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

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Abstract

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, though this may be combined with difficulty switching or disengaging attention.

Keywords: autism spectrum disorder; change blindness; weak central coherence; attention.

Abbreviations: AS (Asperger's syndrome), ASD (autistic spectrum disorder), WCC (weak central coherence), TD (typically developing)

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Introduction

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 evidence currently available however it is not

clear which attentional processes are specifically impaired (see Allen & Courchesne, 2001 or

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, Townsend, Ashkoomoff, Saitoh, Yeung-

Courchesne, Lincoln, James, Haas, Schriebman & Lau, 1994; Leekam & Moore, 2001;

Wainwright-Sharp & Bryson, 1993) or disengaging (Hughes & Russell, 1993; Landry &

Bryson, 2004) and difficulties with visually processing global figures (Happé, 1996), other

research has not found these differences (respectively Neely, 2001; Burack & Iarocci, 1995;

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. So far, 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 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 which changed.

A number of theoretical descriptions of how attention is allocated have been put forward. Rensink's coherence theory (Rensink, 2000a; Rensink, 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, there is so far 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 prioritising the most informative stimuli that need to be attended to. Individual differences can also direct attentional focus; experts on American football are more able to detect changes to a photograph from a game which alter the meaning of the scene than novices to the sport (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 to TD attention. Participants will be introduced to a standard change blindness task in Experiment One, 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 Two which uses the change blindness paradigm to specifically address the issue of the appreciation of context in ASD.

Experiment One

This experiment closely replicates a task developed by Rensink and colleagues (Rensink et. al. 1997) using the flicker paradigm[1]. 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 re-appeared. 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 measures 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

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[1] For examples of this paradigm visit http://www.psych.ubc.ca/~rensink/flicker/ f

were categorised as central. Those items mentioned by none of the observers were categorised as marginal.

The 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 or 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 prioritise central over marginal items. Certain visual search tasks (Plaisted et al. 2001) provide evidence of enhanced performance by people with ASD. Rensink (2000b) has emphasised 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 on 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 autism spectrum disorders (ASD). There were 2 females and 17 males. All

had been diagnosed with either high-functioning autism or Asperger syndrome (AS) using the ADOS (Lord, Rutter, DiLavore & Risi, 1999) and/or the 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 6th 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 is illustrated in Table 1. The groups were group-wise matched on the basis of chronological age, $t_{(36)} = 1.768$, $p = .086$; full-scale IQ (FSIQ), $t_{(36)} = -1.036$, $p = .307$; verbal IQ, $t_{(36)} = .079$, $p = .938$; and performance IQ, $t_{(36)} = -1.618$, $p = .114$.

[Table 1 about here]

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 sub-divided into two conditions. In half the images, the change

was located in an area defined as being of central interest and in the other half the change was marginal. We adopted the same 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 a 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" 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 & Levin, 1997; Simons, 2000) - 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 500ms.

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 300ms, 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 300ms 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 about here: diagram of switch program)

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. Then the Wechsler abbreviated Scale of Intelligence (WASI) was 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 time at which they decide 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 a total 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 sec, SD = 7.4 sec) were spotted faster than marginal changes (mean RT = 19.9 sec, SD = 10.9 sec), as predicted. There was no main effect of group nor any effects of FSIQ (see Table 2).

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 showed 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).

[Figure 2 about here]

[Table 2 about here]

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 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 showed 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

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, Gordon, Mannheim & Rumsey, 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 to 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 switch 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 amount 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 switch 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 switch data is due to the greater sensitivity of this variable, and does not reflect a theoretically important distinction between the two groups.

Experiment Two

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, 1999; 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, 1999).

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 (Kourkoulou, 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 One.

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 sub-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 (2003) categorised these images using a survey in which participants were asked to rate the likelihood of the target object appearing in the scene and the same 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

randomised 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 One.

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 (Rensink et. al, 1997 and Gareze, 2003) 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 directly replicate the analysis by Gareze (2003). Moreover, since ASD and TD participants could vary in the 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 sec, SD = 2.6 sec) were spotted faster than changes to

appropriate ones (mean RT = 6.6 sec, SD = 3.2 sec). No main effect of group was found, there was no two-way interaction between group and image type and no effects of IQ (see Table 3).

