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PAPER

Analogical reasoning ability in autistic and typically developing children

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Abstract

Recent studies (e.g. Dawson et al.*, 2007) have reported that autistic people perform in the normal range on the Raven Progressive Matrices test, a formal reasoning test that requires integration of relations as well as the ability to infer rules and form high-level abstractions. Here we compared autistic and typically developing children, matched on age, IQ, and verbal and non-verbal working memory, using both the Raven test and pictorial tests of analogical reasoning. Whereas the Raven test requires only formal analogical reasoning, the other analogy tests require use of real-world knowledge, as well as inhibition of salient distractors. We found that autistic children performed as well as controls on all these tests of reasoning with relations. Our findings indicate that the basic ability to reason systematically with relations, for both abstract and thematic materials, is intact in autism.*

Introduction

Analogical reasoning requires comparing a source to a target analogue to identify systematic relational correspondences (Gentner, 1983), enabling both adults (Gick & Holyoak, 1980) and children (Holyoak, Junn & Billman, 1984) to transfer knowledge to novel environments. Gentner and Rattermann (1991; Ratterman & Gentner, 1998) proposed that a 'relational shift' occurs between the ages of 4 and 5 in typically developing children. After reaching this age, children primarily reason on the basis of shared relations even in the face of distraction arising from perceptual similarity. Increased working memory capacity for coping with relational complexity (a measure of the number of distinct dimensions of variation that must be processed together in order for a reasoner to reliably solve a problem; Halford, 1993) and increased inhibitory control (Richland, Morrison & Holyoak, 2006) have been proposed as important mechanisms underlying developmental changes in analogical reasoning.

A recent developmental study (Richland *et al*., 2006) with participants from several age groups (3–4, 6–7, 9–11, and 13–14 years of age) systematically manipulated both relational complexity and featural distraction in an analogy task based on finding correspondences between simple visual scenes (line drawings). Pre-tests confirmed that the critical relations (e.g. 'chasing') were recognized by even the youngest children. Richland *et al*.'s results revealed that development of the ability to reason analogically interacts with both relational complexity and featural distraction, with both of these sources of difficulty having a greater impact on younger than older age groups. In addition, younger children were especially likely to make the error of choosing a perceptual/semantic distractor (e.g. matching a cat to another cat when these did not play parallel roles). These findings suggest that changes in analogical reasoning with age depend on the interplay among increases in relevant knowledge, the capacity to integrate multiple relations, and inhibitory control over featural distraction (cf. Diamond, 2006).

Similar conclusions have been reached based on studies with adults (Cho, Holyoak & Cannon, 2007). For example, a dual-task study demonstrated that either a verbal working memory load or an executive load disrupts analogical reasoning (Waltz, Lau, Grewal & Holyoak, 2000), increasing featural relative to relational mapping. It has also been found that people become more susceptible to interference effects at older ages (Viskontas, Morrison, Holyoak, Hummel & Knowlton, 2004). Patients with damage to the prefrontal cortex (a neural substrate of executive functions) are poor at analogical reasoning, especially in the presence of distraction (Krawczyk, Morrison, Viskontas, Holyoak, Chow, Mendez, Miller & Knowlton, 2008; Morrison, Krawczyk, Holyoak, Hummel, Chow, Miller & Knowlton, 2004).

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In the present study we examined the development of analogical reasoning in autistic children. Analogical reasoning in autistic people has received little systematic investigation. Based on some theoretical interpretations (see Rajendran & Mitchell, 2007), it would be expected that autistic children's analogical reasoning would be impaired. For example, analogical reasoning is closely associated with the executive functions (EF) of the prefrontal cortex (Waltz, Knowlton, Holyoak, Boone, Mishkin, de Menezes Santos, Thomas & Miller, 1999), which are often impaired in autism (Hill, 2004). However, such impairment is not universal, and autistic people exhibit varying performance profiles across different executive tasks (Rajendran & Mitchell, 2007), which measure somewhat separable abilities related to sequencing, cognitive flexibility, and inhibitory control. Some studies reported deficits on EF tasks in low- but not high-functioning autistic groups (e.g. Hughes, Russell & Robbins, 1994; Ozonoff *et al*., 2004). There are also some indications that EF deficits in autism as compared to typical controls decrease with age (Happé, Booth, Charlton & Hughes, 2006; Ozonoff *et al*., 2004), although these findings could reflect sampling artifacts (as these studies were not longitudinal). Hill (2004) called attention to the need for studies that examine a wider range of executive-type tasks. Analogical reasoning in autistic people is one such task, which has seldom been examined in conjunction with other tests of executive functioning.

