Journal of Child Psychology and Psychiatry 46:6 (2005), pp 661–672 doi: 10.1111/j.1469-7610.2004.00383.x

The prototype effect in recognition memory: intact in autism?

Catherine J. Molesworth, Dermot M. Bowler, and James A. Hampton
City University, London, UK

Background: There are two accounts of categorization performance in autism: that there is an impairment in prototype formation (Klinger & Dawson, 2001) and that there is an impairment in processing features held in common between stimuli (Plaisted, O'Riordan, & Baron-Cohen, 1998). These accounts, together with central coherence theory (Frith, 1989; Frith & Happé, 1994), imply a reduced or absent prototype effect in autism. **Method:** Children with autism or Asperger syndrome ($n = 15$) matched on age, gender, and verbal mental age with typically developing children ($n = 15$) completed a picture recognition task (Experiment 1). These participants also studied categories of cartoon animals possessing either an average prototype structure (Experiment 2) based on Younger's (1985) stimuli or a modal structure (Experiment 3) based on Hayes and Taplin's (1993b) stimuli. Following the study phases, participants completed recognition tests comprising prototypes and other exemplars with varying degrees of similarity to the prototypes. **Results:** For both participant groups, recognition memory appeared intact (Experiment 1) and a full prototype effect in recognition memory was observed in both Experiment 2 and Experiment 3. **Conclusions:** The present studies fail to support predictions of impaired prototype effects in autism. The discussion focuses on key methodological differences between these studies and those that support claims that central coherence, prototype formation, and common feature processing are impaired in autism. **Keywords:** Autism, Asperger syndrome, prototype, categorization, recognition, central coherence. **Abbreviations:** FR: family resemblance; HFA: higher functioning autism; LFA: lower functioning autism; PPRR: proportion of positive recognition responses; VMA: verbal mental age.

A prototype can be defined as the most representative member of a category. For example, Posner and Keele (1968) created prototype-based artificial categories by designating a random dot pattern as a prototype and then generating further category members by adding random variations. In this way, the prototype was the most representative member of the category because it depicted the average of these variant patterns. The prototype effect in recognition memory refers to an individual's tendency to display false recognition to an unstudied prototype. Participants in Posner and Keele's study, for example, were trained to categorize dot pattern exemplars (excluding the prototypes). In the subsequent recognition test, they displayed almost as much recognition for the prototypes as for previously seen exemplars. Another characteristic of the prototype effect is that recognition levels tend to reflect the degree of similarity between exemplars and the prototype: with high similarity being associated with greater recognition (Cabeza, Bruce, Kato, & Oda, 1999; Omohundro, 1981; Solso & McCarthy, 1981). An analogous prototype effect has been demonstrated using categorization tasks where an unstudied prototype is classified with an equal or greater accuracy than previously studied but less typical exemplars (Metcalfe & Fisher, 1986; Posner & Keele). Both effects have been replicated with a range of stimuli, including dot patterns (Posner & Keele), abstract forms (Homa, Goldhardt, Burruel-Homa, & Smith, 1993), and pictures of faces (Neumann, 1977). Typically developing children (Hayes & Taplin, 1993b) and children with mild learning disabilities (Hayes & Taplin, 1993a) have both demonstrated a prototype effect, and even infants have shown habituation to unseen prototypes (Younger, 1985, 1990).

Theoretical interpretations of the prototype effect reflect some of the long-running controversy over how conceptual knowledge is represented. According to prototype-based accounts, categories are represented by an idealized instance involving the abstraction of information from specific exemplars (Posner & Keele, 1968; Rosch, 1978). Prototype effects have been taken as evidence that this abstraction process occurs (Homa, Sterling, & Trepel, 1981; Posner & Keele). Alternative accounts of conceptual representation, exemplar views, regard concepts as being represented by individual category instances (Medin & Schaffer, 1978; Nosofsky, 1988). Exemplar theories account for prototype effects by assuming that responses are determined by the mean similarity between a target exemplar and other relevant category members stored in memory (Hintzman & Ludlam, 1980; Nosofsky, 1988, 1991).

The literature on concepts in autism has its origins in the work of early writers such as Scheerer, Rothmann, and Goldstein (1945) and Rimland (1964). These speculated that a conceptual impairment was responsible for observed abnormalities in both the social domain (e.g., a lack of reciprocal social interaction) and the non-social domain (e.g., a lack of adaptability to environmental change). Subsequent

Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

research into this conceptual impairment has revealed a mixed picture. Children with lower functioning autism (LFA) have demonstrated intact categorization abilities. For example, Ungerer and Sigman (1987) found that LFA children (with a mental age range of 1 to 3 years) were able to distinguish between simple perceptual categories defined by color and form as well as between members of natural and artifact categories. Tager-Flusberg (1985b) found no differences, in the meanings attributed to superordinate and basic category labels, between an LFA group and two control groups. Additionally, all participant groups showed a similar pattern of word meaning generalization. Tager-Flusberg (1985a) tested the same participant groups with biological and artifact categories using a *matching-to-sample* method. This involved presenting stimuli in groups of three: one target and two choices. The task aim was to select the choice most like the target. Overall, performance on the task suggested that all participants recognized semantic relationships among pictures and words, at basic and superordinate levels, in the same way.

Several other studies have suggested that people with autism do show abnormal responses to categorical information. Dunn, Vaughan, Kreuzer, and Kurtzberg (1999) presented a semantic classification task to children with higher functioning autism (HFA) and controls and measured event-related potential (ERP) responses to words presented auditorally. When the control group participants heard words belonging to the category *animal* their ERP responses suggested that they had activated mental representations of the superordinate category label. The HFA group, in contrast, failed to show these activation patterns. Shulman, Yirmiya, and Greenbaum (1995) administered a range of categorization tests to an LFA group, a learning disability group, and a typically developing group. Autism-specific deficits were revealed in a free sorting task in which LFA children made fewer accurate classifications of representative objects. In another task, LFA children failed more questions designed to test knowledge of class inclusion: such as 'Are all the squares red?' where the correct answer was 'No'. LFA children typically fail to aid their free recall memory by grouping exemplar information into categories (Hermelin & O'Connor, 1970; Minshew, Goldstein, Muenz, & Payton, 1992; Tager-Flusberg, 1991). Adults with Asperger syndrome also demonstrate the effect (Bowler, Matthews, & Gardiner, 1997; Bowler, Gardiner, Grice, & Saavalainen, 2000b).