[Figure 3 about here]

[Table 3 about here]

Switching data

As in Experiment 1, the number of switches within each trial were 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 on all data, 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 switches). A main effect of group was also found, $F_{(1, 35)}$ = 9.240, p = .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 are incapable of taking context into account in a task (Happe, 1994; Frith, 1989). However it is also possible to respond to these data by saying that the task presented here was not straightforwardly about incorporating context into the perceptual process. Instead, the inappropriate objects were defined perhaps by experience more than context. Nevertheless, this argument is flawed since even using experience to identify inappropriate items in a scene requires the integration of difference elements of the scene to define it as a "kitchen" in the first place. Therefore we can conclude that people with autism are capable of identifying context in a complex scene and then using 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, though 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 prioritised for spontaneous attention by each group. In this study we examined the prioritisation of central versus marginal information (Experiment 1) and appropriate versus 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 and 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 responding of people with ASD with that 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 One demonstrated that both groups prioritised central items for attention, resulting in faster rates of detection for changes to central objects. Likewise Experiment Two demonstrated that both groups prioritised 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, Leekam & Findlay, 2005; Lopez & Leekam, 2003).

This principal finding, specifically 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 One. 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, Gordon, Mannheim & Rumsey, 1993; Courchesne et al. 1994; Leekam & Moore, 2001; Wainwright-Sharp & Bryson, 1993).

In Experiment One participants evidently had their attention initially captured by central items, as demonstrated by universally faster responding to central changes than to marginal ones. If no central item was changing, attention then had to be re-directed 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 slowed times to detect marginal changes.

Turning to Experiment Two we find no group effects whatsoever and this could be interpreted as further support for the disengagement hypothesis. In Experiment Two, 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 un-cued tasks where no specific instruction is provided. Future work will focus on investigating whether a different task design with less cueing, would reveal autistic abnormalities in attention to social stimuli. In addition, both experiments used a small sub-set 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 standardised 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. Burack & Iarocci, 1995; 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 examining spontaneous attention to complex stimuli further.

References

Allen, G. & Courchesne, E. (2001). Attention function and dysfunction in autism. *Frontiers of Bioscience, 6*, 105-119.

Burack, J. A., Enns, J. T., Stauder, J. E. A., Mottron, L., & Randolph, B. (1997). Attention and autism: Behavioural and electrophysiological evidence. In D. J. Cohen & F.R. Volkmar (Eds.), *Handbook of autism and pervasive developmental disorders* (pp. 226-247). New York: Wiley.

Burack, J. A., Iarrocci, G. (1995, March). Visual filtering and covert orienting in autism. *Paper presentation, Society for Research in Child Development.*

Casey, B. J., Gordon, C. T., Mannheim, G. B., & Rumsey, J. M. (1993). Dysfunctional attention in autistic savants. *Journal of Clinical and Experimental Neuropsychology, 15*, 933-946.

Courchesne, E., Townsend, J., Akshoomoff, N. A., Saitoh, O., Yeung-Courchesne, R., Lincoln, A. J., James, H. E., Haas, R. H., Schreibman, L. & Lau, L. (1994). Impairment in shifting attention in autistic and cerebellar patients. *Behavioural Neuroscience, 108 (5)*, 848-865

Frith, U. (1989/2003). *Autism: Explaining the enigma.* Oxford: Basil Blackwell.

Gaigg, S. B., Minhas, N., Bowler, D. M., & Richardson-Klavehn, A. (2004, September). Do children with autism use semantic or perceptual strategies to learn words? *Paper presentation, British Psychological Society Developmental Section, Annual Conference.*

Gareze, L. (2003). The role of foveal and extrafoveal vision in the processing of scene semantics. *Unpublished doctoral dissertation.* University of Durham.

Gareze, L., & Findlay J. M. (2002). The processing of semantic information from extra-foveal vision: Can and do we do it? *Perception, 31,* 111-112.

Grimes, J. (1996). On the failure to detect changes in scene across saccades. In K. Akins (Ed.), *Vancouver studies in cognitive science: Vol. 2: Perception* (pp. 89-110). New York: Oxford University Press.

Happé, F. (1994). *Autism: An introduction to psychological theory.* UCL Press: London.

Happé, F. (1996). Studying weak central coherence at low levels: Children with autism do not succumb to visual illusions. A research note. *Journal of Child Psychology and Psychiatry, 37*, 873-877.

Henderson, J. M., & Hollingworth, A. (2000). Eye movements, visual memory and scene representation. *Michigan State University Eye Movement Laboratory Technical Report, 5,* p.1-17.

