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Do children with autism fail to process information in context?

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Background: This research investigated the proposal that children with autism are impaired in processing information in its context. To date, this proposal rests almost exclusively on evidence from verbal tasks. Given evidence of visuo-spatial proficiency in autism in other areas of functioning, it is possible that the ability to use context is spared in the visual domain but impaired in the verbal domain. **Method:** Fifteen children with autism and 16 age and IQ-matched typically developing children were tested on their ability to take account of visual context information (Experiment 1) and verbal context information (Experiment 2) using an adaptation of Palmer's (1975) visual context task. They were also given an adaptation of Tager-Flusberg's (1991) visual and verbal semantic memory task (Experiment 3) and Frith and Snowling's (1983) homograph task (Experiment 4). **Results:** Experiment 1 showed that children with autism were facilitated by the provision of visual context information. Experiments 2 and 3 showed that the same children were also able to use both verbal context information when identifying words and semantic category information in a verbal task when naming and recalling words. However, in Experiment 4 these children had difficulties with a sentence-processing task when using sentence context to disambiguate homographs. **Conclusions:** These findings demonstrate that children with autism do not have a general difficulty in connecting context information and item information as predicted by weak central coherence theory. Instead the results suggest that there is specific difficulty with complex verbal stimuli and in particular with using sentence context to disambiguate meaning. **Keywords:** Autism, cognition, context, central coherence. **Abbreviations:** AD: autistic disorder; TD: typically developing.

Since Frith's (1989) original claim that people with autism lack a natural drive towards central coherence, there has been increasing interest in this proposal as an explanation for the perceptual and cognitive difficulties of people with autism. A key contribution of the proposal is the claim that individuals have a unique profile of perceptual and cognitive abilities in which superiority in processing local, featural information is contrasted with inferiority in processing global and context information. Evidence for this pattern has been examined with respect to low-level visual processing (Happé, 1996; Plaisted, Swettenham, & Rees, 1999; Ropar & Mitchell, 1999; O'Riordan & Plaisted, 2001; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001), high-level visuo-spatial processing (Shah & Frith, 1983, 1993; Brian & Bryson, 1996), semantic memory (Tager-Flusberg, 1991) and sentence processing (Hermelin & O'Connor, 1967; Happé, 1997; Jolliffe & Baron-Cohen, 1999).

The weak central coherence account of autism is wide ranging in its scope of application, yet the empirical evidence for this proposal is still not clearly established. On the one hand, there is considerable evidence to support the claim that children with autism have enhanced ability to discriminate features (Shah & Frith, 1983, 1993). On the other hand, there are contradictory findings as to whether this ability occurs alongside impairment in global processing. Some studies do show evidence of deficits in the ability to process global information (Hermelin & O'Connor, 1967; Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999), whereas other studies show no differences between individuals with autism and non-autistic populations in global tasks (Ropar & Mitchell, 1999; Brian & Bryson, 1996; Plaisted et al., 1999; Pring & Hermelin, 1993; Ramondo & Milech, 1984).

These contradictory findings may be best understood by examining the way that global processing has been conceptualised across different perceptual and cognitive tasks. The impairment in global processing has been interpreted both in terms of a conceptual semantic deficit as originally demonstrated in reading and memory tasks and in terms of a failure to extract holistic perceptual properties as demonstrated by studies of visuo-spatial processing (Happé, 1996). Studies that fail to show differences between autism and non-autism populations tend to be those using visuo-spatial tasks such as visual illusions or the Navon task (Ropar & Mitchell, 1999; Ozonoff, Strayer, McMahon, & Filloux, 1994). This lack of impairment in visuo-spatial tasks seems not to be solely confined to low-level visual processing. Evidence has also been found for intact higher-level semantic processing ability when information is presented visually (Brian & Bryson, 1996; Pring & Hermelin, 1993).

The difficulty with global processing is often described as a difficulty with processing context.

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Evidence that specifically relates to this failure in using context, however, rests almost exclusively with studies of verbal processing. For example, individuals show impairments in the recall of semantically related words (Tager-Flusberg, 1991; Hermelin & O'Connor, 1967). They are also impaired in the use of context information when reading homographs in a sentence-processing task (Frith & Snowling, 1983; Jolliffe & Baron-Cohen, 1999). The results of these studies are considered to demonstrate impairment in the ability to 'integrate information in context', due to difficulties in forming meaningful connections between different items (Happé, 2000).

It is well known clinically that individuals with autism have superior non-verbal skills relative to verbal skills. An obvious question, given that context difficulties have been demonstrated in verbal tasks, is whether the context impairment proposed by the weak central coherence explanation is simply a reflection of difficulties in processing complex verbal stimuli rather than difficulty in making semantic connections between different items. One study, for example, has shown that individuals with autism can make semantic connections between items in a semantic memory task when information is presented using visual, pictorial information (Pring & Hermelin, 1993). This study showed that autism and non-autism populations did not differ in recall for semantically related category items (such as musical instruments) when category information was presented visually. This finding contrasts with other research showing that children with autism are less likely than typically developing children to use related category information to aid recall of a list of words (Tager-Flusberg, 1991). According to these findings, difficulty in making connections between semantically related items might be specific to the verbal domain.

The inability of children with autism to use context information has been mainly demonstrated in sentence-processing tasks. Studies by Frith and Snowling (1983) and Hermelin and O'Connor (1967) show that the more general context information provided by sentences fails to assist individuals with autism to disambiguate homographs or to recall words. To date, no other published studies have examined the ability of people with autism to use other types of contextual information in nonverbal form, such as a visual scene in which certain items typically or rarely occur. An unpublished study by Jolliffe (1997), however, suggests that children with autism may have more difficulty than non-autistic children when detecting an inappropriate item from a visual scene in a visual search task. On the other hand, there is evidence that children with autism have good visuo-spatial skills and can make use of meaningful information when extracting embedded features and recalling information in pictures (Pring & Hermelin, 1993; Brian & Bryson, 1996).

In the current series of studies we investigate the ability of individuals with autism to use information from a contextual scene to prime identification of an object. In Experiment 1 we tested the ability of participants to recognize an object presented in visual pictorial form. In Experiment 2, using the same paradigm, we tested the ability to read a word when context information is presented purely verbally. These experiments draw on visual and verbal priming tasks developed for the typical adult population which show that words (Tulving & Gold, 1963) and objects (Palmer, 1975) are easier to identify when presented after appropriate rather than inappropriate contextual information. The facilitating effect of context is explained by both the perceptual schema model (Biederman, 1981) and the priming model (Friedman, 1979) which both suggest that the presentation of contextual scenes primes the stored representations of schema-consistent object types.

The aim of Experiments 1 and 2 was to test whether the provision of appropriate context would facilitate object and word identification in typically developing children and children with autism. If the ability to use context is spared only in the visual domain, children with autism should be facilitated by context when information is presented pictorially but not when it is presented in written form. In Experiments 3 and 4 we compared performance in these tasks with the traditional semantic recall and sentence-processing tasks known to be difficult for people with autism.

Experiment 1

The aim of Experiment 1 was to test whether the performance of children with autism would be facilitated by the presentation of visual, pictorial context information. Palmer's (1975) visual context task was used to investigate the facilitating effect of contextual scenes in children with autism. Although Palmer's task is not the only task that measures the effect of contextual information on object identification, this paradigm was selected in favour of the object identification paradigm (Biederman, Mezzanotte, & Rabinowitz, 1982) and the measurement of eye-movements in response to Hollingworth and Henderson's (1998) methodological review.

In Palmer's paradigm, a visual contextual scene (i.e., the picture of a kitchen) is presented for 2 sec. This contextual scene is followed by the brief presentation (20, 40, 60 or 120 ms) of an object. The object could be either likely to appear in that scene (i.e., toaster) or unlikely to appear in that scene (i.e., drum). For the control condition the same objects were preceded by a neutral visual scene, consisting of a black frame. According to both the perceptual schema model (Biederman, 1981) and the priming model (Friedman, 1979), the appropriate contextual scene should produce facilitation effects whereas inappropriate contextual scenes should produce neither facilitation nor interference effects. Palmer's (1975) results followed this pattern, showing that appropriate contextual scenes increased the accuracy and confidence of object identification.