Relatively few researchers have explored how individuals with autism process prototypicality. Dunn, Gomes, and Sebastian (1996) examined prototypicality in naturally occurring categories. They presented word fluency tasks to HFA children and to two control groups: one with language impairment and the other with typical development. Participants were asked to list examples of animals and vehicles. The HFA children produced a lower proportion of prototypical responses than either control group. Klinger and Dawson (2001) examined responses to prototypes of artificial categories: presented in the form of cartoon animals. They gave a categorization task to an LFA group, a Down syndrome group, and a typically developing group. Participants were familiarized with the name (e.g., 'Mip') and appearance of each category. A binary forced choice followed between the prototype and another exemplar from the same category. Participants were asked to choose the Mip. If the child responded accurately that both exemplars were Mips they were prompted to select the 'best Mip'. The typically developing group tended to select the prototype whereas both clinical groups performed at chance. Klinger and Dawson interpreted these findings as showing that the clinical groups had impairments in prototype formation.

Klinger and Dawson (2001) suggested that the prototype impairment in the autism group might be a manifestation of a more general cognitive processing abnormality: 'weak central coherence'. Frith (1989) coined the term 'central coherence' to refer to the natural human tendency to 'draw together diverse information to construct higher-level meaning in context' (Frith & Happé, 1994, p. 121). Frith argued that this tendency is weakened in autism. Supporting evidence spans a range of processing levels. For example, there is evidence of difficulty integrating high-level verbal semantic information. In Frith and Snowling's (1983) study, LFA children failed to use sentence context to disambiguate homographs. For instance, they tended to use inappropriate pronunciations of the word *bow* when reading the following sentences: 'He had a pink bow' and 'He made a deep bow'. These findings have also been replicated with an HFA group (Happé, 1997). Jolliffe and Baron-Cohen (2001) have reported an example of weak visuoconceptual coherence. They found that HFA and Asperger syndrome adults were impaired at an object identification task that required the ability to integrate object fragments conceptually. There is also evidence of weak visuospatial coherence. For example, both HFA and LFA performance on the block design subtest of the Wechsler intelligence scales (Wechsler, 1981) was superior to that of controls (Shah & Frith, 1993). This test requires the respondent to copy a geometric design using pre-existing segments. Shah and Frith modified the test by segmenting the design to be copied. This had the effect of increasing the level of control performance on the task to that of the autism groups. Thus, the authors concluded that individuals with autism were superior in their ability to mentally deconstruct the design into constituent parts. Also, Happé (1996) reported an example of difficulty with low-level perceptual integration: She found that LFA children tended not to succumb to visual illusions. Happé argued that these children failed to integrate the relevant parts of the figures with their 'illusion-inducing context'. (However, Ropar & Mitchell, 1999; 2001, failed to replicate this). Klinger and Dawson argued, 'prototype formation requires the ability to integrate information across experiences to form a central gestalt representation and therefore requires 'central coherence' abilities' (p. 122).

Plaisted et al. (1998) have identified another form of categorization impairment in autism. They presented a perceptual learning task to HFA adults and controls. During an initial training phase, participants learnt to discriminate between a pair of dot patterns that shared common elements (i.e., some dot positions). In the subsequent test phase, the control group demonstrated a perceptual learning effect: They were better able to discriminate between a pair of familiar patterns than between a pair of completely novel ones. Neither pair had been presented in the training phase but the familiar pair alone shared the same common elements as the training pair. The autism group failed to show a perceptual learning effect despite success at discriminating between patterns. They appeared unable to exploit the commonalities between the training and test phase. Plaisted et al. attributed this finding to a particular abnormality in perceptual and learning processes in autism: that features held in common between learning and transfer situations suffer weaker processing and that unique features are processed extremely well.

Both theories concerning prototype formation and common feature processing imply that children with autism differ in their use of similarity: specifically that they represent individual stimuli with very steep generalization gradients and do not perceive stimuli as similar unless they are very close in the stimulus space. If this is the case then children with autism should show reduced or absent prototype effects. This prediction is consistent with both exemplar and prototype accounts of category learning. These two theories are alike in their assumption that response to unseen category members is determined by high similarity to previously presented stimuli. Two studies reported here, Experiment 2 and Experiment 3, used the prototype effect in recognition memory to test the theories concerning prototype formation (Klinger & Dawson, 2001) and common feature processing (Plaisted et al., 1998).

Intact general recognition memory has been found in HFA children and adolescents (Barth, Fein, & Waterhouse, 1995; Bennetto, Pennington, & Rogers, 1996) as well as in Asperger syndrome adults (Bowler, Gardiner, & Grice, 2000a; Bowler et al., 2000b). A memory task (Experiment 1) was included to check that this was true also of the HFA children in the present study. This had the additional purpose of familiarizing all participants with experimental procedure.

Experiment 1

Method

Participants. Two groups took part in the study: 15 HFA children and 15 typically developing controls. The participant groups were matched on gender (all participants were boys), individually matched on chronological age (to within four months), and globally matched on VMA. The children in the autism group had been diagnosed by clinicians as having either Asperger syndrome (8) or autism (7) according to established criteria such as those specified by the DSM-IV (American Psychiatric Association, 1994). They were recruited from special education facilities and ranged in chronological age from 8 years and 9 months to 13 years and 11 months. Children in the control group were recruited from local schools in South East England. Their ages ranged from 8 years and 5 months to 14 years and two months. VMA was assessed by the British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Burley, 1997). Nonverbal mental age was assessed using Standard Progressive Matrices (Raven, 1996). Table 1 summarizes participant characteristics.

Materials. All stimuli were black line drawings on white 13 cm by 10 cm cards. There were two response cards differing only with respect to the relative positions, top or bottom, of two sentences: 'I have seen the picture before'/'I have not seen the picture before'. The response cards served as reminders as to what decision had to be made over the stimuli. Also, once participants were trained in their use, these cards enabled participants to make responses without verbal prompts from the experimenter (the first author).

There were 16 practice items. These were divided equally into two categories: plants and flowers. Each

Table 1 Participant characteristics

	Autism group ($n = 15$)	Control ($n = 15$)
Chronological age (years)		
M	11.71	11.73
SD	1.65	1.75
VMA (years)		
M	11.68	11.51
SD	3.02	2.98
Range	5.67–17	6–17
BPVS raw scores		
M	107.40	106.13
SD	21.58	20.38
Range	58–145	61–140
RPM raw scores		
M	38.27	35.07
SD	7.08	10.69
Range	28–52	12–45

Note: VMA = verbal mental age. BPVS = British Picture Vocabulary Scale. RPM = Ravens Progressive Matrices. VMA was derived from the BPVS. Maximum group difference: $t(24) = .97$, $p = .34$ (equal variances not assumed).

category was divided equally into study and test items. There were 32 memory task items. These were divided equally into two categories: animals and vehicles. Again, each of these categories was divided equally into study and test items. For both practice items and memory task items, half the test stimuli were 'old' replicas of the study items, the remainder being novel items.