A deficit in analogical reasoning would also appear to be predicted by another influential cognitive account of autism, the Weak Central Coherence (WCC) theory (Frith & Happé, 1994; Happé, 1999). WCC theory proposes that typically developing individuals tend to engage in global processing, building up a gist-based representation, whereas autistic individuals engage in more detailed, local or piecemeal processing. WCC theory is supported by evidence that autistic children show very good performance on tasks that require attention to local features, such as embedded figures (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983) and block design tests (Shah & Frith, 1993). In contrast, they are less able than typically developing children to benefit from sentence context in disambiguating the meaning of homographs (e.g. Joliffe & Baron-Cohen, 1999). Other evidence suggests that autistic people are impaired in generativity (i.e. using their knowledge spontaneously and flexibly in novel situations; Peterson & Bowler, 2000). Autistic people appear to exhibit reduced processing of similarities between stimuli; instead, they are better at processing differences (Plaisted, 2001), although this characteristic may be restricted to perceptual processing. Autistic people also seem to have difficulty understanding metaphors and other types of non-literal language, such as irony (e.g. Pexman, 2008).

WCC theory has, however, been criticized based on evidence that in the general population various tasks that supposedly measure central coherence are not correlated with each other (Pellicano, Maybery & Durkin, 2005). Moreover, some studies suggest that people with autism are able to process information globally when they are instructed to do so, although they process information locally when no such instructions are offered (e.g. Mottron, Burack, Stauder & Robaey, 1999). A recent study using different versions of the Block Design task demonstrated that locally oriented processing in autistic participants did not imply a deficit in forming global representations (Caron, Mottron, Berthiaume & Dawson, 2006). Another study (Brock, Norbury, Einav & Nation, 2008) examined language-mediated eye movements in an autistic and a verbal ability-matched control group on a task requiring the use of sentence context to discriminate between a target word and a phonologically similar competitor. Performance on this task showed that the effect of sentence context was reduced in individuals with relatively poor language skills, regardless of group membership. Finally, after reviewing a large number of empirical studies of coherence, Happé and Frith (2006) concluded that the finding of a local bias was robust. On the other hand, the findings regarding weak global processing are mixed. Happé and Frith also concluded that the local bias was not a side effect of executive dysfunction or theory of mind deficits, and that it could be overcome through conscious effort.

Given that relational integration involves a form of coherence, it would appear that WCC theory would predict that autism should lead to general impairment of analogical reasoning. In fact, O'Loughlin and Thagard (2000), using a computational model in which coherence is established by constraint satisfaction, predicted (extrapolating from a computer simulation of performance on a homograph task) that the ability to reason analogically is very likely to be impaired in autism. However, the empirical evidence to date has been mixed. Scott and Baron-Cohen (1996) reported that autistic children with a learning disability were able to perform analogical reasoning tasks as well as both typically developing children matched in mental age and a group of children with learning disability who were matched in chronological and mental age. In contrast, Reed (1996) reported that autistic children showed poorer performance than a typically developing group on two out of four analogical reasoning tasks. More recently, Dawson, Soulières, Gernsbacher and Mottron (2007) examined autistic people's performance on the Raven Progressive Matrices test (Raven, 1938), which is designed to measure the ability to form perceptual relations and to reason analogically independent of language and formal schooling. These investigators found that autistic people with a learning disability according to their Wechsler intelligence scores performed in the normal range on the Raven test.

The performance of autistic people on the Raven test suggests that their ability to reason relationally with complex, abstract materials is unimpaired. However, although the Raven test requires integration and processing of complex information (Carpenter, Just & Shell, 1990), it does not require activation and integration of relevant knowledge (as the problems are purely formal). In addition, the presence of distraction is not systematically varied in the Raven test. It thus remains possible that autistic people may have difficulty with analogical reasoning when they have to retrieve and integrate relevant knowledge, or when they have to resist interference (Diamond, 2006).

Another hypothesis is that autistic people solve Raven problems using a different strategy than controls. For example, increased ability to discriminate between and remember highly similar visual patterns is characteristic of autistic people, and has been claimed to underlie their superior performance on the Block Design task (Caron *et al*., 2006). This heightened discrimination ability could contribute to success on the Raven test, which requires choosing the correct response from an array of visually similar patterns (see Figure 1). Superior autistic performance in processing differences, coupled with reduced processing of similarities (e.g. Plaisted, 2001), might also contribute to the observed discrepancy between autistic people's WISC and Raven scores (e.g. Dawson *et al*., 2007).