Palmer's task has not previously been tested on children. However, evidence from other context tasks shows that contextual information influences object identification in children as young as six years of age (McCauley, Weil, & Sperber, 1976). It was therefore predicted that the typically developing children involved in this study would be sensitive to contextual visual information. That is, they would be faster and more accurate at identifying objects after appropriate contextual scenes than after neutral or inappropriate contextual scenes. In contrast, if children with autism have problems connecting the context and item information, as predicted by weak central coherence theory, they will not be facilitated by appropriate context information any more than by non-appropriate context information. No group differences were predicted for object identification overall, given previous findings that individuals with autism can extract meaning from single words and pictures (Ameli, Courchesne, Lincoln, Kaufman, & Grillon, 1988; Eskes, Bryson, & McCormick, 1990).

Method

Participants. Fifteen high-functioning children with autism (Autistic Disorder: AD) took part in the study. Thirteen children were recruited from a range of special schools in Kent, England. The remaining two children had taken part in a previous project, thus their parents were contacted directly. Diagnostic records of each child with autism were checked personally by the researcher at the time of the recruitment. This evidence showed that every child had received a diagnosis of autism by experienced clinicians using the guidelines of standard criteria as DSM III-R (APA, 1987), or ICD-10 (WHO, 1990). No child had a diagnosis of Asperger's syndrome or Pervasive Developmental Disorder (PDD). The children were matched to a sample of 16 typically developing children (TD) on the basis of chronological age (CA). Participants' mental age was assessed with the Weschler Intelligence Scale for Children – Revised (WISC-R; Weschler, 1974). Participants' characteristics are summarised in Table 1.

Table 1 Mean chronological age in months (CA), verbal IQ* (VIQ), performance IQ* (PIQ) and full score* IQ (FIQ) of participants

n	Group		CA*	VIQ*	PIQ*	FIQ*
16	TD	Mean	14:4	94.12	102.87	98.75
		SD	0:10	19.31	18.25	16.20
15	AD	Mean	13:10	83.53	93.80	87.13
		SD	2:4	28.11	20.64	24.93

*Verbal, performance and full-scale scores were measured with the Weschler Intelligence Scale for Children revised (WISC-R; Weschler, 1974).

Neither chronological age, Full scale IQ (FIQ), Verbal IQ (VIQ) nor Performance IQ (PIQ) were significantly different in the two groups ($t(29) = .859$, $p < .397$; $t(29) = 1.548$, $p = .132$; $t(29) = 1.230$, $p = .229$; $t(29) = 1.299$, $p = .204$, respectively). However, as children had not been individually matched, FIQ scores and CA were introduced into each analysis as covariates to test the extent to which these variables were related to the group differences for the dependent variable. Where no significant effects were found for these covariates, a simpler ANOVA model was tested.

Visual context task. Three changes were made to Palmer's paradigm to adapt the task for children with autism. First, the confidence scale used by Palmer was not used as it was considered that a measure requiring participants to reflect on their performance might be difficult to administer to this group. Instead a reaction time measure was applied, as it has been successfully used in other studies investigating the effects of contextual scenes in object detection (e.g., Biederman, 1972; Boyce, Pollatsek, & Rayner, 1989; Boyce & Pollatsek, 1992). A voicekey was therefore attached to the computer to measure the time from the onset of the object to the participant's response.

Second, the exposure time was changed. Palmer presented the target objects for very short times of either 20, 40, 60 or 120 msec. As children with autism have difficulty recognising visual stimuli presented for less than 1000 msec (Teunisse, 1996), the objects were presented instead for a maximum of 3000 msec, or until participants responded.

Finally, Palmer used a between-participants design. Due to the small sample of participants with autism it was necessary to use a repeated-measures design. The main advantage of using a between-participants design is that the same object can be paired with different contextual scenes and thus it is possible to test the differential effects of each type of contextual scenes in the same object. A within-participants design, on the other hand, may be problematic as the repeated presentation of the same object, each time paired with a different contextual scene, may influence participants' responses. A new complete set of stimuli was created by selecting sets of triplets of objects matched in terms of complexity and familiarity. Once these triplets were created, each object of the triplet was randomly assigned to a condition to ensure that any difference between contextual conditions might not be explained by differences in the complexity or familiarity of the different objects.

In order to test the adapted visual context task and new reaction time measures, a study was first conducted with a group of 17 normal adult participants. It was predicted that appropriate visual contextual scenes would facilitate object identification and thus, adults would identify faster and more accurately those objects that were preceded by appropriate contextual scenes. On the basis of previous research, no interference effects of inappropriate contextual scenes were predicted. Results confirmed this prediction. Reaction times were faster when objects were preceded by appropriate contextual scenes than when preceded by either neutral or inappropriate contextual scenes. The increase in exposure time in the new task, however, resulted in ceiling effects for accuracy data.

Design. A 3 (Context: Appropriate (A) vs. Neutral (N) vs. Inappropriate (I)) by 2 (Group: AD vs. TD) mixed design was employed. The dependent measures were reaction time on correct trials and number of correct responses. Reaction times were measured from the presentation of each object to the acoustic onset of the participant's verbal response by means of a voicekey attached to the computer.

Materials and apparatus. Eight triplets of objects were selected from the standardised set of pictures created by Snodgrass and Vanderwart (1980). Within each triplet, the objects were matched on familiarity, complexity and image agreement to ensure that any differences in reaction times between conditions were due to the effects of the contextual scenes and not to differences in the characteristics of the objects. Once the triplets were constructed, the objects were assigned randomly to one of the three conditions so that each of the objects in one condition had a match in the other two conditions.

Each object was then paired to a contextual scene. For the *appropriate context condition*, 8 objects were paired with visual scenes in which the object would be very likely to appear in everyday life (i.e., Kitchen–Jug). For the *inappropriate condition*, eight objects were paired with visual scenes in which the object would not be likely to appear in everyday life (i.e., Office–Lemon). The remaining eight objects were paired to the same neutral scene, *no context condition*. Neutral contextual scenes as in Palmer's original design consisted of a black rectangular frame only (14 × 10 cm.). The contextual scenes were selected from children's books or drawn by the experimenter. Examples of stimuli for appropriate and inappropriate conditions are shown in Figure 1.

Objects and contextual scenes were black drawings over a white background. All the scenes were drawn

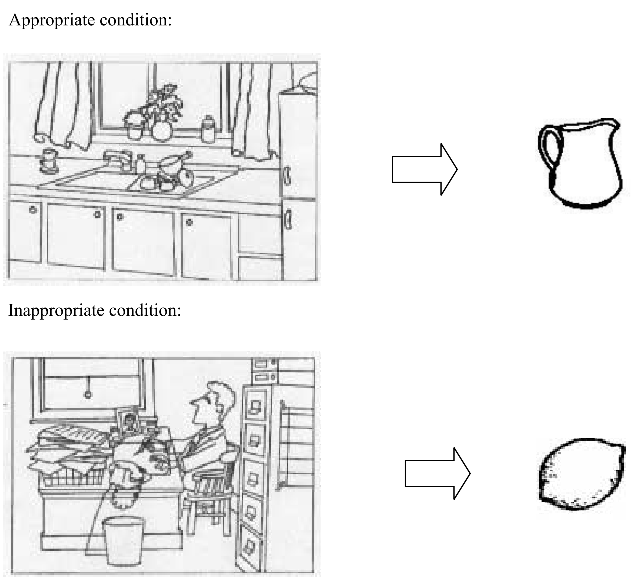

Figure 1 Examples of contextual scenes and objects used in Experiment 1 (Visual Context Task)

within a black rectangular frame of 14 cm ×10 cm. Contextual visual scenes did not contain the target object. The stimuli were presented in a Macintosh laptop computer using Superlab software.

Procedure. Participants were tested individually in a quiet room either at their school or at home. The children were told that they would see a series of pictures on the computer screen, some depicting visual scenes and some single objects. Their task was to name the objects and not the scenes. Before the proper experiment began, participants were given three training trials to ensure they understood the procedure. The contextual scenes for these trials were a 'Garden', a 'Post Office' and a 'Room'. The objects chosen were 'Cap', 'Bottle' and 'Button'. During these trials the experimenter pointed to the objects that they had to name. Only if the child understood the procedure was the proper experiment started. All children understood the procedure by the end of the training session.