Hollingworth, A., & Henderson, J. M. (2000). Semantic informativeness mediates the detection of changes in natural scenes. *Visual Cognition, 7 (1/2/3),* 213-235.

Howlin, P., & Asgharian, A. (1999). The diagnosis of autism and Asperger syndrome: Findings from a survey of 770 families. *Developmental Medicine and Child Neurology*, *41,* 834-839.

Hughes, C. & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology, 29 (3)*, 498-510.

Kourkoulou, A., Findlay, J. M. & Leekam, S. R. (2005, September). Global processing in autism using the contextual cueing paradigm. *Poster presentation, British Psychological Society, Developmental Section Annual Conference*

Landry, R. & Bryson, S. E. (2004). Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry, 45 (6)*, 1115-1122.

Leekam, S., López, B., & Moore, C. (2000). Attention and joint attention in preschool children with autism *Developmental Psychology, 36,* 261-273.

Levin, D. T., & Simons D. J. (1997). Failure to detect changes to attended objects in motion pictures. *Psychonomic Bulletin and Review, 4 (4),* 501-506.

López, B., & Leekam, S. R. (2003). Do children with autism fail to process information in context? *Journal of Child Psychology and Psychiatry, 44 (2),* 285-300.

López, B., Donnelly, N., Hadwin, J. A., & Leekam, S. R. (2004). Face-processing in high-functioning adults with autism: Evidence for weak central coherence *Visual Cognition, 11 (6),* 673-688.

Lord, C., Rutter, M., DiLavore, P., & Risi, S. (1999). *Autism Diagnostic Observation Schedule - WPS Edition.* Los Angeles, CA: Western Psychological Services.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24,* 659-685.

Mottron, L., Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In J. A. Burack, T. Charman, N. Yirmiya, & P.R. Zelazo (Eds.), *The development of autism : Perspectives from theory and research* (pp. 131-148). Mahwah, NJ: Lawrence Erlbaum Associates.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S., & Enns, J. T. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism: Evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry, 44 (6),* 904-913.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9*, 353-383.

Neely, J. (2001**).** Attention shifting to social and non-social cues in high-functioning individuals with autism spectrum disorders. *Unpublished doctoral dissertation.* University of Durham.

O'Regan, J. K., Rensink, R. A., & Clark, J. J. (1999). Change blindness as a result of 'mud splashes'. *Nature*, *398*, 34.

Pashler, H. (1988). Familiarity and visual change detection. *Perception and Psychophysics, 44 (*4), 369-378.

Plaisted, K., Swettenham, J. & Rees, L. (1999). Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry, 40 (5)*, 733-742.

Plaisted, K., O'Riordan, M., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 719-730.

Rensink, R., O'Regan, K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science, 8 (5),* 368-373.

Rensink, R. A. (2000a). The dynamic representation of scenes. *Visual Cognition, 7 (1/2/3),* 17-42.

Rensink, R. A. (2000b). Visual search for change: A probe into the nature of attentional processing. *Visual Cognition, 7,* 345-376.

Rensink, R. A. (2001). Change blindness: Implications for the nature of visual attention. In M. Jenkin & L. Harris (Eds.), *Vision and Attention,* (pp.169-188). New York: Springer.

Rinehart, N. J., Bradshaw, J. L., Moss, S. A., Brereton, A. V., & Tonge, B. J. (2000). Atypical interference of local detail on global processing in high-functioning autism and Asperger's disorder. *Journal of Child Psychology and Psychiatry, 41 (6)*, 769-778.

Ropar, D., & Mitchell, P. (1999). Are Individuals with Autism and Asperger's Syndrome Susceptible to Visual Illusions? *Journal of Child Psychology and Psychiatry, 40*, 1283-1293.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry, 34,* 1351-1364.

Shapiro, K. L. (2000). Change blindness: Theory or paradigm? *Visual Cognition, 7 (1/2/3),* 83-91.

Simons, D. (1996). In sight, out of mind: When object representations fail. *Psychological Science, 7 (5),* 301-305.

Simons, D. J. & Levin, D. T. (1997). Change blindness. *Trends in Cognitive Sciences, 1 (7),* 261-267.

Simons, D. J. & Levin, D. T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin and Review, 5 (4),* 644-649.

