005; López & Leekam, 2003). If people with autism have weak central coherence they will not show differential responding according to inappropriate or appropriate context, whereas if people with autism can take account of context, they will respond in the same way as typical comparison participants.

Method

Participants

Participants were the same as those used in Experiment 1.

Design

The experiment had a mixed design with group (ASD and TD) as between-subjects factor and context as a within-subjects factor with two levels, appropriate and inappropriate.
Materials
The images were contextual change blindness images, first used by Gareze (2003; Gareze & Findlay, 2002) in a flicker paradigm and provided for this study by the author. These images are photographs of rooms in normal homes. The difference between each pair consists of the disappearance/appearance of an object. In this case, the images were not manipulated using a computer program but a pair of images were taken, one with and one without the target object. Since the camera was mounted on a tripod and the pictures include only static objects, no other differences between the images are apparent. The images were divided into two conditions. In half the images, the object that changed was appropriate to the scene and in half the object was inappropriate. Gareze categorized these images using a survey in which participants were asked to rate the likelihood of the target object appearing in the scene and this definition was adopted for the current study.

This second task was designed to assess how contextual information affects the time taken to spot a difference between two images. Eighteen trials were presented, preceded by three practice trials. There were nine appropriate trials and nine inappropriate trials, in a randomized order. The trials were also counterbalanced so that in half the key object was present in the first image and in half the object appeared in the second image.

Program
The images were incorporated into the switch program described in Experiment 1.

Procedure
Participants were tested in a quiet room in their college. They were given an information sheet designed to be comprehensible to all involved and were then asked to fill in a consent form.

All participants were given this second change blindness task in a single session immediately after the standard change blindness task used in Experiment 1. Previous research (Gareze, 2003; Rensink et al., 1997) has demonstrated that practice effects are not a feature of change detection tasks and there was no likelihood that experience with the first task (detecting changes to marginal or central items in a natural scene) would enhance performance in either of the contextual change detection conditions of the second task.

Participants were introduced to the computer program by a set of instructions on the screen. The instructions were read out and explained if necessary by the investigator and the participant then took three practice trials. Following the practice trials was a brief reminder of the keys to press and another opportunity to ask questions if required. Each participant completed all 18 trials and was then debriefed.

Results
Scoring
The same criteria for scoring was used as for Experiment 1. Once again, t tests showed that there were no significant differences in the number of incorrect responses made by each group (t(36) = 0.58, p = .565; ASD mean = 0.32, SD = 0.58; TD mean = 0.21, SD = 0.54). Likewise, there were no significant differences in the number of incorrect responses to appropriate trials (t(36) = 0.68, p = .501; ASD mean = 0.26, SD = 0.56; TD mean = 0.16, SD = 0.37) and the number to inappropriate trials (t(36) = 0, p = 1; ASD mean = 0.05, SD = 0.23; TD mean = 0.05, SD = 0.23) made by each group. There were also no significant differences between groups when the different types of incorrect responses (mistake, wrong or pass) were analysed separately.
Response time data
Response times for correct trials only are reported, in order to replicate directly the analysis by Gareze (2003). Moreover, since ASD and TD participants could vary in the length of time at which they decided to give up and pass the trial (i.e. their persistence at the task), inclusion of incorrect trials could reveal a spurious group difference. A total of 10 trials were excluded in this way, out of 684 undertaken by participants. Response times were measured in milliseconds as the time from the presentation of the first image to the time that the participant found the difference and duly pressed the correct key. Examination of the data revealed no significant outliers. Therefore all correct trials from all participants were included in the final analysis.

A separate mixed ANCOVA (Type I sums of squares) was performed on response time data with image type (appropriate/inappropriate) as a within-subjects factor, group (ASD/TD) as a between-subjects factor and FSIQ as a covariate. The analysis revealed a significant effect of image type, \( F_{(1, 35)} = 24.842, p < .001 \). This occurred because changes to inappropriate items (mean RT = 4.9 seconds, \( SD = 2.6 \) seconds) were spotted faster than changes to appropriate ones (mean RT = 6.6 seconds, \( SD = 3.2 \) seconds). No main effect of group was found, there was no two-way interaction between group and image type and no effects of IQ (see Figure 3 and Table 3).

Switching data
As in Experiment 1, the number of switches within each trial was also analysed.