Each participant was then given 24 trials composed of the same sequence as in Palmer's original study except for the change in the time exposure of the target object. The sequence thus was as follows: a) presentation of the contextual scene for 2000 msec; b) a delay of 1300 msec and c) the presentation of the target object for a maximum of 3000 msec, or until the child responded. Unlike Palmer's procedure, participants were not informed of the existence of the three different conditions or the nature of the experiment. The trials were presented in a random order. Participants were instructed to name only the objects and not the contextual scenes.

Results

Scoring criteria. Responses were scored as correct if the most common name for the object or a synonym was given. Those responses that were not specific (i.e., 'apple' for 'strawberry') or referred to a higher semantic category (i.e., 'fruit' for 'strawberry') were scored as incorrect, and therefore excluded from the analysis of RT data. One trial in the appropriate condition of the visual task had to be excluded from the analysis as none of the children in either group named it correctly. All children mistook a 'nail file' for either a 'knife or a 'pen'. As none of these objects appear usually in a 'bathroom' the trial was deleted from all analyses.

Accuracy data. Data for 5 trials (0.7% of data, 4 trials from AD children) had to be excluded from the analysis due to equipment malfunction. Due to the missing trials, raw data were converted into proportion scores for the purpose of analysis (see Table 2 for summary of results).

The data were analysed by means of a mixed ANOVA with group as the between-participants factor (TD vs. AD) and context as the within-participants factor (appropriate vs. neutral vs. inappropriate). The analysis of the accuracy data revealed that there was a significant main effect of

Table 2 Mean proportion of accurate responses and mean reaction times in the appropriate (A), neutral (N) and inappropriate (I) conditions in Experiment 1

			Accuracy			Reaction times		
n	Group		A	N	I	A	N	I
16	TD	Mean	.944	.885	.871	937.04	1056.93	1087.63
		SD	.075	.096	.107	178.51	185.67	164.64
15	AD	Mean	.911	.836	.757	987.3	1024.26	1060.60
		SD	.107	.121	.158	245.63	229.5	259.86

context ($F(2, 58) = 9.632$, $p = .001$). Pair-wise comparisons using Bonferroni adjustment for family-wise errors indicated that for both groups the provision of an appropriate context facilitated accuracy in the identification of objects as compared to providing a neutral ($p = .010$) or an inappropriate context ($p = .001$). The comparison between providing a neutral context and providing an inappropriate context was not significant ($p = .340$).

The interaction between group and context was not significant ($F(2, 58) = 1.464$, $p = .240$) indicating that, in terms of accuracy, both groups of children were affected by the context to the same extent. The main effect of group was significant ($F(1, 29) = 5.459$, $p = .027$) as typically developing children were more accurate than children with autism at naming objects.

Reaction time data. The experimenter was behind the child at all times to ensure that the response recorded was the child's verbal response and not any other sound but despite this precaution, extraneous sounds were recorded after stimuli onset for some trials. Twenty-three trials were deleted for the above-mentioned reasons (2.63% of the total trials; 13 from children with autism). Table 2 shows the mean RT on correct trials to appropriate, neutral and inappropriate trials for each group.

A mixed ANOVA was conducted on these data, with context (appropriate vs. inappropriate vs. no context) as a within-subjects factor and group (AD vs. TD) as a between-subject factor. The analysis revealed a significant main effect of context ($F(2, 58) = 6.267$, $p = .003$). To further investigate the context effect, pair-wise comparisons using Bonferroni adjustment to correct for family-wise errors were carried out. These comparisons showed that all children were faster at identifying objects when these were preceded by an appropriate context than when preceded by a neutral ($p = .029$) or an inappropriate context ($p = .003$). The comparison between the neutral and inappropriate contexts, as in the studies with adults, did not yield significance ($p = .999$).

Neither the interaction between context and group nor the main effect of group was significant ($F(2, 58) = 1.019$, $p = .367$; $F(1, 36) = .002$, $p = .963$ respectively). Children with autism were as fast as typically developing children at identifying objects.

Discussion

The results of this study showed that children with autism, like age-matched controls, were faster and more accurate in identifying objects after an appropriate contextual scene than after either neutral or inappropriate contextual scenes. Moreover, children with autism used visual contextual information to aid object identification to the same extent as typically developing children. These results fail to support the claim that children have a global deficit in terms of 'connected meaning'.

The findings indicate that stored representations of schema-consistent object types are available and can be accessed in a priming paradigm (Biederman, 1981; Friedman, 1979). The findings also extend the results of Pring and Hermelin (1993) by showing that when stimuli are presented visually, individuals with autism make use of semantic information. We show further that children with autism not only make use of semantic category information but also make use of other kinds of visual context such as location information when identifying objects.

At first sight, these results appear to refute the unpublished finding by Jolliffe (1997) that individuals with autism have difficulty judging whether an item, for example a squirrel, is inappropriate in a visual scene such as a beach. However, Jolliffe's task required individuals to make an evaluation of appropriateness that might be much more difficult than the current task which simply tested accuracy and time to name an object. Also the current task depended on facilitation of appropriate context rather than on interference by inappropriate context.

An unexpected finding was that children with autism made more errors overall in naming objects than TD children. The higher frequency of errors cannot be explained by differences in either IQ or chronological age as neither of these measures covaried significantly with overall performance. Further inspection of children's Verbal IQ and Performance IQ scores separately also showed that these also did not selectively covary with accuracy. The group difference in naming errors was surprising as previous research has shown that children with autism can extract semantic information from single words and pictures (Eskes et al., 1990; Ameli et al., 1988). The examination of the type of errors made by each group also did not reveal more semantic errors in the autism group. The majority of errors in both groups were visual errors (TD: 68.08%; AD: 68.11%), for example 'spade' instead of 'broom'. This type of error was followed by semantically related errors (TD: 27.65%; AD: 28.98%), for example 'bikini' for 'vest', and finally by higher category errors where they produced a word that referred to the higher-level category (i.e., 'insect' for 'fly'). There was no significant difference between groups in the type of errors made. Overall, this analysis suggests that AD children are not showing a semantically related impairment for single word naming but they are simply less accurate overall in naming objects.

Despite the fact that children with autism were less accurate in object naming they were nevertheless able to use visual contextual information to aid object identification. A possible explanation for this finding is that the presentation of visual information aided their ability to use context and it remains possible that they might not be facilitated by context when verbal stimuli alone were used. To examine whether this ability is found not only when information is presented visually but when information is restricted to the verbal domain, a verbal adaptation of the visual context task was administered.

Experiment 2

In the present experiment the visual context task was adapted to investigate the ability of children with autism to connect words on the basis of meaning without the presence of visual information. To adapt the visual context task for this purpose, each contextual scene and object was substituted for the word that best described that scene or object. Otherwise, the procedure and design remained the same as in the visual context task.

The resulting verbal context task highly resembled a semantic priming task. A semantic priming task typically consists of the presentation of a prime word followed by a word that can be either related or unrelated to it. Participants have to either read the second word or decide whether the second word is a real word. A large body of evidence demonstrates that presentation of prime words facilitates word identification (Meyer & Schvaneveldt, 1971; Becker, 1980). Furthermore, unlike in visual context tasks, there is sound evidence indicating that the presentation of unrelated or inappropriate prime words hinders word identification (Neely, 1976; Becker, 1980).

Verbal priming effects appear very early in development, as young as 6 years of age (Radeau, 1983), and priming effect sizes are reported to be larger in younger children than in adults, although this is due to larger overall reaction times that inflate the difference between conditions rather than greater sensitivity to context (Chapman, Chapman, Curran, & Miller, 1994). Although there are no studies to date investigating verbal priming effects in children with autism, Tager-Flusberg (1991) has shown that children with autism have difficulty using verbal semantic information to aid recall in a memory task. According to the predictions of Weak Central Coherence theory this is due to failure to connect words such as 'horse' with the category 'animal'.

If the difficulty with context is confined to verbally presented stimuli only, children with autism would have difficulties connecting a prime word with a target word. In Experiment 2 it was predicted that typically developing children would show both facilitation effects for appropriate context and interference effects for inappropriate context. Individuals with autism in contrast might show neither facilitation or interference effects.

Method

Participants. The same participants as in the previous study took part in this experiment. To avoid practice effects from Experiment 1, the study was carried out 4–7 months after the earlier experiment.

Design. The same mixed design as in the previous experiment was used.