Simons, D. J. (2000). Current approaches to change blindness. *Visual Cognition*, *7 (1/2/3),* 1-15.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs*, *74 (11 Whole No. 498).*

Treisman, A., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12 (1),* 97-136.

Wainwright-Sharp, J. A. & Bryson, S. E. (1993). Visual orienting deficits in high-functioning people with autism. *Journal of Autism and Developmental Disorders, 23 (1)*, 1-13.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence (WASI)* USA: Psychological Corporation.

Werner, S., & Thies, B. (2000). Is "change blindness" attenuated by domain-specific expertise? An expert-novices comparison of change detection in football images. *Visual Cognition*, *7 (1/2/3),* 163-173

Table 1 Means and SDs of IQ and age for ASD and TD participants

	ASD		TD	
	mean	**SD**	**mean**	**SD**
Age (years)	19.95	2.59	18.21	3.41
Overall IQ	93.63	9.45	97.32	12.29
Verbal IQ	97.05	12.88	96.74	11.81
Performance IQ	82.16	11.15	98.21	11.90

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

	RT (ms)				Switches				Switches/second			
	Central		Marginal		Central		Marginal		Central		Marginal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ASD	13571.38	7146.33	23947.46	11439.64	4.46	1.41	10.13	3.98	0.42	0.24	0.53	0.38
TD	11095.24	7639.88	15880.03	8930.95	3.62	1.65	6.07	2.78	0.45	0.31	0.48	0.31

Table 3 *Means and standard deviations of response time, number of switches and switches per second for Experiment 2*

	RT (ms)				Switches				Switches/second			
	Appropriate		Inappropriate		Appropriate		Inappropriate		Appropriate		Inappropriate	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ASD	7245.44	3394.39	5436.3	2809.97	3.81	2	2.36	0.78	0.58	0.23	0.53	0.24
TD	5916.99	2890.79	4349.48	2371.87	2.73	1.01	1.64	0.74	0.57	0.32	0.49	0.32