In the present study we employed three analogical reasoning tasks: the Raven's Advanced Progressive Matrices (APM), a picture analogy task (Krawczyk *et al*., 2008), and a scene analogy task (Richland *et al*., 2006). Both the picture analogy and the scene analogy task require the use of real-life knowledge. In the more difficult versions of both tasks, participants have to resist perceptual and semantic interference. We also investigated the effect of age on analogical reasoning within both the autistic and the control group. If the autistic group relies on different abilities to solve analogical reasoning problems, they may show different developmental patterns from the control group.

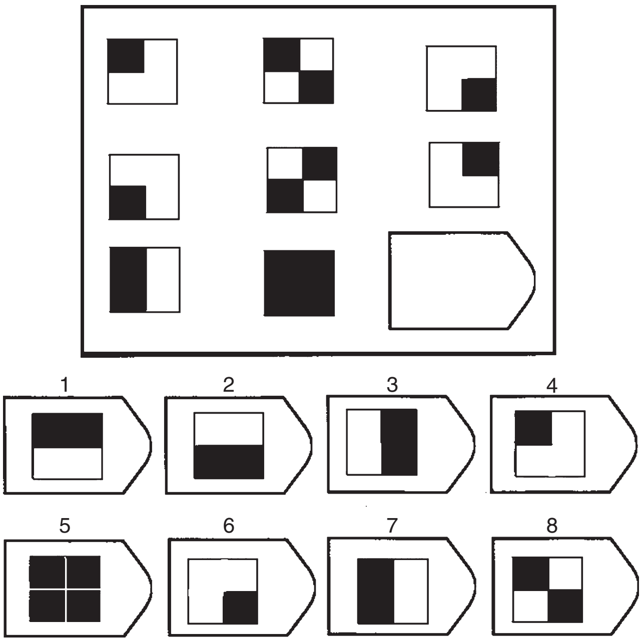

Figure 1 *A matrix problem similar to those in Advanced Progessive Matrices.*

Method

Participants

Twenty-three children (four females) with autism (Autistic Disorder: AD) took part in the study. The children were between the ages of 11 and 16 (mean age 13 years 7 months) and lived near Plymouth, UK. Diagnostic records of the children showed that every child had received a diagnosis of autism by experienced clinicians using the guidelines of DSM-IV (American Psychological Association, 1994). No child had a diagnosis of Asperger's syndrome or Pervasive Developmental Disorder. All participants in the AD group had a language delay, and at the time of the testing they took part in language and communication development classes in specialist units within their schools.

In addition, 49 typically developing children (19 females), between the ages of 11 and 16 (mean age 13 years 2 months) participated in the study as a control group. Children in the control group had no known clinically significant impairment or diagnosis.

Materials

Measures of verbal and non-verbal intelligence and working memory

To match the groups we administered a short form of the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991) and a verbal and a non-verbal working memory measure. The short form of the WISC consisted of the Vocabulary and the Block Design subtests, reported to have the highest reliability and validity compared to the other two subtest short forms of the WISC (used jointly, these two subscales have reliability of r_{tt} = .91 and validity of r = .86; Sattler, 2001, Table A-16). As the children were from different age groups, and we were interested in their absolute computational capacity rather than their IQs, we used raw scores on the tasks for our analyses and for matching the samples. We also administered the *counting span task*, a verbal working memory measure with a processing and a storage component (for a detailed description see Handley, Capon, Beveridge, Dennis & Evans, 2004), and a computer-administered version of the Corsi blocks task (based on Vandierendonck, Kemps, Fastame & Szmalec, 2004), a visuospatial counterpart to verbal working memory span tasks. We used both a forward and a backward recall version of the task. The forward recall version is a purer measure of visual-spatial working memory, whereas the backwards version additionally loads on central executive resources (Vandierendonck *et al*., 2004).

Analogical reasoning tasks

To measure analogical reasoning ability we used Set 1 of the Advanced Progressive Matrices test (Raven, Raven & Court, 1998), a picture analogy task, and a scene analogy task. Set 1 of the APM consists of 12 items (see Figure 1 for an example). It is usually used as a practice and screening set for the full test, and draws upon all the intellectual processes sampled on the full test (though it does not extend to the highest complexity levels).

The *picture analogy task* was adapted from Krawczyk *et al*. (2008). These problems were presented as pictures in the format A:B::C:? (e.g. sandwich:lunchbox::hammer:?). Participants had to complete the analogy with one of four answer choices presented as separate pictures beneath the problem. In *distractor* problems, the four response options contained the correct solution (e.g. toolbox), together with a perceptual distractor (e.g. gavel), a semantic distractor (e.g. nail), and a picture unrelated to the C term (e.g. ribbon). In *non-distractor* problems, the two distractors were replaced by two additional unrelated items. The first two problems (a distractor and a non-distractor one) were for practice and were not included in the analyses. These were followed by another eight distractor and eight non-distractor problems (in a fixed random order). See Figure 2 for examples of a distractor and non-distractor problem. The particular items used in the distractor and non-distractor conditions were counterbalanced across participants within each group.