Materials. In order to keep the materials as close as possible to the visual context task, the words chosen for this experiment were those that best described the pictures used in the visual context task. For instance, the picture of a kitchen was substituted by the word 'Kitchen' and the picture depicting the jug was substituted by the word 'Jug'. The 'Nail file' object was deleted from the item list in the visual context task as none of the children had been able to identify it in Experiment 1. This object was therefore substituted in the verbal task by the word 'Brush'. For the neutral condition trials, before presenting the target word a series of five Xs were presented. All stimuli were presented in capital letters.

Procedure. Children were tested in a quiet room either at their school or at home. The same procedure as for the visual task was followed. Three training trials were used to ensure that children understood the task before the commencement of the experiment. These training trials were the same as the ones used in the visual task but presenting words instead of pictures. Thus the priming stimuli used for the training trials were the words 'Garden', 'Post Office' and 'Stairs' and the targets were 'Bottle', 'Cap' and 'Button'. Children were instructed to name the second word. All children understood the task by the end of the training trials. This experiment was carried out at least four months after Experiment 1.

Results

Accuracy data. The data for one typically developing child could not be collected due to equipment malfunction. An exploration of the accuracy data revealed that the data were significantly

Table 3 Mean proportion of accurate responses and mean reaction times in the appropriate (A), neutral (N) and inappropriate (I) conditions in Experiment 2

			Accuracy			Reaction times		
n	Group		A	N	I	A	N	I
15	TD	Mean	.992	.992	.925	624.76	676.00	713.62
		SD	.032	.032	.199	107.18	152.86	179.72
15	AD	Mean	.992	1.00	.925	617.60	715.27	744.40
		SD	.030	.00	.113	108.52	138.66	171.18

skewed in all conditions due to ceiling effects in both groups (see Table 3 for summary of results). Twenty-one children (70%) had perfect scores in all three conditions and 7 children (23%) had only one naming error over the three conditions. Due to the high percentage of perfect or nearly perfect scores, none of the attempted transformations (e.g., logarithmic, square root, and inverted transformations) could correct the distribution of the data, thus no further analysis was carried out on the accuracy data.

Reaction time data. Twenty-one (2.84%; 7 from children with autism) trials needed to be removed from the analysis because of sounds picked up by the voicekey. A summary of the results is shown in Table 3.

As for the previous experiment, FIQ and CA were introduced in the analysis as covariates to correct for differences between the groups in these measures. CA did not covary significantly with either overall performance ($F(1, 26) = .439$, $p = .513$) or context ($F(2, 52) = .432$, $p = .651$). FIQ, however, covaried significantly with both overall performance and context and was thus kept in the analysis ($F(1, 26) = 5.810$, $p = .023$; $F(2, 52) = 14.075$, $p = .001$, respectively).

The data were analysed by means of a mixed ANCOVA with context (appropriate vs. inappropriate vs. no context) as a within-subjects factors and group (AD vs. TD) as a between-subject factor and FIQ as a covariate. The statistical analysis revealed a significant main effect of context ($F(2, 54) = 19.908$, $p = .001$). Pair-wise comparisons using Bonferroni adjustment to correct for family-wise errors revealed that all children were faster at recognising words when preceded by an appropriate context than when preceded by a neutral ($p = .002$) or an inappropriate context ($p = .001$). The comparison between the neutral and inappropriate context also yielded significance ($p = .002$).

Neither the interaction between context and group nor the main effect of group was significant ($F(2, 54) = 1.292$, $p = .283$; $F(1, 27) = .029$, $p = .867$ respectively). Children with autism were as fast as typically developing children identifying words and they were affected by contextual information to the same extent.

Discussion

This study tested whether a context deficit would be found for individuals with autism when information was presented in the verbal domain only. Results showed that on the contrary, children with autism were as sensitive to verbal context as typically developing children. Both groups had similar facilitation effects in that words that were related to the prime were identified faster than words preceded by a neutral prime. Also, both groups had similar interference effects in that words preceded by inappropriate primes were identified less rapidly than words preceded by neutral primes. The results of Experiment 1 and Experiment 2 therefore provide evidence that children with autism take account of context whether information is provided with or without the presence of visual information.

Unlike Experiment 1, children with autism were as accurate as TD children in correctly reading words. This result could have been due to the practice effects from presentation of the same words that they earlier named from pictures. The time delay between testing sessions, however, makes this unlikely. More likely is that the task in this experiment did not involve searching for a word but simply reading it, and therefore this task was less demanding. Despite an overall improvement in both accuracy and speed for both groups between the two experiments, however, the context effects remained.

The results of Experiments 1 and 2 showed no difference between autism and non-autism groups and no interaction effects. Yet, the pattern of means for RT in Tables 2 and 3 raised the possibility that there might be differences between the groups that failed to be detected due to insufficient power. For example, as Table 2 shows, the mean difference between appropriate and neutral conditions appears to be larger for typically developing than for children with autism in the case of visual stimuli whereas the same mean difference appears larger for the autism children for verbal stimuli (Table 3). To check for the possibility of a Type II error, we carried out formal power analyses for each experiment. Effects sizes gave a power of .80 or above for every analysis. This indicates that the lack of significant group difference and interaction effect is genuine. The different pattern found for each group across verbal and visual stimuli might nevertheless warrant further attention in future research investigations.

The results of Experiment 2 appear to contradict evidence supporting a deficit in the use of verbal contextual information from a single word semantic memory task (Tager-Flusberg, 1991). One possibility is that children with autism have difficulty connecting single words on the basis of meaning but only in tasks that involve making connections between subordinate and superordinate category information. This might be due to an alternative explanation such as failure to organise information hierarchically.

A closer look at the evidence for inability to use context in semantic memory tasks, however, reveals mixed findings. Two studies have found evidence of difficulties integrating words on the basis of meaning in single word tasks. In one study, Tager-Flusberg (1991) presented children with autism, typically developing children and developmentally delayed children with two types of lists. One list contained semantically related words (i.e., animals) and another list contained unrelated words drawn from different semantic categories. While the two comparison groups recalled more words from the list of animals than from the list of unrelated words, the recall rates of children with autism did not differ for two types of list, indicating an inability to use semantic information to aid recall. An earlier study by Hermelin and O'Connor (1967) also presented lists of unrelated words and lists of words pertaining to two semantic categories (i.e., nine, blue, three, two, red...). They did not find differential performance between autism and non-autism groups for the number of items recalled in each list. However, they did find that children with learning disabilities but not children with autism tended to recall words of the same semantic category clustered together (i.e., nine, three, two, blue, brown, red...).

In contrast, two other studies have failed to find a deficit in use of semantic information to aid recall in autism. A study by Ramondo and Milech (1984), which like Hermelin and O'Connor (1967) used more than one category of item in the memory lists given to participants, failed to find a group difference in the number of items recalled from the semantically related and unrelated lists. Also, a study by Pring and Hermelin (1993) suggests that any difficulties in Tager-Flusberg's task are overcome when visual information is provided. Experiment 3 aimed to investigate if the difficulty in autism to use semantic information to aid recall is confined to verbal tasks by use of an adapted version of Tager-Flusberg's task which included a visual condition as well as the original verbal stimuli used by Tager-Flusberg.

Experiment 3

In Experiment 3 we used an adapted version of Tager-Flusberg's task to test recall of semantic category information in both visual and verbal domains. If children with autism have a problem with semantic category information that is confined to the verbal domain they should show poorer recall of semantically related information only in the verbal condition but not in the visual picture condition. Like Ramondo and Milech (1984) and Hermelin and O'Connor (1967), information from more than one semantic category was presented to children.

Method

Participants. The same participants as in the two previous experiments took part in this experiment. This experiment was administered in the same session as Experiment 2.

Design. A 2 (modality: visual vs. verbal) by 2 (list: semantically related vs. unrelated) by 2 (group: AD vs. TD) mixed design was employed. The dependent measure was the number of words recalled correctly from each list.

Materials. Half the stimuli were the same materials as used by Tager-Flusberg. One list contained words drawn from different categories (apple, brown, cabin, drum, farm, elephant, lamp, onion, pencil, pot, shirt, thumb). The semantically related list contained words from the same semantic category (bear, cow, giraffe, horse, lion, monkey, pig, rabbit, racoon, sheep, turtle). Tager-Flusberg reported that she matched the words in these two lists approximately for frequency.