Procedure. Participants were tested singly in a quiet room. The practice session was completed first. Participants were told that they had five seconds to study each of the practice study cards. Boucher and Lewis (1992) mention the difficulty of keeping the attention of some children focused on tasks like this, so participants were encouraged to pay attention to the study cards by means of a straightforward categorization task. They had to sort each card into one of two piles according to category: plants versus flowers. They were told to look at each card carefully and were warned that their memory for these cards would be tested. The study cards were shuffled and handed one at a time to each participant who was told to leave the card face up, obscuring the other items beneath it in the pile. If the participant's attention wandered, he was prompted to look at the card again and any mistakes in placing cards were corrected immediately by the experimenter. Participants then completed the practice test session. At the start, they were told that some of the test cards were exact copies of cards they had seen before, and some were new. They had to look at each card carefully and decide if they had seen the same picture before. They were familiarized with a response card and told to guess if unsure of the answer. The test cards were shuffled and placed face up in a single pile on the table one at a time. Participants responded in their own time by pointing to the relevant place on the response card. The memory task followed immediately with a procedure that was identical to the one described above for the practice session. Response card type was counterbalanced across participants.

Results and discussion

The mean proportion of correct recognition responses from the memory task was similar for both participant groups: .87 ($SD = .13$) for the autism group and .81 ($SD = .17$) for the controls. The difference between groups was not significant: $t(28) = 1.05$, $p = .30$). One sample t-tests revealed that for each group responding was significantly above the chance level of .5: $t(14) = 11.19$, $p < .01$ for the autism group and $t(14) = 6.91$, $p < .01$ for the control group. These reasonably high levels of memory task performance indicated successful use of the response cards by both participant groups and that recognition memory was intact in both groups. The absence of group differences suggested that performance on these two variables was similar for both participant groups.

Experiment 2

In this experiment, participants were familiarized with categories that were very similar to those used by Klinger and Dawson (2001). The stimuli were cartoon animals that were organized around average prototypes. These prototypes possessed features (e.g., legs or nose) that were the category average in size. Following a short study phase, participants made recognition responses to five exemplar types that were of decreasing similarity to the prototype. If there is a problem in integrating information across experience, as proposed by central coherence theory (Frith, 1989; Frith & Happé, 1994), and if there is an impairment in the formation of prototypes (Klinger & Dawson, 2001) and in processing common features (Plaisted et al., 1998), then the usual prototype effect should not be replicated in the autism group using a recognition test. The recognition responses of the autism group should not reflect similarity to the prototype to the same extent as those of the control group. It is unlikely that such a reduced effect could be attributable to poorer recognition memory. This is because the autism group performed similarly to the control group on the memory task (Experiment 1).

Method

Participants. The same participants from Experiment 1 were recruited.

Materials. The stimuli were presented on white cards identical to those used in Experiment 1. A similar method to that described in Younger (1985) and Klinger and Dawson (2001) was used to create average category stimuli consisting of cartoon animals. Similarity was manipulated by varying the size of animal features. Each exemplar possessed six features that were varied along a dimension with five equal steps from value 1 to value 6. One particular feature could have any of the six discrete values. Alternatively, if it belonged to the prototype, it took the average value (3.5 on the scale). The size of the steps between values varied across features but was constant for each single feature (e.g., for the 'insect neck' the values 1, 2, 3, 4, 5, and 6 represented increments of 4 mm). Exemplars varied in their global similarity or family resemblance (FR) to the prototype. In addition to the prototype (with all feature values set at 3.5), three exemplar types were generated. These possessed features that could take one of two possible values. The exemplar types with corresponding feature values in parentheses are as follows: high FR (3, 4), medium FR (2, 5), and low FR (1, 6).

There were 16 study items, 8 'monsters' and 8 'insects', and 34 test items: 17 from each category. The study items bore medium FR to their respective prototype. See Table 2 for a description of study item structure for insects. The monster study items had an identical structure.

The test items for each category consisted of 4 replicas of study items (old medium FR exemplars) and 13 new items. The latter comprised one prototype and four items each of high, medium and low FR exemplars. Table 3 gives a description of feature values for insect test items. Monster test items had an identical structure. Figure 1 illustrates the prototype and other new test exemplars from the insect category.

The studies of Klinger and Dawson (2001) and Younger (1990) each had two types of exemplar represented within the study sets. One type had features with values of 2 and 4: similar in size to those of the prototype that had features values all set at 3. The other exemplar type had features with values of 1 or 5: less similar to the prototype features. In contrast, the study sets of the present experiments contained only medium FR exemplars. This single exemplar type was selected so that the results would reveal more information about what strategies participants were using. If they simply memorized single features from the study set, failed to integrate them, and then responded to test items on the basis of how confusable test item features were with study item features, then recognition scores would not reveal a prototype effect. Medium FR exemplars would receive the highest recognition because they shared identical features with the study set. Also, recognition scores for prototype, high FR, and low FR exemplars would be very close because their features all differed from the most similar study item features by roughly the same value (1.5, 1, and 1 units respectively). If, however, participants were integrating the features to produce an average then their responses would be determined by similarity to this average (i.e, the prototype) and therefore would demonstrate a prototype effect. (The prototype, high FR, medium FR, and low FR feature

Table 2 Study stimuli for average prototype categories: insect feature values

	Insect features					
Item No.[a]	Neck length	Nose length	Wing position[b]	Sting length	Body band width	Antenna length
1	5	2	2	5	2	5
2	2	2	5	5	2	5
3	5	5	2	2	2	5
4	2	5	2	5	2	5
5	2	5	5	2	5	2
6	2	2	5	5	5	2
7	5	5	2	2	5	2
8	5	2	5	2	5	2

Note: [a]All items are medium family resemblance exemplars. [b]As measured from the bottom of the neck.