Figure 1. A sample set of images, illustrating the sequence of images within a trial
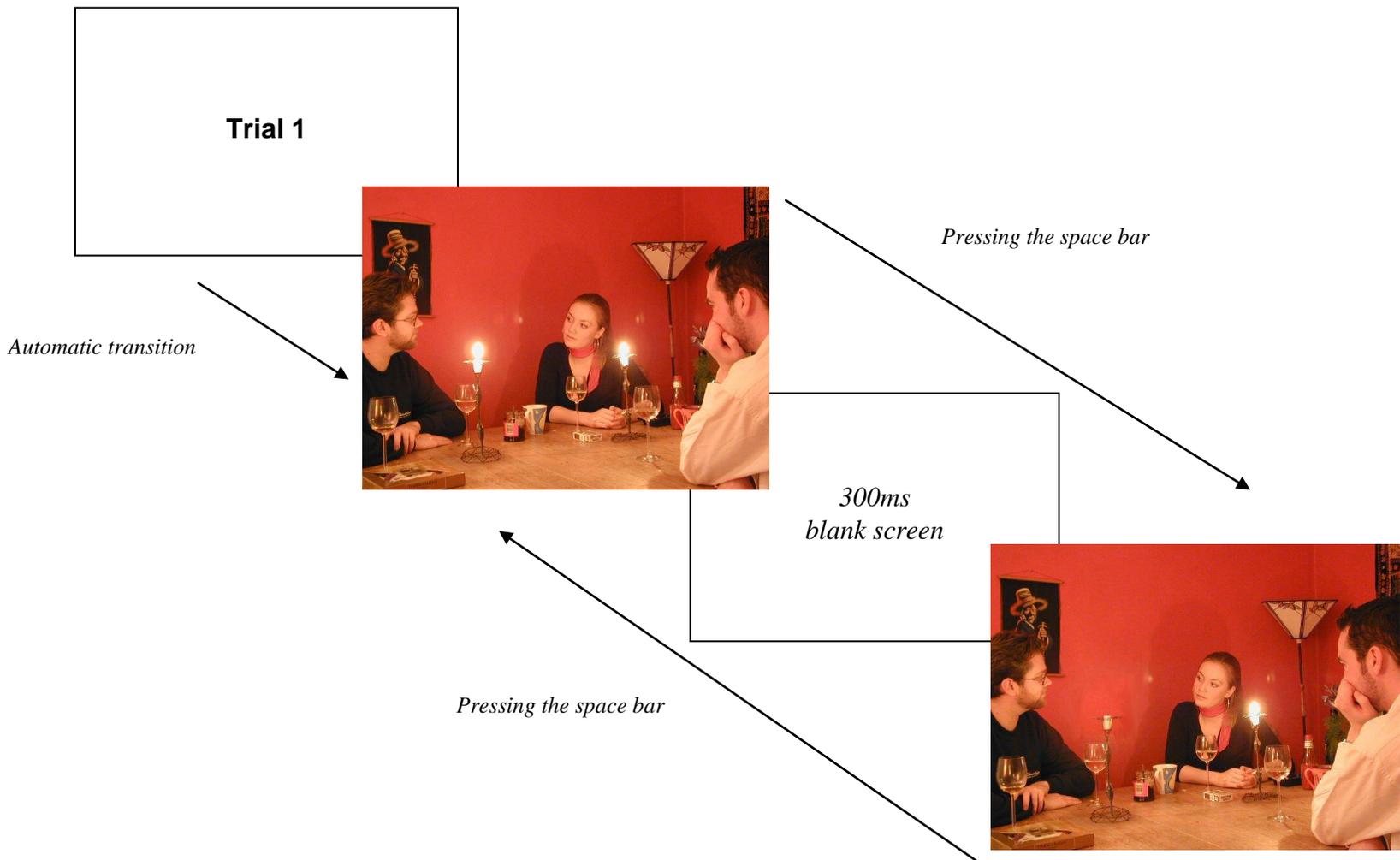
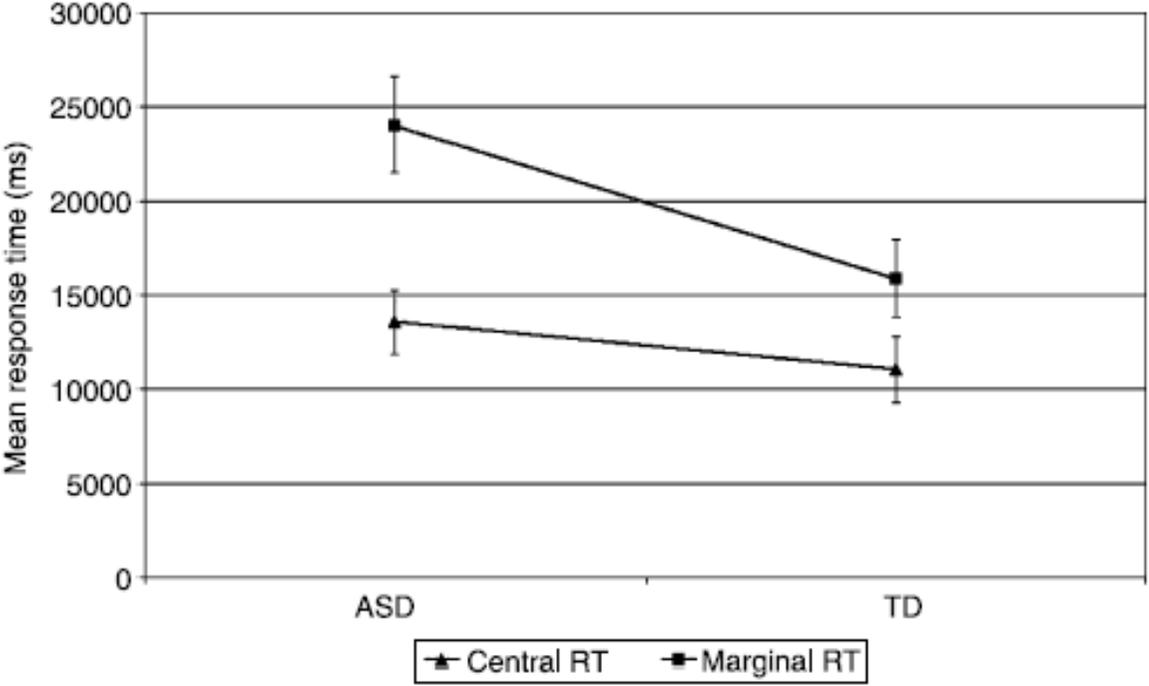*Figure 2.* Mean response time by group to Experiment 1 item changes

Figure 3. Mean response time by group to Experiment 2 item changes