To explore the possibility of differences in performance in different semantic categories, another pair of lists was added to the procedure. Of these, one list contained words of vehicles (bike, boat, bus, car, helicopter, motorbike, plane, roller skate, sledge, train, truck, wagon). The other list contained words from different semantic categories (birds, biscuits, booklet, drink, gentlemen, hill, seven, sugar, tonic, toothpaste, word, yellow). The words of these two lists were individually matched using the Celex lexical database frequency table (Baayen, Piepenbrock, & Gulikers, 1995).

To further explore potential differences in performance between the visual and verbal domain in autism, a new visual picture condition was added to the original procedure. Four sets of pictures were used, each containing 12 pictures of objects. The two semantically related sets were the same lists of animals and vehicles used in the verbal condition. The unrelated sets contained pictures from different semantic categories (Animal matched list: axe, barrel, harp, kite, mushroom, rolling pin, spinning top, suitcase, thimble, trumpet, watering can, windmill; Vehicles matched list: brush, coat, flute, fork, racket, scissors, screwdriver, tie, toaster, trousers, violin, whistle). The pictures of the unrelated sets were matched individually to the semantically related sets of pictures on the basis of familiarity and complexity. All the pictures were taken from the standardised set of pictures created by Snodgrass and Vanderwart (1980). The pictures were presented one at a time in a Macintosh laptop computer.

Procedure. All children were tested in a quiet room either at their school or at home. Following Tager-Flusberg's procedure, a practice set of four simple words (pin, cat, tea, wall) or four objects (flower, frog, sock, star) was used to familiarise the child with the task. Half of the children in each group received the verbal condition first and the other half received the visual condition first.

The session began with the experimenter explaining the task to the child. In the verbal condition children were told that the experimenter would read a list of words and when the list was finished the child had to recall as many words as possible from the list. For the visual condition they were told that they would see a series of pictures in the screen of the computer and after the series was finished they would have to recall as many objects as possible. After these instructions, the experimenter read the words of the practice trial in a monotone voice or presented the four pictures of the practice trial. All children understood the aim of the task after the practice trial.

Once the practice trial was completed, the child was presented with one test list. The order of the lists was counterbalanced within each modality condition across participants. The items from each list were presented in random order at a rate of one word/object every two seconds. The experimenter recorded all the words that were correctly or incorrectly recalled by the child.

Results

The number of correctly recalled items from the two semantically related and the two unrelated lists of each modality condition are shown in Table 4.

As can be seen, both groups of children performed better in the related than unrelated conditions in both the visual and verbal domain although AD children had lower recall rates in all conditions. To test if the difference between semantic conditions was statistically significant an ANCOVA with modality (visual vs. verbal) and list (related vs. unrelated) as within-participants factors, group as a between-participants factor and FIQ scores and CA as covariates was conducted on the data. Neither FIQ nor CA, however, significantly covaried with either modality, list or group, thus these scores were removed from subsequent analysis.

The ANOVA revealed a significant main effect of list ($F(1,29) = 108.39$, $p = .001$), indicating that children recalled significantly more words from the semantically related lists than from the unrelated lists. Unlike Tager-Flusberg's study, the interaction between list and group was not significant ($F(1,29) = 1.152$, $p = .292$).

The main effect of group was significant. TD children recalled more items than children with autism ($F(1,29) = 10.071$, $p = .004$), indicating a general memory deficit in autism. No main effect of modality was found ($F(1,29) = .009$, $p = .927$), nor was the interaction between modality and list significant ($F(1,29) = 2.301$, $p = .998$), indicating that the provision of related material improves performance on the visual and verbal domains. Furthermore, the interaction between modality, list and group was non-significant ($F(1,29) = .159$, $p = .693$), providing further evidence for semantic processing in both the verbal and visual domain in autism.

Table 4 Mean number of items recalled from related and unrelated lists in Experiment 3 (Maximum = 24)

			Visual condition		Verbal condition	
n	Group		Related	Unrelated	Related	Unrelated
16	TD	Mean	14.37	9.62	14.12	9.93
		SD	1.99	1.89	2.06	1.84
15	AD	Mean	11.80	7.67	11.33	8.20
		SD	4.10	2.16	3.52	2.18

Discussion

The results of this study indicate that, as in Experiment 2, children with autism are able to integrate words on the basis of meaning and they do so to the same extent as TD children. In relation to modality, children with autism showed evidence of connecting semantically related items in both the visual and verbal domains. Thus, Experiments 1, 2 and 3 all provide evidence that the ability to connect items on the basis of meaning is intact in autism in both the visual and verbal domains.

The results of this study differ from those found by Tager-Flusberg. One possible explanation for this difference relates to the type of category items that were included in Tager-Flusberg's study. Both the current study and the previous studies by Ramondo and Milech (1984) and Hermelin and O'Connor (1967) included items from at least one more category and all three studies failed to find group differences in recall between related and unrelated lists.

Post-hoc analyses supported this hypothesis. Results for the lists used by Tager-Flusberg (i.e., animal and matched unrelated lists) show a similar pattern in our study to the results reported by Tager-Flusberg (1991), except that the children in the present study had overall higher recall rates, as would be expected due to the higher chronological age of participants. Specifically, for the stimuli used by Tager-Flusberg (original animal verbal lists) there was a significant main effect of list (Related mean = 6.49 (.309); Unrelated mean = 4.47 (.238); ($F(1,29) = 52.45$, $p = .001$) and a significant interaction between group and list (Related mean: TD = 7.25 (1.34); AD = 5.73 (2.05); Unrelated mean: TD = 4.62 (1.45); AD = 4.33 (1.17); $F(1,29) = 4.858$, $p = .036$)), indicating that AD children were less sensitive to semantic information than were TD children. The main effect of group was only marginally significant ($F(1,29) = 3.587$, $p = .068$). These results replicate those of Tager-Flusberg (1991).

The only comparison that showed a significant group by list interaction was the original animal verbal list. None of the other lists (vehicles visual and verbal and animals visual) did so. Thus it can be concluded that the results from this study do not support the claim for impairment in the ability to use semantic relations.

It is difficult to explain why only Tager-Flusberg's original lists produced an interaction effect indicating a failure of children with autism to use semantic information while the new lists did not. The only differences between the original lists and the new ones was that whilst the original were matched approximately on frequency (as reported in Tager-Flusberg, 1991), the new lists were individually matched exactly on frequency, and in the case of pictures, individually matched on familiarity and complexity. If the words included in the animal lists were more frequent than in the unrelated list, this would result in an additional advantage for TD children if they are more sensitive to word frequency effects.

The children with autism in Tager-Flusberg' study had, on average, a verbal mental age of 5 years. The children that took part in this study had an average age of 14 years, and due to the high IQ levels, similar mental ages. It could be argued that the difference in results is due to differences in the age of participants. However, the children used in this study, despite being older, performed similarly to Tager-Flusberg's sample with respect to the original lists. Hence, this explanation can be ruled out. If we had used only the original lists we would have found the same results as Tager-Flusberg.

It is still possible, though, that there is a developmental delay in semantic processing in autism. To confirm the existence of an impairment in younger children with autism it would be necessary to conduct a study with young children using a wider range of material, and not the original set used by Tager-Flusberg. The pattern of results in this study has confirmed that performance varies depending on the set of stimuli. For this reason, it seems especially important to use a wide range of stimuli when investigating the ability to process semantic relations.

Children with autism had in general lower recall rates than TD children, confirming previous findings showing a general memory impairment in autism (Boucher & Warrington, 1976). Over and above this impairment though, children with autism were as able as TD children in the use of semantic information to aid recall.

To summarise, none of the three experiments reported here provide evidence supporting the claim that high-functioning individuals with autism fail to process information in its context as Frith (1989) suggested. The individuals with autism tested in these studies were no different than typically developing children in their ability to integrate stimuli on the basis of semantic information, whether information was presented visually or verbally and whether connections in meaning were based on items within semantic categories or objects associated with familiar everyday locations.

The question still remains whether individuals with autism fail to integrate context information in sentence-processing tasks which involve semantic connections across multiple, sequentially presented stimuli. Two different types of tasks have been used in previous research; memory tasks and the homographs task. In the memory tasks the recall rates of sentences ('They went to the theatre') vs. word strings ('School run the on girl') are compared. The evidence from these studies is contradictory. Research has shown that typically developing children benefit to a greater extent than children with autism from the presentation of sentences (e.g., Frith, 1969; Wolff & Barlow, 1979). It is not clear, however, the extent to which the deficit is specific to autism. Hermelin and O'Connor (1967) found that children with learning difficulties benefit to greater extent by the provision of sentences than children with autism. In contrast, Ramondo and Milech (1984) failed to find differences with a learning difficulty sample and in another study it was found that the deficit is related to low memory span (Fyffe & Prior, 1978).