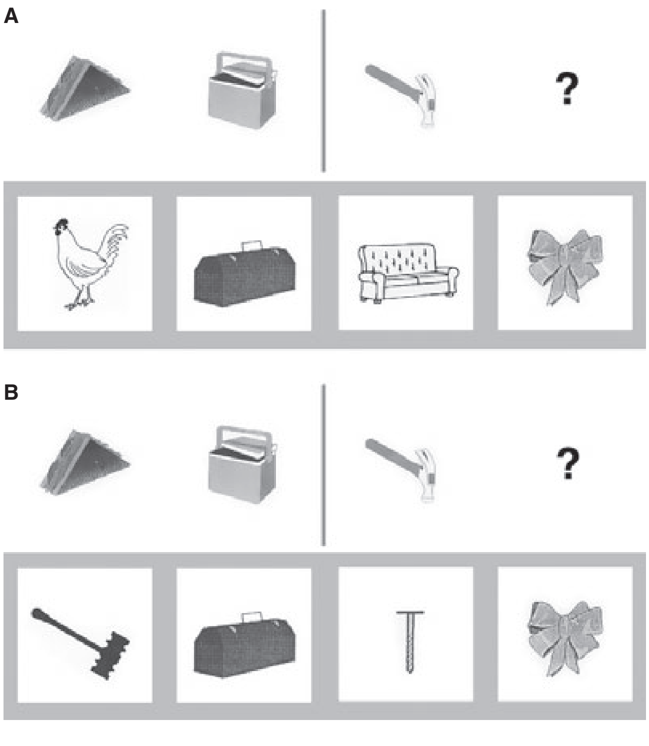

Figure 2 *Non-distractor and distractor versions of a picture analogy problem (A: non-distractor; B: distractor).*

The *scene analogy task* was adapted from Richland *et al*. (2006). The problems consisted of a pair of pictures (source and target analogues, arranged vertically). In each picture four or five objects appeared in simple relationships (see Figure 3). Two or three of these objects were involved in a critical relationship, such as 'hanging' (e.g. a baby monkey hanging on an adult monkey, which was hanging on the trunk of an elephant). An arrow pointed to one of the objects in the source scene (e.g. the adult monkey), and participants had to find the object corresponding to this object in the target scene (e.g. a girl, given that a doll is hanging on a girl who in turn is hanging on a tree). There were 20 problems, five in each of four conditions that systematically varied the number of relation tokens that needed to be mapped, one or two (e.g. one or two tokens of the 'hanging' relation in each picture), and the presence or absence of an object in the target scene that was either featurally similar to (distractor condition) or dissimilar to (non-distractor condition) the object to be mapped in the source scene (e.g. a monkey in the target picture that visually and semantically resembled the adult monkey in the source, versus a cat that did not resemble the object in the source). The particular pairs of scenes used in each of the four conditions were counterbalanced across participants within each group.

Procedure

The children took part in two sessions. In one session they performed the analogical reasoning tasks. This session took about 30 minutes, and the children completed the tasks in groups. In the other session, participants were administered the individual differences measures. This session took about 20 minutes, and children performed the tasks individually, supported by the experimenter.

Results

We first compared the autistic and the control groups on the individual differences measures (see Table 1). The groups did not differ significantly on the WISC, or on the verbal and non-verbal working memory tasks (including the backwards version of the Corsi blocks task, a measure of executive functions). We calculated the reliability of the counting span task by performing a split-half correlation between odd and even trials between each set level, and used the Spearman-Brown formula to obtain an estimate of the reliability of the task. The reliability of this measure was 0.72. Similarly, we computed the reliability of the forwards and backwards versions of the Corsi blocks task. The reliability of the forwards version was 0.63 and of the backwards version was 0.61, levels considered acceptable (Rust & Golombok, 1999).