Table 3 Test stimuli for average prototype categories: insect feature values

	Insect features					
Item no. (Exemplar type)	Neck length	Nose length	Wing position[a]	Sting length	Body band width	Antenna length
1 (Old Medium FR)	5	2	2	5	2	5
2 (Old Medium FR)	5	5	2	2	2	5
3 (Old Medium FR)	2	5	5	2	5	2
4 (Old Medium FR)	2	2	5	5	5	2
5 (New Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
6 (New High FR)	3	4	3	4	3	4
7 (New High FR)	4	3	4	3	4	3
8 (New High FR)	3	3	4	4	3	4
9 (New High FR)	4	4	3	3	4	3
10 (New Medium FR)	2	5	5	2	2	5
11 (New Medium FR)	5	2	5	2	2	5
12 (New Medium FR)	5	2	2	5	5	2
13 (New Medium FR)	2	5	2	5	5	2
14 (New Low FR)	1	6	1	6	1	6
15 (New Low FR)	6	1	6	1	6	1
16 (New Low FR)	1	1	6	6	1	6
17 (New Low FR)	6	6	1	1	6	1

Note: FR = Family resemblance. [a]As measured from the bottom of the neck.

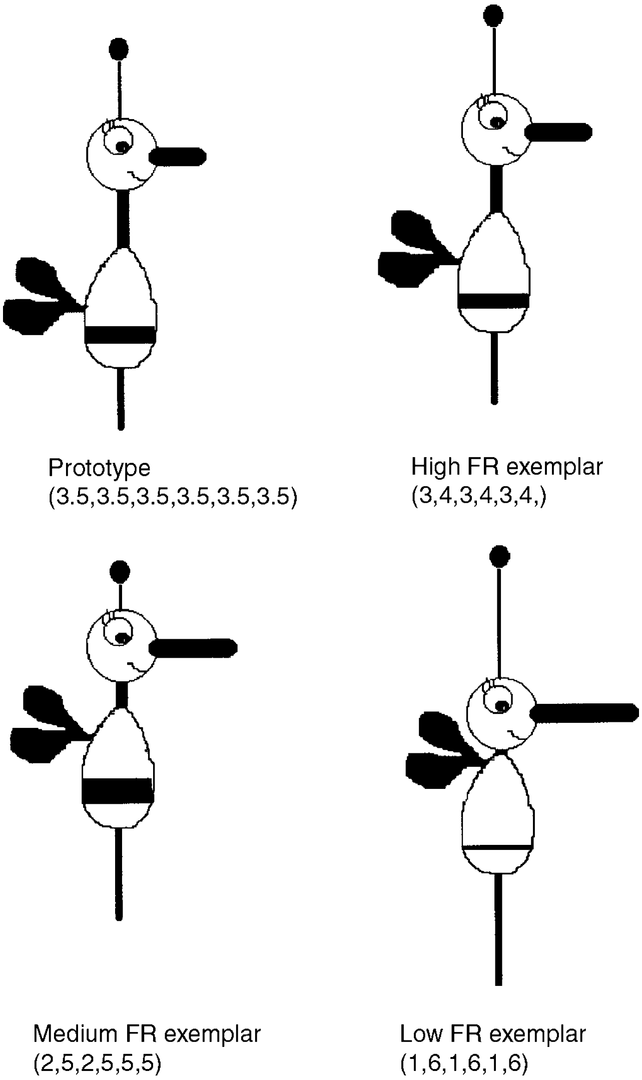

Figure 1 Examples of average category test stimuli. All are from the insect category. Figures in brackets represent feature values for neck length, nose length, wing position, sting length, body band width, and antenna length respectively

values all differed from prototype feature values by 0, .5, 1.5, and 2.5 units respectively.)

Procedure. All participants completed the average category task (Experiment 2) after the memory task (Experiment 1) and both tasks were completed within a week. The instructions and procedure for the average category recognition task were identical to those used for the memory task except that during the study phase participants had to sort the cards into 'monster' and 'insect' categories. Also before the test phase participants were warned that deciding if they had seen a card before might get 'a bit tricky' since many of the cards might look very similar to the ones they had seen before. They were told to try their best and to guess if they were unsure. The study cards were shuffled before each presentation as before. However, the test cards were divided into one of two possible blocked orders: one being the reverse of the other. The blocked orders were counterbalanced across participants. In each order, every exemplar was separated by a minimum of seven cards from another exemplar of the same category and FR level. This was intended to reduce the influence that test exemplars might exert on each other because representations of ill-defined categories are thought to be dynamic in the sense that they are easily modified by relevant experience (Homa et al., 1993).

Results and discussion

The frequency of positive recognition responses, selecting the response 'I have seen the picture before', was counted for each subject and exemplar type. The proportion of positive recognition responses (PPRR) was then calculated. These represented true recognition for the 'old' exemplars and incorrect responses (i.e., false alarms) for the remainder. The maximum possible number of positive recognition responses was 2 for the prototypes and 8 for each of the other exemplar types. (For each of these exemplar types, a chance level response would be 1 and 4 respectively.) The two participant groups were very similar in terms of the number of prototypes that they recognized. All individuals recognized at least one prototype, with 11 individuals from the autism group and 10 from the control group recognizing both. An independent samples t-test revealed no significant difference between the proportion of prototypes selected by the two participant groups: $t(28) = .39$, $p = .70$.

Both participant groups showed the same pattern of results. A higher proportion of prototypes and high FR exemplars were identified (incorrectly) as old than the actual study item replicas (old medium FR exemplars). There was no difference in recognition levels between old and new medium FR items, and the least false recognition was received for the low FR exemplars. Figure 2 illustrates data from all exemplar types. These comprised five levels: prototype, high FR, medium (old) FR, medium (new) FR, and low FR. The presentation order of Experiments 2 and 3 was counterbalanced across participants and included in the following analysis: The PPRRs were analyzed using a 2 (group) $\times$ 5 (exemplar type) $\times$ 2 (order) mixed, repeated measures ANOVA. This revealed a significant main effect of exemplar type: $F(4,104) = 52.47$, $p < .01$. No other effects or interactions were statistically significant: maximum $F(1,26) = 1.72$, $p = 0.20$. Repeated contrasts confirmed that high FR exemplars received a significantly greater PPRR than old medium FR exemplars, $F(1,26) = 10.59$, $p < .01$, and that new medium FR exemplars received a significantly greater PPRR than low FR exemplars, $F(1,26) = 119.44$, $p < .01$. The contrasts between the remaining exemplar types were not significant: prototype and high FR, $F(1,26) = 1.63$, $p = .21$, also old medium FR and new medium FR, $F(1,26) = .15$, $p = .70$.