The studies using homograph tasks, on the other hand, have consistently found a deficit in autism to use context information. Even high-functioning adults with 'residual' characteristics of autism have been shown to have difficulty with such tasks (Jolliffe & Baron-Cohen, 1999). This task also involves the ability to disambiguate information from sentences. In the homographs task, originally developed by Frith and Snowling (1983), children have to read sentences aloud. Each of these sentences contains a homograph word, which are words that have two different pronunciations (i.e., 'tear'). The sentence can be consistent with the frequent pronunciation of the homograph (i.e., 'There was a big tear on her cheek') or the rare one (i.e., 'There was a big tear on her dress').

The aim of this task is to assess the extent to which participants make use of sentence context information. If participants use context they would give the same number of each type of pronunciation. If, on the other hand, participants do not take in account contextual information they would tend to give the most frequent pronunciation. Happé (1997) and Jolliffe and Baron-Cohen (1999) and in an earlier version of the task, Frith and Snowling (1983), have found that individuals with autism tend to give the most frequent pronunciation regardless of the context.

In addition, Happé's study also found that the position of the homograph in the sentence influences performance. She found that children were more accurate when the homograph was placed towards the end of the sentence than when it was presented at the beginning of the sentence and hence there was no contextual information. The influence of the position of the homograph in the sentence, however, had a larger impact in typically developing children than children with autism. Jolliffe and Baron-Cohen did not find the same position effect but unlike Happé who tested children, Jolliffe and Baron-Cohen tested adults with autism and Asperger's syndrome and a comparison sample of non-autistic adults. It is possible that, as Jolliffe and Baron-Cohen (1999) suggested, with more advanced reading ability adults are able to read ahead and thus perform similarly irrespective of the position of the homograph. The aim of this study was to replicate Happé's and Jolliffe and Baron-Cohen's studies with children, using the same design, materials and procedure.

Experiment 4

Experiments 1–3 showed that individuals with autism took account of context information when connecting single items on the basis of meaning. The current study tested the same sample of children on Frith and Snowling's (1983) homograph task in order to determine whether these children would have difficulty processing context information in a sentence context. If so, this might be because of the complexity of the items to be processed or because of difficulties with the ambiguity of a homograph. If children with autism have specific difficulty with reading homographs in context, they should give the most frequent pronunciation of the homographs regardless of the context. It was also predicted that children with autism would be less sensitive than typically developing children to the position of the homograph in the context sentence.

Method

Participants. The same participants as in the previous experiments took part in this experiment.

Design. The experiment had a mixed design with two within-participants factors: type of pronunciation (frequent vs. rare) and position of the homograph (before context vs. after context). The between-participants factor was group (children with autism vs. typically developing children).

Materials. Four homograph words were used in the experiment (tear, row, bow and lead). Although previous studies have used an additional homograph word, read, the two different pronunciations of this word, unlike the other homographs, depend on syntactic and not semantic context. As there is evidence of spared syntactic abilities in autism (Bartolucci, Pierce, Streiner, & Eppel, 1976; Frith & Snowling, 1983), this word was excluded from the original design to avoid confounding effects.

The stimuli consisted of sixteen sentences, the same as in Happé's (1997) original study except for the four sentences containing the word 'read'. None of the sentences referred to mental states or were social in nature (see Appendix 1 for examples of stimuli). As in Happé's study, there were four types of sentences: frequent pronunciation and homograph before sentence context, frequent pronunciation and homograph after sentence context, rare pronunciation and homograph before sentence context and rare pronunciation and homograph after sentence context.

The pre-test list used by Happé (1997) was presented to participants to assess their ability to read the target words. This comprised thirteen single words including the four homographs words. Only one child (in the autism group) gave the two pronunciations of each of the homographs. All children gave the most frequent pronunciation of 'bow' and all except two children (one AD and one TD) gave the most frequent pronunciation of 'row'. The two pronunciations of the other two homographs ('tear' and 'lead') were more evenly distributed. All pre-test words were printed onto a single card while sentences containing homographs were presented on individual cards one at a time.

Procedure. Children were tested in a quiet room either at their school or at home. The pre-test words were always presented first. Children were told that they would see a list of words that they were to read aloud. All participants read this list without difficulty. Sentence cards were shuffled before the administration of the test to ensure random order presentation. After the pre-test was completed the experimenter told participants that they would be given cards each containing a single sentence and that they had to read them aloud. The experimenter then handed one card at a time to the child. The experimenter recorded the pronunciation of the homograph, any reading mistakes and any self-corrections regarding the pronunciation of the homographs. As in Happé's (1997) study, children were not alerted to the special status of the homographs so that spontaneous processing style could be assessed.

Results

Scoring criteria. Following Happé (1997) and Jolliffe and Baron-Cohen (1999), those trials in which participants corrected themselves were regarded as correct (self-corrected score). However, the first pronunciation attempt (initial score) was also recorded and this more stringent score is also reported below. As in Jolliffe and Baron-Cohen's study, the data were severely positively skewed (see Table 5 for summary of results). Even after applying logarithmic transformation of the data this skew was not improved, thus non-parametric tests were used. As the investigation of interactions between conditions was not possible using these tests, separate analyses were conducted to analyse the number of frequent pronunciations given by the two groups and the effects of the position of the homograph in the sentence.

Pronunciation frequency. To test for the effect of pronunciation frequency, the self-corrected scores for the two frequent conditions (before and after) were combined in a composite score. The scores for the two rare conditions (before and after) were also

Table 5 Mean number of homographs pronounced context appropriately (Maximum = 4)

			Frequent pronunciation		Rare pronunciation	
n	Group		Before	After	Before	After
16	TD	Mean	3.38	3.50	3.25	3.62
		SD	.79	.97	.86	.62
15	AD	Mean	3.33	3.73	1.73	2.20
		SD	.98	.59	1.58	1.52

combined in a single score. Two Mann–Whitney tests were performed using these combined scores to compare the two groups. These tests revealed that whilst there were no differences in the number of frequent context-appropriate responses given by the two groups ($U = 114.5$, $p = .830$), there was a significant difference in the number of context-appropriate rare pronunciations given ($U = 49.5$, $p = .004$). AD children gave significantly fewer context-appropriate rare pronunciations than did TD children. This was the case whether the homograph was placed before or after the context (before: $U = 54.0$, $p = .008$; after: $U = 52.5$, $p = .006$). Furthermore, there was a significant within-subject difference in the number of rare versus frequent pronunciations given by the AD group ($Z = -2.595$, $p = .009$) but not in the TD group ($Z = -.214$, $p = .831$). These analyses confirmed that AD children tend to give the most frequent pronunciation regardless of context.

This result was confirmed by the analysis using the more 'stringent' score (i.e., initial pronunciation only). Children with autism gave significantly fewer rare responses than TD children (AD mean: 3.27 (2.65); TD mean: 5.62 (1.36); $U = 52$, $p = .006$). Within-subject analysis also showed that AD children, but not TD children, gave significantly more frequent than rare responses (AD frequent mean: 6.93 (1.39), rare mean: 3.17 (2.65), $Z = -2.925$, $p = .003$; TD frequent mean: 6.19 (1.33), rare mean: 5.62 (1.36), $Z = -1.276$, $p = .202$).

Position of homograph. To test for the effects of the position of the homograph in the sentence (before or after the context), the frequent and rare scores were combined into a single score for the before condition and the after condition.

Children with autism had significantly more correct responses when the homographs were placed after the sentence context than when placed before the context ($Z = -.2.36$, $p = .018$). Surprisingly, TD children's performance did not improve significantly when the homographs were placed after the sentence context ($Z = -1.778$, $p = .075$). Two Mann–Whitney tests were performed to compare the performance of the two groups. These tests revealed that TD children were more accurate than children with autism when the homographs were placed before ($U = 50.5$, $p = .005$) and after the context ($U = 67.5$, $p = .037$). Further analysis of initial uncorrected scores, however, showed that TD children were also affected by position. They were more accurate when homographs were presented after than before the sentence context (TD: $Z = -3.128$, $p = .002$). Furthermore, the position effects were, as predicted, larger than in the autistic sample (AD: $Z = -2.027$, $p = .043$) although the interaction could not be tested statistically.