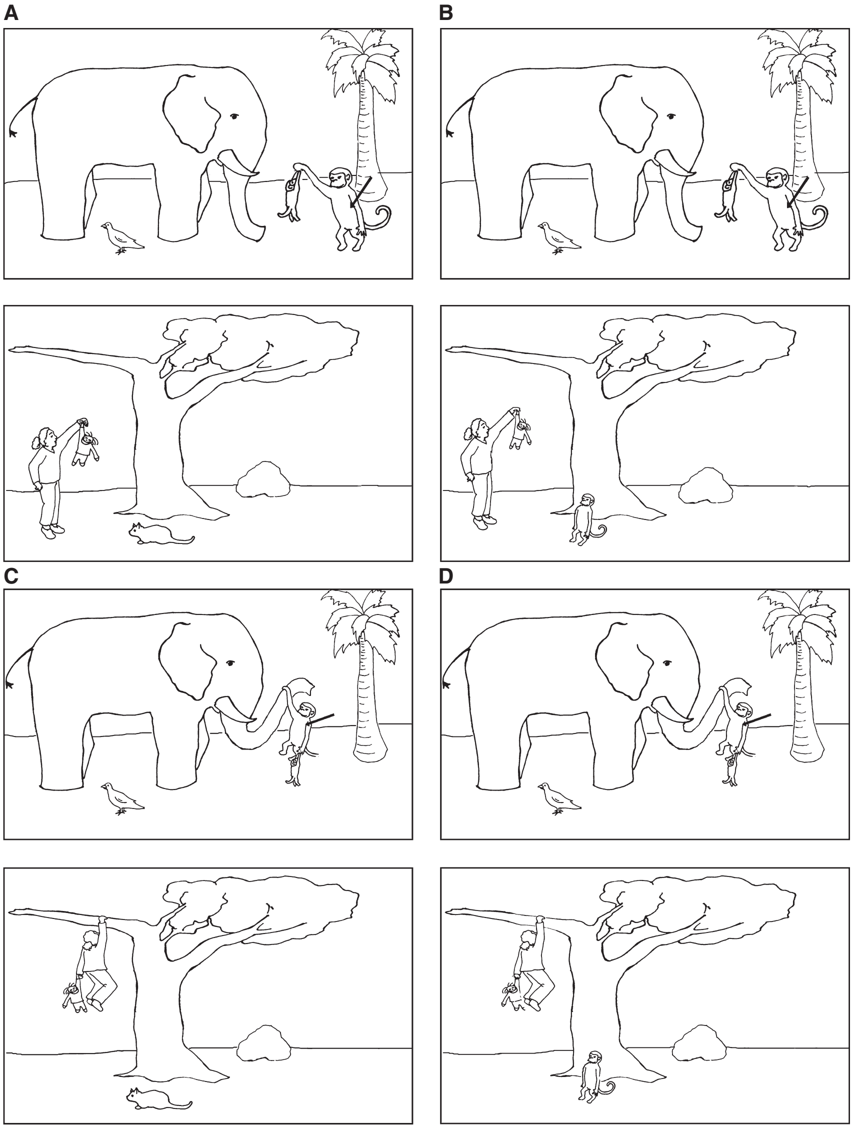

Figure 3 *Different versions of a scene analogy problem: (A) one relation/no distractor; (B) one relation/distractor; (C) two relations/no distractor; (D) two relations/distractor.*

Table 1 *Mean scores (standard deviations in parentheses) for individual differences measures across groups*

	Autistic	Control
WISC Block design	48.00 *(12.4)*	45.47 *(11.5)*
WISC Vocabulary	25.39 *(8.8)*	28.69 *(7.8)*
Counting span	21.09 *(9.3)*	24.41 *(8.4)*
Corsi forwards	10.52 *(3.9)*	10.22 *(3.0)*
Corsi backwards	9.22 *(3.7)*	9.00 *(2.6)*

Table 2 *Mean age and estimated IQ (standard deviations in parentheses) for each of the four participant groups*

	Autistic		Control	
	Younger (*n* = 10)	Older (*n* = 13)	Younger (*n* = 29)	Older (*n* = 20)
Age (months)	147.6 *(8.1)*	178.2 *(10.8)*	144.4 *(10.4)*	177 *(10.2)*
Estimated IQ	97.4 *(10.5)*	99.3 *(13.3)*	98.7 *(11.8)*	101.8 *(8.5)*

For the purpose of analyzing performance on the analogy tasks, we divided our samples into two age groups (younger and older). (See Table 2 for mean age and estimated IQs for each group.) The estimated full-scale IQ score was based on performance on the Vocabulary and Block Design subtests of the WISC-III, and it was calculated using formulas in Sattler (2001). A 2 (group: control versus autistic) by 2 (age: younger/older) ANOVA on the estimated IQs indicated that there were no differences between age groups, between the autistic and control group, nor was there any interaction between age and group membership (*Fs* $< .8$, p values $> .4$)

We first compared the groups with respect to performance on Set 1 of the APM (see Table 3). A 2 × 2 ANOVA with age group and autistic/control group as between-subjects variables yielded a reliable main effect of age ($F(1, 71) = 6.5$, $p < .05$, $\eta_p^2 = .09$). There was no significant effect of group (autistic/control) and no interaction between age and group.