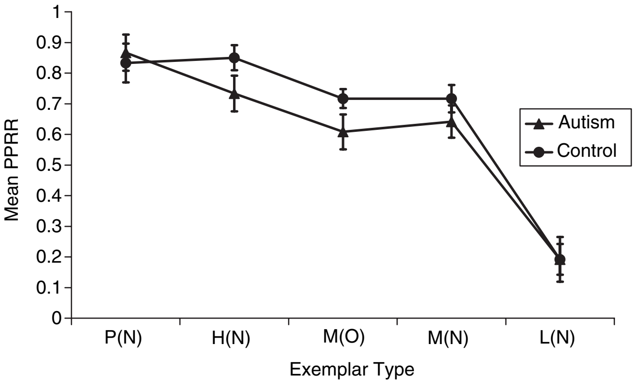

Figure 2 Average category: Mean proportion of positive recognition responses (PPRR) for each participant group and exemplar type. FR = family resemblance. P = prototype, H = high FR exemplars, M = medium FR exemplars, L = low FR exemplars, (N) = new exemplars, and (O) = old exemplars. Error bars represent standard error of the mean. PPRR was calculated out of responses to two prototypes and to eight each of the remaining exemplar types

The aim of this experiment was to see whether a prototype effect could be obtained in the recognition memory of HFA children using an average category structure. The full effect was obtained in both the autism and control groups. New category prototypes and high FR exemplars received greater levels of recognition than exemplars that were actually studied. Furthermore, the two participant groups differed neither in overall level of exemplar recognition nor in the degree to which similarity to a category prototype affected recognition. In both groups the lower the family resemblance of novel exemplars the less false recognition they tended to receive. Thus it seems unlikely that individuals in either group responded on the basis of how confusable individual features belonging to test items were with individual features belonging to study items. If they were doing this, as discussed earlier, there would be no prototype effect. The proposals that autism is characterized by impairments in prototype formation (Klinger & Dawson, 2001) and common feature processing (Plaisted et al., 1998) were unsupported by this study. No group differences were found in how the correlational structure of stimuli was represented in memory.

Experiment 3

Hayes and Taplin (1993a, 1993b) used an alternative method for manipulating inter-exemplar similarity within prototype-based categories. This involved the creation of modal prototypes. These possessed the feature types that occurred most frequently in the study sets. Such feature types varied in identify, for example, a head feature could be square, circular, or a diamond in shape. If there is an abnormality concerning the perception of similarity as implied by the theories concerning prototype formation (Klinger & Dawson, 2001) and common feature processing (Plaisted et al., 1998), then a reduced or absent prototype effect in recognition memory should be manifest with the use of modal prototypes.

Method

Participants. The same participants from Experiments 1 and 2 took part.

Materials. The modal category stimuli consisted of drawings of cartoon animals presented on cards as in Experiment 2. Two categories were represented by 16 study items: 8 ‘animals’ and 8 ‘birds’. The stimuli were constructed using similar methods to those of Hayes and Taplin (1993b). The exemplars had six features each of which could take on one of five possible feature values. For example, the bird beaks could take on one of five different shapes. Each study item (medium FR exemplar) shared three out of six features with the relevant category prototype. For each of the two categories, eight study items were constructed so that all the prototype feature values occurred four times in the set. Non-prototype features occurred only once. Table 4 shows the configuration of the study item feature values for the bird category. The animal study items had an identical structure.

There were 34 test items with 17 items from each category. These consisted of a prototype and four

Table 4 Study stimuli for modal prototype categories: bird feature values

	Bird features					
Item no.[a]	Beak	Wing	Head crest	Foot	Tail	Body marking
1	1	1	1	2	2	2
2	2	1	1	1	3	3
3	3	2	1	1	1	4
4	4	3	2	1	1	1
5	1	4	1	3	1	5
6	5	1	3	1	4	1
7	1	1	4	4	5	1
8	1	5	5	5	1	1

Note: [a]All items are medium family resemblance exemplars.

Table 5 Test stimuli for modal prototype categories: bird feature values

Item no.[a]	Bird features					
	Beak	Wing	Head crest	Foot	Tail	Body marking
1 (Old Medium FR)	1	1	1	2	2	2
2 (Old Medium FR)	4	3	2	1	1	1
3 (Old Medium FR)	2	1	1	1	3	3
4 (Old Medium FR)	1	5	5	5	1	1
5 (New Prototype)	1	1	1	1	1	1
6 (New High FR)	1	5	1	1	1	1
7 (New High FR)	1	1	4	1	1	1
8 (New High FR)	1	1	1	3	1	1
9 (New High FR)	1	1	1	1	2	1
10 (New Medium FR)	3	1	1	2	1	4
11 (New Medium FR)	1	1	3	3	1	5
12 (New Medium FR)	5	2	1	1	4	1
13 (New Medium FR)	1	4	4	1	5	1
14 (New Low FR)	4	4	1	3	2	5
15 (New Low FR)	5	3	3	1	4	2
16 (New Low FR)	2	1	4	4	5	3
17 (New Low FR)	3	2	2	2	1	4

Note: FR = Family resemblance.

items each of the following exemplar types: high FR, old medium FR, new medium FR, and low FR. For each category, the prototype shared five features in common with high FR exemplars, three features in common with both the new and old medium FR exemplars, and one feature in common with the low FR exemplars. See Table 5 for test stimuli feature values for birds. Animal test items had an identical structure. See Figure 3 for examples of modal category test stimuli.

Procedure. The procedure was identical to that of Experiment 2 except that children were told to sort the study cards into two piles of ‘birds’ and ‘animals’. All participants completed the memory task (Experiment 1) and the modal category task (Experiment 3) within a week. The two category tasks (Experiments 2 and 3) were completed on separate days and the presentation order of these two tasks was counterbalanced across participants.

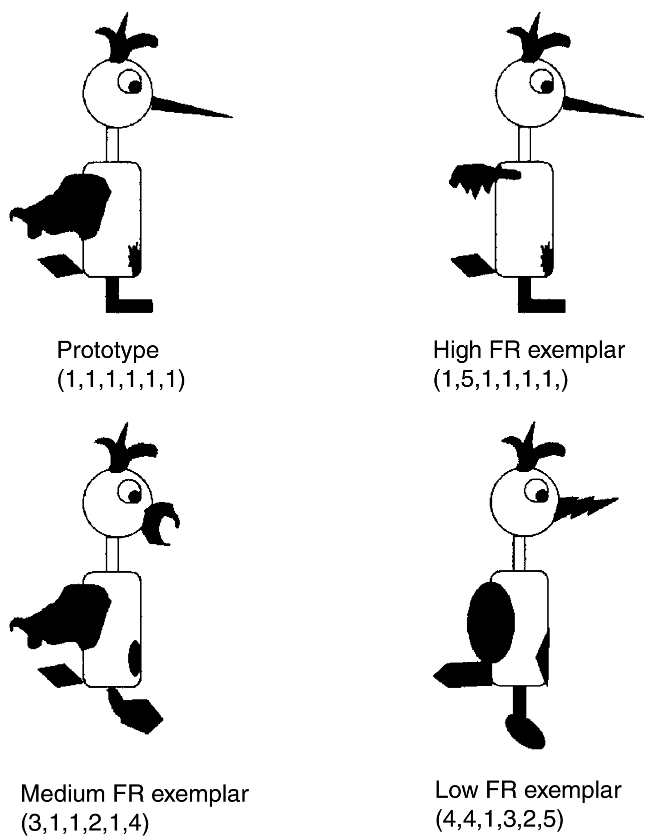

Figure 3 Examples of modal category test stimuli. All are from the bird category. Figures in brackets represent feature values for beak, wing, head crest, foot, tail, and body markings respectively