Discussion

The results of this experiment support the evidence of Frith and Snowling (1983), Happé (1997) and Jolliffe and Baron-Cohen (1999) showing that children with autism are impaired in using sentence context in a homograph task. Whereas typically developing children gave the pronunciation most appropriate to the context of the sentence, children with autism did not adapt their pronunciation to sentence context and gave the most frequent pronunciation for the homograph. Given the proficiency shown by children with autism in our earlier experiments, it appears that difficulties in processing context information are specific to particular characteristics of this task.

Analysis of the effect of position of the homograph using the more stringent initial score revealed that children in both groups gave more context-appropriate pronunciations when the homograph was placed at the end rather than at the beginning of the sentence. This result is consistent with Happé's findings, although her findings were based only on self-corrected rather than initial responses. In our study we did not find a position effect for self-corrected responses in the typically developing group. This was because the typically developing group made a large number of self-corrections which cancelled out the position differences revealed by their initial score. Typically developing children made 34 corrections to their initial responses. Twenty-nine (85%) of these were made when homographs were placed before the context. In contrast, children with autism made 15 corrections, 9 (60%) of which were made when the homograph was placed after the sentence context.

Although the results help to identify the difficulty in autism as specifically related to ambiguous information within a sentence context, alternative explanations for the results are possible. An obvious explanation is that children with autism simply lack knowledge of the rare pronunciations of the homographs. In this study and the studies of Happé (1997) and Jolliffe and Baron-Cohen (1999), children's specific knowledge of rare homographs was not tested. However, in one study by Snowling and Frith (1986) subjects were informed that each word had two possible meanings and were given training in the alternative use of each word. Performance for all children improved following training but children with autism did not show any greater improvement than non-autistic children. This result is not sufficient to rule out the possibility that children with autism might be less familiar at the outset with low frequency words, and especially with ambiguous homograph words. Further studies are needed in which the effects of training are assessed against baseline knowledge and using stimuli that are controlled in terms of both frequency and ambiguity.

Children with autism made fewer self-corrections. This could be explained by either lack of knowledge of the rare pronunciation or lack of access to the two alternative pronunciations simultaneously. It might also be explained in terms of a lack of self-monitoring. Despite the lack of self-correction, however, children with autism still gave more correct responses when the homograph was presented after rather than before the sentence suggesting that children with autism may be capable to some extent of using sentence context. On balance then, the claim of a failure to take account of sentence context is best described not as an absolute impairment, but relative only to the ability of typically developing children.

General discussion

The weak central coherence account of autism makes the proposal that children with autism are impaired in processing information in its context. This difficulty in making use of context has been attributed to a problem with forming meaningful connections between semantically related items (Happé, 2000). To date, however, the evidence in support of this claim has rested mainly on the results of verbal tasks involving either recall of semantically related words or reading of sentences. As individuals with autism are known to have good visuo-spatial ability, the aim of the current research was to investigate whether they would be able to make use of context when information was presented in the visual domain.

Experiment 1 used an adaptation of Palmer's (1975) visual perception task to assess the influence of contextual scenes in object identification. For context information to have a facilitative effect on performance, children needed to link a visually presented contextual scene with an object that was either typically or untypically associated with that scene. Results showed that children with autism were as able as the comparison group to use visual contextual information to facilitate object identification. Surprisingly, Experiment 2 showed that the ability to take account of appropriate context was not confined to pictorial information but was also found when verbal information alone was presented.

Both these experiments suggest that children with autism can make meaningful connections between items. The results were unexpected in the light of evidence that children with autism have difficulty with a semantic memory task in which words are connected by means of their superordinate category (Tager-Flusberg, 1991). This evidence is often cited as providing support for the weak central coherence account (Happé, 2000). To examine the discrepancy between our findings and those of Tager-Flusberg (1991), the original semantic memory task was given to the participants of Experiment 1 and 2. In addition, another set of stimuli was added in order to include more than one semantic category. The results of this replication showed that, contrary to previous findings, children with autism did use semantic category information to aid recall when several categories were used and the earlier reported results seemed to be confined to the particular set of stimuli employed in the original study.

Experiments 1 to 3 therefore failed to support the case for weakness in central coherence. Individuals with autism performed like non-autistic samples and were sensitive to context and in general were also sensitive to semantic category information, regardless of whether the information was presented in visual picture form or purely verbally. Since these tasks require the integrating of single items on the basis of meaning, it is possible, in contrast to the suggestion by Happé (2000), that meaningful connections between words and objects are not weakened in autism, at least when tested in single word/picture tasks.

The replication of the homographs test in Experiment 4, however, did provide evidence of a deficit in the use of contextual verbal information in autism. Children with autism, as in previous studies, failed to give context-appropriate pronunciations and instead tended to give the most frequent pronunciation of the homographs. This task differs from the other three experiments in that it involves sentence processing and the processing of ambiguous stimuli.

We appear therefore to have isolated the impairment in using context as a specific impairment in using sentence context to disambiguate meaning. Possibly then, as suggested by Brian and Bryson (1996), the ability to make meaningful connections between single items is intact, whereas ability to integrate multiple items of information with sentences is impaired for children with autism. The evidence of these experiments seems to support Brian and Bryson's interpretation and fails to support the weak central coherence hypothesis. However, further research is needed to establish the extent to which these findings are related to developmental level. While older, more able children with autism might have a selective impairment with sentence it is possible that children with lower ability levels would also have difficulty with context even in single item tasks. Whether or not the ability to make connections between single items also presents difficulties for younger, less able children, it will be important to understand how this difficulty specifically relates to context.

Several alternative interpretations of these results also should be considered. One is that children with autism might lack familiarity with rare forms of homograph words or have difficulty accessing these words. This might be due to constraints in their language processing ability more generally. In a previous study in which training was provided in the alternative use of homograph words (Snowling & Frith, 1986), children with autism did not show any impairment in the homograph task, indicating that when assisted, children are able to access the rare form of homograph word. What is not clear is whether children with autism were initially less familiar with the rare forms of homographs from the outset and acquired these forms in the training or whether they were aware of both meanings from the outset but failed to access them using context until additional cues were given. Further research is needed that separates out initial familiarity, word frequency and type of training. Our own finding, that children with autism perform better when homographs are presented after rather than before the sentence, suggests that children can make use of context to aid access of rare pronunciation and meaning but are less able to do this than children in the comparison group. The results of Experiments 1 and 3 suggested that this might be related to lack of word knowledge. They made more errors in object naming and recalled fewer words in Experiment 3, suggesting that their recall performance may be sensitive to the effects of word frequency.

Another alternative to the view that children with autism have difficulties in integrating multiple items of information is the hypothesis that children may have difficulty with processing ambiguous stimuli in which two representations need to be held simultaneously. This hypothesis would predict that it is the ambiguity that creates the problem for children with autism rather than the context. If it is the case that the central difficulty for children with autism is with processing ambiguity rather than with processing sentence context, it is likely that children will have difficulty not only with processing ambiguous words in sentence contexts but also with processing ambiguous single words. This should be possible to test using a variation of the priming task described in Experiments 1 and 2 in which either sentences or single words are presented before the homograph word. In addition to difficulties in the verbal domain, a specific problem with ambiguity might also be evident in the visual domain. Children with autism may also have specific difficulties accessing the two interpretations of an ambiguous figure and this problem might also be independent of their ability to use context information.

If the difficulty with processing ambiguous information is independent of context, this problem would be equally well explained by both theory of mind and executive function explanations of autism. For example, the ability to represent alternative interpretations is considered to require metarepresentational ability (Perner, 1991) and is a hallmark of 'theory of mind'. The ability to shift between alternatives is also proposed as a critical element of executive function ability (Russell, 1998; Pennington & Ozonoff, 1996). There is some reason to predict that difficulty with ambiguity might not be independent of context, however. Happé (1997) found that performance on the homograph task is not associated with performance on theory of mind tasks. This result suggests that the homograph task involves additional cognitive demand. It is possible that the sentence context in the homograph task might be important in addition to the problem with ambiguity.