Table 3 *Mean number of correct responses on the Advanced Progressive Matrices test (standard deviations in parentheses) across groups*

Autistic		Control	
Younger	Older	Younger	Older
6.7 *(2.1)*	8.5 *(2.1)*	6.0 *(2.8)*	7.2 *(2.2)*

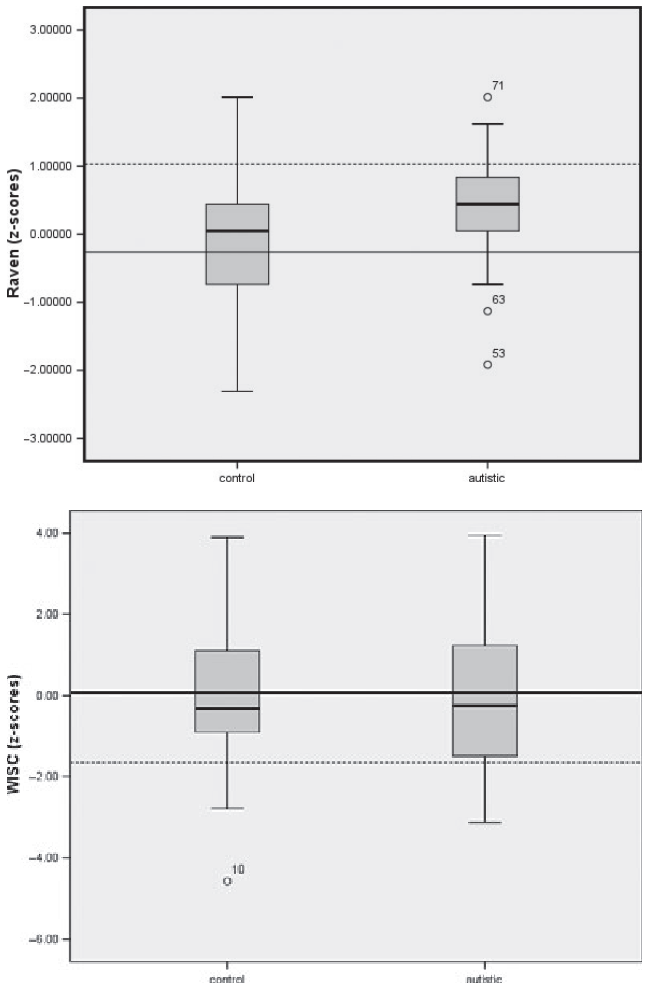

Figure 4 *Box plots showing performance on the WISC and the Raven test. Raw scores were converted into z-scores based on data from all participants (z-scores for the two subtests of the WISC were averaged). The vertical rectangle for each group shows the distribution of the middle 50% of scores, and the error bars attached to both ends of these rectangles extend out to include 100% of the data (with three outliers plotted separately). The solid black lines bisecting each rectangle represent the medians of the distributions. The thick black line intersecting the y-axis represents the mean score of the typically-developing group, while the thin black line intersecting the y-axis represents 1 standard deviation below or over the mean score of the typically developing group.*

Figure 4 plots the distribution of scores on the WISC (summing over the two subtests) and on the APM for the autistic and control conditions (over all ages). The sample of autistic children tested by Dawson *et al.*

Table 4 *Mean number of correct responses (standard deviations in parentheses) across groups on the distractor and non-distractor picture analogy problems*

	Autistic		Control	
	Younger	Older	Younger	Older
Non-distractor	7.6 *(.5)*	7.4 *(.7)*	7.4 *(.9)*	7.4 *(.8)*
Distractor	5.4 *(1.3)*	5.3 *(1.6)*	5.4 *(1.3)*	5.4 *(1.7)*

(2007) scored significantly higher on the Raven test than on the Wechsler scales of intelligence. For our samples the distributions overlap substantially, though the trend does favor the autistic group on the APM. Our autistic sample consisted of individuals with IQs in the normal range only, whereas the autistic participants in the Dawson *et al.* study were drawn from a wider range of abilities according to their Wechsler scores. It is likely that the profile of cognitive strengths and weaknesses is generally less uneven for autistic individuals without a learning disability. We replicated the finding of Dawson *et al.* (2007) that the relative difficulty of the Raven items was highly correlated between the autistic and control children, $r(10) = .89$, suggesting that the test measured the same construct in the two groups. Similarly, the correlations between the WISC subtests were moderate, and virtually identical for the two groups ($r(21) = .45$, $p < .05$ for the autistic, and $r(47) = .47$, $p < .01$ for the control group), indicating that the intelligence tests measure the same construct in both groups.