Results and discussion

A data-recording problem resulted in data from one matched pair being excluded from the analysis, so there were 14 individuals in each participant group. Prototype false recognition levels for the two participant groups were similar. All control participants recognized at least one prototype and seven recognized both. The frequency of participants with autism recognizing none, one, and both prototypes were 3, 3, and 8 respectively. PPRR was calculated for each exemplar type as in Experiment 2. An independent samples t-test revealed no significant difference between the proportion of prototypes recognized by the two participant groups: $t(22) = .54$, $p = .59$ (equal variances not assumed).

For both participant groups, a higher proportion of prototype and high FR exemplars were incorrectly identified as old than the actual replicas of study items. There was no difference in recognition levels between both old and new medium FR items. Low FR exemplars elicited the least false recognition.

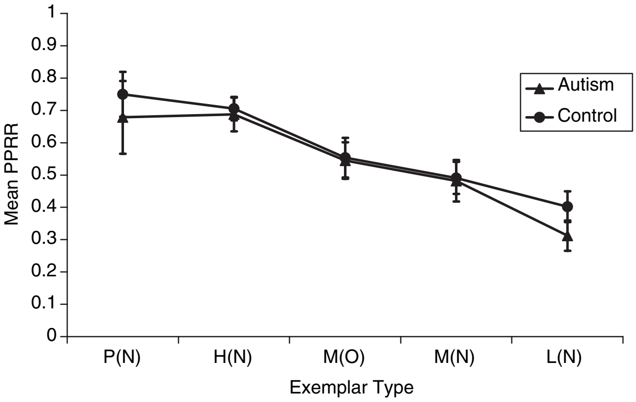

Figure 4 Modal category: Mean proportion of positive recognition responses (PPRR) for each participant group and exemplar type. FR = family resemblance. P = prototype, H = high FR exemplars, M = medium FR exemplars, L = low FR exemplars, (N) = new exemplars, and (O) = old exemplars. Error bars represent standard error of the mean. PPRR was calculated out of responses to two prototypes and to eight each of the remaining exemplar types

Figure 4 illustrates data from all the exemplar types. The order in which participants completed Experiments 2 and 3 were entered into the following analysis: The PPRRs were analyzed using a 2 (group) × 5 (exemplar type) × 2(order) mixed, repeated measures ANOVA. This revealed a significant main effect of exemplar type: Greenhouse-Geisser $F(3, 66) = 12.66$, $p < .01$. No other main effects or interactions were significant: maximum $F(1,24) = 1.24$, $p = .28$. Repeated contrasts confirmed that high FR exemplars received a significantly greater PPRR than old medium FR exemplars $F(1,24) = 10.05$, $p < .01$ and that new medium FR exemplars received a significantly greater PPRR than low FR exemplars $F(1,24) = 8.92$, $p < .01$. The contrasts between the following exemplar types were not significant: prototype and high FR, $F(1,24) = .06$, $p = .81$, also old and new medium FR, $F(1,24) = 1.30$, $p = .26$.

The aim of this experiment was to test the hypothesis that children with autism would fail to demonstrate a prototype effect in recognition memory using a modal category structure. Such an effect is dependent upon sensitivity to the common elements present between stimuli. The fact that the HFA children exhibited the effect represents a lack of support for the accounts that suggest impairments in prototype formation (Klinger & Dawson, 2001) and in common features processing (Plaisted et al., 1998). The two groups did not differ in overall recognition levels or in the degree to which similarity to the prototype affected recognition. The more features that an exemplar shared with the category prototype the greater recognition it tended to receive.

General discussion

The hypotheses that children with autism would fail to demonstrate a full prototype effect in recognition memory using an average category structure (Experiment 2) and a modal category structure (Experiment 3) were unsupported; a full prototype effect was demonstrated in recognition memory in both these experiments. The fact that effects were obtained with different stimulus structures supports the generality of the findings. Klinger and Dawson (2001) describe what can be considered both 'strong' and 'weak' accounts of category learning in autism. The strong version holds that individuals with autism may fail to form prototype representations. The present studies limit the generality of this version by demonstrating that HFA children can show prototype effects. These results also fail to support the weak version of Klinger and Dawson's theory, that prototype formation is impaired, as well as failing to provide evidence of a deficit in common feature processing (Plaisted et al., 1998).

Several methodological differences between the studies could account for the discrepancies between their results. In Klinger and Dawson's (2001) study participants had to make a decision on category membership (e.g., by selecting the Mip or the best Mip). In the present studies, participants simply had to make a recognition decision by deciding whether or not they had seen the stimulus before. Several studies have demonstrated that experimental manipulations can differentially affect recognition and categorization performance (Homa et al., 1993; Knowlton & Squire, 1993; Nosofsky & Zaki, 1998; Palmeri & Flanery, 1999). For example, Knowlton and Squire found that amnesic patients demonstrated intact categorization prototype effects despite impaired recognition. So, the possibility remains that prototype effects are also dissociable in autism with intact recognition memory and impaired categorization processes. Another possibility is that the LFA children in Klinger and Dawson's study were confused by the experimental task. The question that asked them to select the Mip from two category members was ambiguous; either choice was 'correct' because both items were Mips. These children may have been less able to use context to guide their answers because of difficulty understanding the pragmatic implications of language (Baron-Cohen, 1988; Eales, 1993; Tager-Flusberg, 1981). In contrast, the question used in the present studies was relatively straightforward with a single correct answer: Participants were asked if they had seen the test item before.

Both clinical groups in Klinger and Dawson's study, neither of which showed a prototype effect, had developmental delay. Additionally, their VMA was lower on average than that of the HFA group in the present studies. There are two ways in which both these factors, developmental delay and low VMA, could affect the expression of the prototype effect.