To conclude, our findings demonstrate that children with autism are facilitated by context information presented either visually or verbally. They do not have difficulties making 'meaningful connections' when items of information are presented singly. Their difficulties with the homograph task indicate a problem in either integrating multiple items of information or with selecting between multiple interpretations but the extent to which this difficulty is influenced by more general constraints of their language-processing ability is difficult to determine at this stage. Evidence still remains from other sources that children with autism might have difficulty processing global, context information, including evidence of failure to use semantic knowledge in language comprehension (Tager-Flusberg, 1981) and failure to process faces globally (López, Donnelly, Hadwin, & Leekam, submitted). However, given the results presented in this paper, it is not possible to conclude that there is a general deficit in processing context information.

Author note

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References

Ameli, R., Courchesne, E., Lincoln, A., Kaufman, A., & Grillon, C. (1988). Visual memory processes in high-functioning individuals with autism. *Journal of Autism and Developmental Disorders*, *18*, 601–615.

American Psychology Association. (1987). *Diagnostic and statistical manual of mental disorders* (3rd edn, revised). Washington, DC: author.

Baayen, R.H., Piepenbrock, R., & Gulikers, L. (1995). *The Celex Lexical Database* (CD-ROM). Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Becker, C. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition*, *8*, 493–512.

Bartolucci, G., Pierce, S., Streiner, D., & Eppel, D. (1976). Phonological investigation of verbal autistic and mentally retarded children. *Journal of Autism and Childhood Schizophrenia*, *6*, 303–316.

Biederman, I. (1972). Perceiving real-world scenes. *Science*, *177*, 77–80.

Biederman, I. (1981). Do background depth gradients facilitate object identification? *Perception*, *10*, 573–578.

Biederman, I., Mezzanotte, R., & Rabinowitz, J. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology*, *14*, 143–177.

Boucher, J., & Warrington, E. (1976). Memory deficits in early infantile autism: Some similarities to the amnesic syndrome. *British Journal of Psychology*, *67*, 73–87.

Boyce, S., Pollatsek, A., & Rayner, K (1989). Effect of background information on object identification. *Journal of Experimental Psychology: Human Perception and Performance*, *15*, 556–566.

Boyce, S., & Pollatsek, A. (1992). Identification of objects in scenes: The role of scene background in object naming. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *18*, 531–543.

Brian, J.A., & Bryson, S.E. (1996). Disembedding performance and recognition memory in autism/PDD. *Journal of Child Psychology and Psychiatry*, *37*, 865–872.

Chapman, L., Chapman, J.P., Curran, T., & Miller, M. (1994). Do children and the elderly show heightened semantic priming? How to answer the question. *Developmental Review*, *14*, 159–185.

Eskes, G., Bryson, S., & McCormick, T. (1990). Comprehension of concrete and abstract words in autistic children. *Journal of Autism and Developmental Disorders*, *20*, 61–73.

Friedman (1979). Framing pictures: The role of knowledge in automatized encoding of memory for gist. *Journal of Experimental Psychology*, *3*, 316–355.

Frith, U. (1969). Emphasis and meaning in recall in normal and autistic children. *Language and Speech*, *12*, 29–38.

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

Frith, U., & Snowling, M. (1983). Reading for meaning and reading for sound in autistic and dyslexic children. *Journal of Developmental Psychology*, *1*, 329–342.

Fyffe, C., & Prior, M. (1978). Evidence for language recoding in autistic retarded and normal children: A re-examination. *British Journal of Psychology*, *69*, 393–402.

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.

Happé, F. (1997). Central coherence and theory of mind: Reading homographs in context. *British Journal of Developmental Psychology15*, 1–12.

Happé, F. (2000). Parts and wholes, meaning and minds: Central coherence and its relation to theory of mind. In S. Baron-Cohen, H. Tager-Flusberg, & D.J. Cohen (Eds.), *Understanding other minds* (2nd edn). Oxford: Oxford University Press.

Hermelin, B., & O'Connor, N. (1967). Remembering of words by psychotic and subnormal children. *British Journal of Psychology*, *58*, 213–218.

Hollingworth, A., & Henderson, J. (1998). Does consistent scene facilitate object perception? *Journal of Experimental Psychology: General*, *127*, 398–415.

Jolliffe, T. (1997). *Central coherence dysfunction in autistic spectrum disorder*. Unpublished PhD Thesis, University of Cambridge.

Jolliffe, T., & Baron-Cohen, S. (1999). A test of central coherence theory; linguistic processing in high-functioning adults with autism or Asperger's syndrome: Is local coherence impaired? *Cognition*, *71*, 149–185.

López, B., Donnelly, N., Hadwin, J., & Leekam, S. Face processing in high-functioning adolescents with autism: evidence for weak central coherence? Paper submitted to *Visual Cognition*.

McCauley, C., Weil, C., & Sperber, R. (1976). The development of memory structure as reflected by semantic-priming effects. *Journal of Experimental Child Psychology*, *22*, 511–518.

Meyer, D., & Schvaneveldt, R. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, *90*, 227–234.

Neely, J.H. (1976). Semantic priming and retrieval from lexical memory: Evidence of facilitatory and inhibitory processes. *Memory and Cognition*, *4*, 648–654.

O'Riordan M., & Plaisted, K. (2001) Enhanced discrimination in autism. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *54A*, 961–979.

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

Ozonoff, S., Strayer, D.L., McMahon, W.M., & Filloux, F. (1994). Executive function abilities in autism and Tourette's syndrome: An information processing approach. *Journal of Child Psychology and Psychiatry*, *35*, 1015–1032.

Palmer, S. (1975). The effects of contextual scenes on the identification of objects. *Memory and Cognition*, *3*, 519–526.

Pennington, B., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *37*, 51–87.

Perner, J. (1991). *Understanding the representational mind*. Cambridge, MA: Bradford Books, MIT Press.

Pring, L., & Hermelin, B. (1993). Bottle, tulip and wineglass: Semantic and structural picture processing by savant artists. *Journal of Child Psychology and Psychiatry*, *34*, 1365–85.

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*, 733–742.

Radeau, M. (1983). Semantic priming between spoken words in adults and children. *Canadian Journal of Psychology*, *37*, 547–556.

Ramondo, N., & Milech, D. (1984). The nature and specificity of the language encoding deficit in autistic children. *British Journal of Psychology*, *75*, 95–103.

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.

Russell, J. (1998). How executive disorders can bring an inadequate 'theory of mind'. In J. Russell (Ed.), *Autism as an executive disorder*. Oxford: Oxford University Press.

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry*, *24*, 613–620.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry*, *8*, 1351–1364.

Snodgrass, J., & Vanderwart, M. (1980). A standarized set of 60 pictures: Norms of name agreement, image agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 174–215.

Snowling, M., & Frith, U. (1986). Comprehension in 'hyperlexic' readers. *Journal of Experimental Child Psychology*, *42*, 392–415.

Tager-Flusberg, H. (1981). Sentence comprehension in autistic children. *Applied Psycholinguistics*, *2*, 5–24.

Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence for a cognitive deficit. *British Journal of Developmental Psychology*, *9*, 417–430.

Teunisse, J.P. (1996). *Understanding face processing in autism: An investigation of the perception of faces in high-functioning individuals with autism*. Doctoral dissertation, Katholieke Universiteit Brabant, Netherlands.

Tulving, E., & Gold, C. (1963). Stimulus information and contextual information as determinants of tachistoscopic recognition of words. *Journal of Experimental Psychology*, *66*, 319–327.

Wolff, S., & Barlow, A. (1979) Schizoid personality in childhood: A comparative study of schizoid, autistic and normal children. *Journal of Child Psychology and Psychiatry*, *20*, 29–46.

Wechsler, D. (1974). *Weschler Intelligence Scale for Children – Revised*. New York: The Psychological Corporation.

World Health Organization (1990). *International classification of diseases* (10th edn). Geneva: WHO.

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Appendix 1 Examples of sentences used in Experiment 4 (Homographs Test)

Frequent pronunciation before context:

'There was a big tear on her cheek.'

Frequent pronunciation after context:

'Molly was very happy but on Lily's cheek there was a big tear.'

Rare pronunciation before context:

'There was a big tear in her dress.'

Rare pronunciation after context:

'The girls climbed over the hedge. Mary's dress was spotless, but in Lucy's dress there was a big tear.'