Performance on the picture analogy task (see Table 4) was analyzed using a $2 \times 2 \times 2$ mixed ANOVA with distraction (present/absent) as a within-subjects factor, and age group (younger/older) and group (autistic/control) as between-subjects factors. A main effect of distraction was obtained ($F(1, 68) = 123.3, p < .01, \eta_p^2 = .65$). No other main effect or interaction was significant, indicating that autistic and control subjects suffered equal impairment from the presence of distractors as response options. Additional 2×2 ANOVAs with group (autistic/control) and age group (younger/older) as between-subjects variables were performed to test for possible differences in the number of perceptual, semantic and other errors that children made on the picture analogy task. No reliable effects of age or group were found.

In order to further assess whether the autistic and control groups solved the picture analogy problems using similar strategies, we performed an item analysis. For each group, we obtained the mean percent correct for each of the 16 basic items, collapsing across the distractor and non-distractor versions. If there were reliable differences among items, and if both sets of participants solved the problems using similar strategies, then we would expect to find a robust correlation between the difficulty of the individual items across the groups. The relative difficulty of the picture analogy items was indeed highly correlated between the autistic

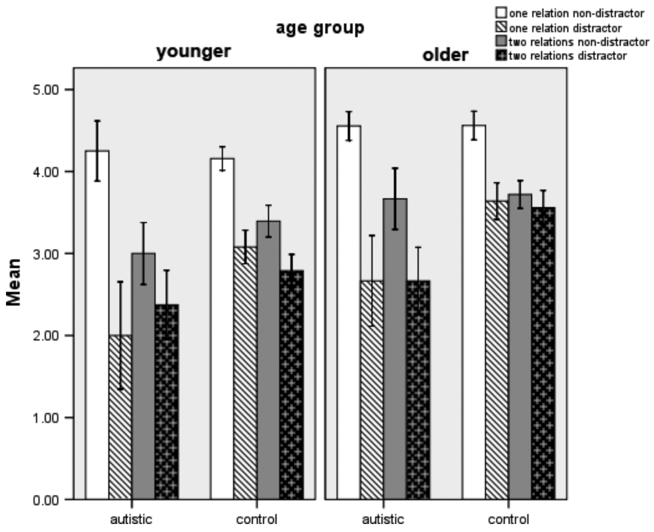

Figure 5 *Mean number of correct responses across groups for the different conditions of the scene analogy problems (error bars: ±1 standard error of mean).*

and control children, $r(14) = .81$, suggesting that both groups solved the problems using similar strategies.

Finally, Figure 5 depicts mean performance on the scene analogy task. We performed a $2 \times 2 \times 2 \times 2$ mixed ANOVA on the scene analogy task to examine the effects of relational complexity (one or two relations: within-subjects), distraction (present/absent: within-subjects), group (autistic/control: between-subjects) and age (younger/older: between-subjects). This analysis revealed a main effect of relational complexity ($F(1, 68) = 14.78$, $p < .01$, $\eta_p^2 = .18$), a main effect of distraction ($F(1, 68) = 44.5$, $p < .01$, $\eta_p^2 = .40$), and a relational complexity by distraction interaction ($F(1, 68) = 14.75$, $p < .01$, $\eta_p^2 = .18$). The effect of age was also significant ($F(1, 68) = 8.95$, $p < .01$, $\eta_p^2 = .12$). This pattern reflected the fact that children performed worse on problems with higher relational complexity or in the presence of distraction. As is apparent in Figure 5, the profile of accuracy across conditions was very similar for autistic and control children, and the performance of autistic children was statistically indistinguishable from that of the control group at either age level.

We also compared the groups with respect to the number of perceptual, relational and other errors that they made on the scene analogy task. These 2×2 between-subjects ANOVAs (autistic/control, younger/older) revealed that the number of relational errors decreased with age ($F(1, 71) = 4.8$, $p < .05$, $\eta_p^2 = .07$). No other reliable differences were found between the groups. We also performed an item analysis similar to that reported above for the picture analogy task. For each group, we obtained the mean percent correct for each of the 20 basic pairs of scenes, collapsing across the four conditions. The relative difficulty of the scene analogy items was highly correlated between the autistic and control children, $r(18) = .71$, again suggesting that the two groups used similar strategies to perform the analogy task.

Discussion

In the present study we compared a group of autistic children with a group of typically developing children on the Raven Advanced Progressive Matrices test and two knowledge-based tests of analogical reasoning. The autistic and the control groups were closely matched in age, general intelligence, and verbal and non-verbal working memory. We found no differences between the two groups on any of the analogical reasoning tasks. Performances of the autistic and the typically developing children were equally impaired by increased relational complexity and by the presence of perceptual and semantic distractors. Older children within both the autistic and control groups scored higher on the APM and on the scene analogy problems than did younger children, and the older groups made fewer relational errors on the scene analogy problems than did younger children.