They could directly influence the mental representations assumed to drive the prototype effect. Alternatively, these two factors could exert their influence indirectly by interacting with the demands of the experimental tasks involved in producing the effect. Although a direct influence is a theoretical possibility, existing evidence suggests that this is unlikely. The fact that a prototype effect has been observed in infants (Younger, 1985; 1990) suggests that the effect does not follow a developmental trajectory. There is also evidence that mild non-organic developmental delay does not affect prototype formation (Hayes & Taplin, 1993a). Indeed, the fact that the prototype effect has been demonstrated by pigeons (Huber & Lenz, 1996; Jitsumori, 1996) seems to indicate that a fundamental learning process is responsible.

The developmental delay or lower VMA of the participants in Klinger and Dawson's (2001) study may have affected aspects of performance indirectly. For example, the LFA group may have failed to respond to the prototype because they had difficulty retaining visual information. There is evidence that LFA (but not HFA) children perform at chance on delayed matching-to-sample visual recognition tests (Barth et al., 1995). The HFA group in the present study appeared not to share this difficulty as shown by the presence of prototype effects and high memory task scores.

The present findings failed to support the common features account. The methodology that supported this account is very different from that used in the studies reported here. Plaisted et al. (1998) used a perceptual learning task with dot pattern stimuli. In contrast, the studies reported here used a prototype effect task with cartoon animal stimuli. One possibility is that the two tasks utilized different levels of processing. The common features account may be an accurate portrayal of information processing at the level tested by Plaisted et al. However, it may not be an accurate account at the level involved in the production of prototype effects in response to cartoon animals.

The studies reported here appear to provide examples of intact central coherence in autism. Both participant groups responded to the test exemplars as if they had integrated visual information from the study phases. The test exemplars varied in the level of integration that they represented. For example, average medium FR exemplars represented an absence of integration because they possessed features that were identical to those of the study sets. The average prototypes represented high levels of integration because they possessed features that were the category average in size and that had not actually appeared in the study sets. Participants' simple binary responses were influenced by the degree of integration represented by the test stimuli: the higher the integration, the greater the level of positive recognition. These findings stand in contrast to studies that demonstrate a reduced ability to integrate information in autism and that refer to this impairment as weak central coherence (e.g., Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 2001). These studies required participants to produce responses that are more complex. For example, the object identification task employed by Jolliffe and Baron-Cohen, presented participants with pictures of object fragments. The required response was the name of the whole object. The preceding observations imply that: Central coherence is intact where individuals with autism make simple judgments that reflect the levels of integration already inherent in stimuli; central coherence is weak where individuals with autism are required to make a response that is a direct integration of stimuli. If this dichotomy is replicable, there are two possibilities. The apparent weak central coherence impairment in integration may actually represent a deficit of late processing. Specifically, this deficit would occur at the point where an integrated mental representation is translated into a response that reflects that integration, for example, the naming of a whole object (Jolliffe & Baron-Cohen). The other possibility is that this particular type of weak central coherence represents a dissociation: implicit (unconscious) processing is intact and explicit (conscious) processing is impaired. The participants in Jolliffe & Baron-Cohen's study, for example, could not name the objects correctly without some conscious awareness of the processes involved in integrating the fragments. However, participants in the present studies could make responses that were influenced by the degree of integration present in stimuli, without any conscious awareness of this particular stimulus property.

In conclusion, the present studies failed to support predictions of an impaired or absent prototype effect in autism. These predictions were derived from accounts suggesting impairments in prototype formation (Klinger & Dawson, 2001), in common feature processing (Plaisted et al., 1998), and in central coherence (Frith, 1989). The present studies possess several methodological aspects that are absent in one or more of the studies that support these accounts. Any one of these aspects may have favored the expression of prototype effects by children with autism. These include: an autism group that is high functioning, cartoon animal stimuli, and a requirement for simple binary responses. Also, the task question was unambiguous and taxed recognition memory. Further research is required to isolate and test these methodological differences to see which ones critically affect the performance of individuals with autism.

Author note

Catherine J. Molesworth, Department of Psychology, City University; Dermot M. Bowler, Department of

Psychology, City University; James A. Hampton, Department of Psychology, City University.

Acknowledgements

The first author was supported by a Research Student Bursary from the Department of Psychology, City University, London. This article is based on data presented as a poster at the British Psychological Society Developmental Section Annual Conference, Bristol, September 2000. We wish to thank the children and their teachers for their invaluable help as well as anonymous referees for comments on an earlier draft of this paper.

Correspondence to

Catherine Molesworth, Department of Psychology, City University, Northampton Square, London EC1V 0HB, UK; Email: c.j.molesworth@city.ac.uk

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th edn). Washington, DC: Author.

Baron-Cohen, S. (1988). Social and pragmatic deficits in autism: Cognitive or affective? *Journal of Autism and Developmental Disorders*, *18*, 379–402.

Barth, C., Fein, D., & Waterhouse, L. (1995). Delayed match-to-sample performance in autistic children. *Developmental Neuropsychology*, *11*, 53–69.

Bennetto, L., Pennington, B.F., & Rogers, S.J. (1996). Intact and impaired memory functions in autism. *Child Development*, *67*, 1816–1835.

Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry*, *33*, 843–859.

Bowler, D.M., Gardiner, J.M., & Grice, S.J. (2000a). Episodic memory and remembering in adults with Asperger syndrome. *Journal of Autism and Developmental Disorders*, *30*, 295–304.

Bowler, D.M., Gardiner, J.M., Grice, S., & Saavalainen, P. (2000b). Memory illusions: False recall and recognition in adults with Asperger's syndrome. *Journal of Abnormal Psychology*, *109*, 663–672.

Bowler, D.M., Matthews, N.J., & Gardiner, J.M. (1997). Asperger's syndrome and memory: Similarity to autism but not amnesia. *Neuropsychologia*, *35*, 65–70.

Cabeza, R., Bruce, V., Kato, T., & Oda, M. (1999). The prototype effect in face recognition: Extension and limits. *Memory and Cognition*, *27*, 139–151.

Dunn, L.M., Dunn, L.M., Whetton, C., & Burley, J. (1997). *The British Picture Vocabulary Scale*. London: NFER-Nelson.

Dunn, M., Gomes, H., & Sebastian, M. (1996). Prototypicality of responses of autistic, language disordered, and normal children in a word fluency task. *Child Neuropsychology*, *2*, 99–108.