Examination of the data revealed a serious kurtosis \( (k = 4.384) \) in the switching data only. Therefore a square-root transformation was performed, reducing the kurtosis to an acceptable level \( (k = 2.153) \) given the relatively small sample size.

A separate mixed ANCOVA (Type I sums of squares) was performed on switching data with image type (appropriate/inappropriate) as a within-subjects factor, group (ASD/TD) as a between-subjects factor and FSIQ as a covariate. The analysis revealed a significant effect of image type, \( F_{(1, 35)} = 50.136, p < .001 \). This occurred because changes to inappropriate items (mean = 2 switches, \( SD = 0.83 \) switches) were spotted after fewer switches than changes to appropriate ones (mean = 3.3 switches, \( SD = 1.7 \)

![Figure 3. Mean response time by group to Experiment 2 item changes.](image-url)
<table>
<thead>
<tr>
<th></th>
<th>ASD</th>
<th>TD</th>
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<th>ASD</th>
<th>TD</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>RT (ms)</td>
<td></td>
<td>Switches</td>
<td></td>
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<tr>
<td></td>
<td>Appropriate</td>
<td>Inappropriate</td>
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<td>Inappropriate</td>
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<tr>
<td></td>
<td>Mean</td>
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<tr>
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<td>4349.48</td>
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</table>

Table 3. Means and standard deviations of response time, number of switches and switches per second for Experiment 2.
switches). A main effect of group was also found, $F_{(1, 35)} = 9.240, p = 0.004$. This arose because the ASD group made more switches on average than the TD group (see Table 3). There was no interaction between group and image type and no effects of IQ.

An analysis was made of the number of switches made by each group per second. This revealed no significant difference between the ASD group and the TD group in switches made per second, nor were there any interactions between rate of switching and either image type or FSIQ.

**Discussion**

In this second experiment, both groups showed very similar patterns of response to the two types of images presented. Response time and switching data indicate that both groups detect changes to inappropriate objects more rapidly than changes to appropriate ones. In turn, this suggests that both groups have their attentional selection process affected by contextual information. This result contradicts weak central coherence (WCC) theory’s suggestion that people with autism have difficulty with taking context into account in a task (Frith, 1989; Happé, 1994). However it is also possible to respond to these data by arguing that the task presented here did not involve incorporating context into the perceptual process. Instead one might argue that the inappropriate objects were defined by experience more than context. Nevertheless, even using experience to identify inappropriate items in a scene requires the integration of different elements of the scene to define it as a ‘kitchen’ in the first place. Therefore we can conclude that people with autism are able to identify context in a complex scene and then use that context as a selection tool when deciding which items upon which to focus their attention.

In addition, this study revealed that people with autism were using slightly more switches per second than their TD peers. As Table 3 shows, this reflects the fact that the ASD group also had longer response times overall than the TD group, although in the response time analysis this difference did not reach significance. Furthermore, the analysis of switches per second supports the conclusion that both groups approached the task with a similar strategy. Therefore, once more, this result is attributed to a difference in the nature of the response time and switch variables and dismissed as lacking theoretical importance.

**GENERAL DISCUSSION**

The current study used the change blindness paradigm to examine the attention of people with ASD. In this paradigm, speed of response to a change blindness trial indicates importance of the area of change to that individual. Therefore, by comparing ASD and TD response times, it is possible to reveal which aspects of the environment are prioritized for spontaneous attention by each group. In this study, we examined the prioritization of central vs. marginal information (Experiment 1) and appropriate vs. inappropriate contextual information (Experiment 2).

Results showed first that the adaptation made to the methodology, using a new switch method rather than a flicker technique, was effective in producing change blindness in both experimental tasks. Previous data have shown that a number of different interruptions used to mask the movement cue normally signalling a change can induce change blindness (Simons & Levin, 1997). However, the timing of these interruptions has normally been prescribed by the experimental design, whereas in the
case of this new switch method, participants themselves could control their image viewing and the same effects were found.

Second, both tasks produced main effects of image type in the direction expected for typical adults. Experiment 1 replicated the findings of Rensink et al. (1997) showing that change blindness is exaggerated when people are asked to detect changes to items considered marginal to the scene, whereas responses are faster for central items. Experiment 2 showed that contextual information influences responses to a change blindness task. Objects that are incongruous with the rest of a scene can be spotted much more rapidly than congruous items. This finding supported previous data (Hollingworth & Henderson, 2000), although effects of context in change blindness tasks have not been found universally (Gareze & Findlay, 2002).