Our results for these analogy tasks confirmed patterns observed previously with non-autistic populations (Krawczyk *et al.*, 2008; Richland *et al.*, 2006), but provided no evidence of differential performance between the autistic and non-autistic groups. Moreover, we replicated the finding of Dawson *et al.* (2007) that the relative difficulty of the Raven items was highly correlated between the autistic and control children, arguing against the possibility that the two groups use substantially different strategies to solve the problems. In addition, the difficulty of individual items on both the picture analogy and scene analogy tests correlated highly between the two groups. Although relatively superior performance of autistic people on the Raven test (as compared to general intelligence as measured by the WISC) could be related to enhanced perceptual processing, it seems implausible to attribute normal performance on the picture analogy and scene analogy problems to group differences in perceptual abilities, as the relationally matched source and target items in these problems were visually dissimilar.

Our findings support the hypothesis that the ability to reason analogically is intact in autism, not only for abstract problems such as the Raven test (Dawson *et al.*, 2007), but also for knowledge-based problems (the picture analogy and scene analogy tasks). The present findings are consistent with those of previous studies that found intact analogical reasoning performance in autistic people (e.g. Dawson *et al.*, 2007; Scott & Baron-Cohen, 1996). At a more general level, our findings concur with previous evidence that autistic people are as susceptible to context effects as are controls matched in verbal ability (Brock *et al.*, 2008). Our results suggest boundary conditions on the hypothesis that autistic people have problems with using their knowledge spontaneously and flexibly in novel situations (Peterson & Bowler, 2000) insofar as basic analogical reasoning would seem to require some ability to use knowledge flexibly. Our results are also inconsistent with the hypothesis that autistic people exhibit reduced processing of similarity between stimuli and situations (Plaisted, 2001), as analogical transfer crucially depends on recognizing similarities. Contrary to predictions based on various versions of the WCC theory (Frith & Happé, 1994; O'Loughlin & Thagard, 2000), autistic children were able to create systematic mappings between stimuli (which requires processing of stimuli in context and establishing coherence), even in the face of perceptual distractors that encourage use of a perceptual matching strategy. Altogether, the present findings paint a picture very different from Kanner's original description of autism, which stated that 'If the slightest ingredient [of a situation, performance or sentence] is altered or removed, the total situation is no longer the same and therefore is not accepted as such…' (Kanner, 1943, p. 246).

The prerequisites for successful analogical reasoning include access to relevant real-world knowledge, as well as intact working memory and executive functions. As autistic people sometimes have working memory and other impairments of executive functions when compared to IQ-matched controls (for reviews see Hill, 2004; Rajendran & Mitchell, 2007), it is possible that some autistic people will have problems with analogical reasoning when they are matched to controls on IQ only, but not on measures of executive functioning. (See Pellicano, Maybery, Durkin & Maley, 2006, for evidence concerning the relationship between executive function deficits and problems with integrating information.) Autistic people may also have difficulty when analogical reasoning requires the processing of complex verbal material (Lopez & Leekham, 2003) or picking up and integrating cross-modal cues (Pexman, 2008).

In summary, the present findings indicate that autism *per se* does not imply an inability to reason analogically. It is important to note that all the analogy tasks used in the present study involved pictorial rather than verbal presentation of the problems. Moreover, the problems were either purely formal (APM), or required highly constrained knowledge largely provided directly by the pictorial stimuli (picture analogies and scene analogies). According to the Task Support Hypothesis (Bowler, Gardiner & Berthollier, 2004), autistic individuals show greater difficulty in retrieving and integrating background knowledge with a problem context when retrieval is not directly cued by a task. Recently, Sahyoun, Soulières, Belliveau, Mottron and Mody (2009) investigated simple analogical reasoning in participants with high-functioning autism (HFA) or else Asperger's syndrome, comparing these groups with age- and IQ-matched typically developing participants as controls. All participants solved pictorial problems that differed in whether they necessitated semantic or visuo-spatial processing, or could be solved relying on either type of information. Sahyoun *et al.* found that although there were no differences either across problem types or across groups in accuracy rates, participants with HFA showed a different profile of reaction times from the other two groups. In particular, HFA participants were slowest on problems that required semantic processing. Our findings leave open the question of whether a difference in reaction times would be found between the autistic and control groups when solving the present tasks (indicating a difference in efficiency of processing), as well as the question of whether analogical reasoning ability in autism would also be intact for tasks that provide less support for memory retrieval. However, the answers to these questions will not alter the present conclusion that the basic ability to reason analogically is unimpaired in autism. The lack of impairment for autistic children on these analogy tasks, when compared to typically developing children matched on intelligence and executive functioning, should help guide the development of more specific hypotheses about the source of difficulties observed for autistic people in other reasoning tasks.

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