Dunn, M., Vaughan, H., Kreuzer, J., & Kurtzberg, D. (1999). Electrophysiologic correlates of semantic classification in autistic and normal children. *Developmental Neuropsychology*, *16*, 79–99.

Eales, M.J. (1993). Pragmatic impairments in adults with childhood diagnoses of autism or developmental receptive language disorder. *Journal of Autism and Developmental Disorders*, *23*, 593–617.

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

Frith, U., & Happé, F. (1994). Autism: Beyond 'theory of mind'. *Cognition*, *50*, 115–132.

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

Happé, F.G.E. (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.G.E. (1997). Central coherence and theory of mind in autism: Reading homographs in context. *British Journal of Developmental Psychology*, *15*, 1–12.

Hayes, B.K., & Taplin, J.E. (1993a). Development of conceptual knowledge in children with mental retardation. *American Journal on Mental Retardation*, *98*, 293–303.

Hayes, B.K., & Taplin, J.E. (1993b). Developmental differences in the use of prototype and exemplar-specific information. *Journal of Experimental Child Psychology*, *55*, 329–352.

Hermelin, B., & O'Connor, N. (1970). *Psychological experiments with autistic children*. Oxford: Plenum Press.

Hintzman, D.L., & Ludlam, G. (1980). Differential forgetting of prototypes and old instances: Simulation by an exemplar-based classification model. *Memory and Cognition*, *8*, 378–382.

Homa, D., Goldhardt, B., Burruel-Homa, L., & Smith, J.C. (1993). Influence of manipulated category knowledge on prototype classification and recognition. *Memory and Cognition*, *21*, 529–538.

Homa, D., Sterling, S., & Trepel, L. (1981). Limitations of exemplar-based generalization and the abstraction of categorical information. *Journal of Experimental Psychology: Human Learning and Memory*, *7*, 418–439.

Huber, L., & Lenz, R. (1996). Categorization of prototypical stimulus classes by pigeons. *Quarterly Journal of Experimental Psychology*, *49B*, 111–133.

Jitsumori, M. (1996). A prototype effect and categorization of artificial polymorphous stimuli in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, *22*, 405–419.

Jolliffe, T., & Baron-Cohen, S. (2001). A test of central coherence theory: Can adults with high-functioning autism or Asperger syndrome integrate fragments of an object? *Cognitive Neuropsychiatry*, *6*, 193–216.

Klinger, L.G., & Dawson, G. (2001). Prototype formation in autism. *Development and Psychopathology*, *13*, 111–124.

Knowlton, B.J., & Squire, L.R. (1993). The learning of categories: Parallel brain systems for item memory and category knowledge. *Science*, *262*, 1747–1749.

Medin, D.L., & Schaffer, M.M. (1978). Context theory of classification learning. *Psychological Review*, *85*, 207–238.

Metcalfe, J., & Fisher, R.P. (1986). The relation between recognition memory and classification learning. *Memory and Cognition*, *14*, 164–173.

Minshew, N.J., Goldstein, G., Muenz, L.R., & Payton, J.B. (1992). Neuropsychological functioning in nonmentally retarded autistic individuals. *Journal of Clinical and Experimental Neuropsychology*, *14*, 749–761.

Neumann, P.G. (1977). Visual prototype formation with discontinuous representation of dimensions of variability. *Memory and Cognition*, *5*, 187–197.

Nosofsky, R.M. (1988). Exemplar-based accounts of relations between classification, recognition, and typicality. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 700–708.

Nosofsky, R.M. (1991). Tests of an exemplar model for relating perceptual classification and recognition memory. *Journal of Experimental Psychology: Human Perception and Performance*, *17*, 3–27.

Nosofsky, R.M., & Zaki, S.R. (1998). Dissociations between categorization and recognition in amnesic and normal individuals: An exemplar-based interpretation. *Psychological Science*, *9*, 247–255.

Omohundro, J. (1981). Recognition vs. classification of ill-defined category exemplars. *Memory and Cognition*, *9*, 324–331.

Palmeri, T.J., & Flanery, M.A. (1999). Learning about categories in the absence of training: Profound amnesia and the relationship between perceptual categorization and recognition memory. *Psychological Science*, *10*, 526–530.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry*, *39*, 765–775.

Posner, M.I., & Keele, S.W. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology*, *77*, 353–363.

Raven, J.C. (1996). *Standard Progressive Matrices*. Oxford: Oxford Psychologists Press.

Rimland, B. (1964). *Infantile Autism*. New York: Appleton-Century-Crofts.

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.

Ropar, D., & Mitchell, P. (2001). Susceptibility to illusions and performance on visuospatial tasks in individuals with autism. *Journal of Child Psychology and Psychiatry*, *42*, 539–549.

Rosch, E. (1978). Principles of categorization. In E. Rosch, & B.B. Lloyd (Eds.), *Cognition and categorization* (pp. 27–48). Hillsdale, NJ: Lawrence Erlbaum.

Scheerer, M., Rothmann, E., & Goldstein, K. (1945). A case of 'idiot savant': An experimental study of personality organization. *Psychological Monographs*, *58* (4, Whole No. 269).

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.

Shulman, C., Yirmiya, N., & Greenbaum, C.W. (1995). From categorization to classification: A comparison among individuals with autism, mental retardation, and normal development. *Journal of Abnormal Psychology*, *104*, 601–609.

Solso, R.L, & McCarthy, J.E (1981). Prototype formation of faces: A case of pseudo-memory. *British Journal of Psychology*, *72*, 499–503.

Tager-Flusberg, H. (1981). On the nature of linguistic functioning in early infantile autism. *Journal of Autism and Developmental Disorders*, *11*, 45–56.

Tager-Flusberg, H. (1985a). Basic level and superordinate level categorization by autistic, mentally retarded, and normal children. *Journal of Experimental Child Psychology*, *40*, 450–469.

Tager-Flusberg, H. (1985b). The conceptual basis for referential word meaning in children with autism. *Child Development*, *56*, 1167–1178.

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.

Ungerer, J.A., & Sigman, M. (1987). Categorization skills and receptive language development in autistic children. *Journal of Autism and Developmental Disorders*, *17,* 3–16.

Wechsler, D. (1981). *Wechsler adult intelligence scales – revised*. New York: The Psychological Corporation.

Younger, B.A. (1985). The segregation of items into categories by ten-month-old infants. *Child Development*, *56*, 1574–1583.

Younger, B. (1990). Infant categorization: Memory for category-level and specific item information. *Journal of Experimental Child Psychology*, *50*, 131–155.

Manuscript accepted 17 May 2004