In comparing the responses of people with ASD with those of a TD comparison group, the overriding finding is that both groups seem to select the same items in a scene for focused attention. Experiment 1 demonstrated that both groups prioritized central items for attention, resulting in faster rates of detection for changes to central objects. Likewise, Experiment 2 demonstrated that both groups prioritized contextually inappropriate items for attention, resulting in an advantage for detecting these changes. This second finding challenges the view that people with autism have difficulty perceiving and using context spontaneously (Kourkoulou et al., 2005; López & Leekam, 2003).

The lack of a main effect of group for both experimental tasks, refutes the suggestion that change blindness tasks, being likened to visual search tasks, would elicit faster responding from the group with ASD. However, it is not possible to discover from these data whether this indicates a fundamental difference between change blindness and visual search tasks, or whether our ASD group do not possess the particular visual search ability demonstrated by Plaisted and colleagues (2001).

The second major finding of this study is the interaction between group and image type evident in Experiment 1. This interaction resulted from the fact that while both groups responded at a similar speed to central changes the ASD group showed even slower responding to marginal changes than their TD counterparts. This interaction was supported by the same pattern in the switching data. It is possible that this result indicates a problem in the ASD group with disengaging attention from central objects (Hughes & Russell, 1993; Landry & Bryson, 2004) or shifting attention between different objects (Casey et al., 1993; Courchesne et al., 1994; Leekam & Moore, 2001; Wainwright-Sharp & Bryson, 1993).

In Experiment 1, participants evidently had their attention initially captured by central items, as demonstrated by universally faster responses to central changes than to marginal ones. If no central item was changing, attention then had to be redirected to search among marginal elements of the image. It is possible that people with autism found this disengagement from central items to begin searching among marginal items especially difficult, resulting in particularly slow times to detect marginal changes.

Turning to Experiment 2, we find no group effects whatsoever and this could be interpreted as further support for the disengagement hypothesis. In Experiment 2, the changes occurred either to an appropriate or inappropriate object in the scene. In this case it can be argued that there was no need to disengage attention since the object that changed was always a prominent element in the scene whether appropriate or not. However, this is a post-hoc explanation and it is dubious whether disengagement from a category of items (the central items in a scene) can be compared with disengagement from a single stimulus (e.g. Landry & Bryson, 2004). The current data cannot fully answer the question of whether problems in disengaging attention played a part in these experiments.
The study had a number of limitations that will need to be overcome in future research. The main limitation concerns the issue of cueing. Participants were told to look for a change between two images, leading them to form an expectation about the nature of the task and to adopt a strategy for success. This instruction may have altered participants' attentional focus so that the results indicate what our participants' attention is capable of, rather than what they might attend to spontaneously. When cues have been used in tasks that test visual search (Plaisted et al., 2001), memory (Gaigg, Minhas, Bowler, & Richardson-Klavehn, 2004) or face processing (López, Donnelly, Hadwin, & Leekam, 2004), people with autism have been found to demonstrate abilities that they are not capable of in uncued tasks where no specific instruction is provided. Future work will focus on investigating whether a different task design with less cueing might reveal autistic abnormalities in attention to social stimuli. In addition, both experiments used a small subset of the images used in the original studies in order to prevent exhaustion of the sample. The data collected here could be strengthened by repetition of each experiment using a larger number of trials.

In conclusion, this application of a standardized method to a new population reveals an apparently normal attentional selection process in adults with AS and high-functioning autism. ASD participants show reduced response times when the centrality or contextual inappropriateness of the stimulus is increased. Taken at face value, the current results suggest typical allocation of attention by people with autism viewing a complex scene. Close up, atypicalities in attending to marginal aspects of the visual scene were indicated by individuals with ASD compared with TD individuals, and these atypicalities may be related to difficulties shifting or disengaging attention from central items.

The contradictions between these conclusions and other studies which have produced opposing results (e.g. Iarocci & Burack, 2004; Shah & Frith, 1993) can only be reconciled by further study of the exact nature of perceptual functioning in ASD. However, these results demonstrate good performance by ASD individuals. The change blindness paradigm has also been shown to be a successful task to use with both TD and ASD individuals to investigate attention, and may be highly suited to use with younger children. These results therefore leave open the opportunity for further examination of spontaneous attention to complex stimuli.

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