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ORIGINAL PAPER

The Perception of Animacy in Young Children with Autism

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Abstract Visual perception may be a developmental prerequisite to some types of social understanding. The ability to perceive social information given visual motion appears to develop early. However, children with autism have profound deficits in social cognitive function and may fail to see social motion in the same way that typically developing children do. We tested the hypothesis that children with autism fail to discriminate animate motion, using a novel paradigm involving simple geometric figures. The subjects were 23 children with autism (c.a. 70.7 mos.), 18 children with other developmental disabilities (c.a. 68.2 mos.), and 18 typically developing children (c.a. 46.4 mos.). Children saw two circles moving on a screen and were rewarded for identifying the one that moved as if animate. A control condition required children to identify the heavier of two objects. Children with autism initially showed a deficit in categorizing objects as animate (though no deficit on the control task), but showed no deficit in this ability after they had reached criterion in the training phase. These results are discussed in terms of the social orienting theory of autism, and the possibility that animacy perception might be preserved in autism, even if it is not used automatically.

Keywords Autism · Perception · Animacy · Theory of mind · Intentionality

Humans are uniquely social animals and there appear to be many specific cognitive processes underlying human social abilities. Visual perception may underlie social understanding in humans, both developmentally and temporally. Much of the social information that is available to humans is visual information. Humans have access to social information through the visual perception of facial expression, gestures, and various kinds of animate or biological motion cues, for example.

Early and foundational work in the area of animacy perception was done by Michotte (1963) who suggested that simple motion cues provided the foundation for social perception in general. We know from the early work of Heider and Simmel (1944) that simple geometric figures can be seen as having goals, desires, intentions and emotions, based on their motion alone. Following this tradition, myriad studies have shown that people can perceive animacy, intentions, emotion and personalities attributed to simple geometric figures based on their movements (Hashimoto, 1966; Morris & Peng, 1994; Rime, 1985). In fact, we know that adults are capable of seeing animacy based entirely on motion cues as simple as the acceleration and change in direction of a figure no more complex than a dot (Tremoulet & Feldman, 2000). Recently, modern experimentalists have suggested that in adults the visual system is capable of perceiving social information and recovering social structure from very simple motion displays (Scholl & Tremoulet, 2000).

Young Children Can See Visual Motion as Social

The perception of simple moving figures as animate may be foundational both in the sense that in adults this visual perception happens early in social cognitive processes, and in the sense that animacy perception is an early developmental step. The ability to see moving geometric figures as

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animate apparently develops early. Three and 4-year-olds attribute desires, goal, emotions and personalities to figures in Heider and Simmel's display, just as adults do (Berry & Springer, 1993). Other studies using various geometric figures as ''characters'' have found that infants as young as 12 months old see these figures as intentional, based on motion cues (Csibra, Gergely, Biro, Koos, & Brockbank, 1999; Dasser, Ulbaek, & Premack, 1989; Gergely, Nadasdy, Csibra, & Biro, 1995; Premack, 1990). Infants as young as three months of age prefer to look at a display of 2 disks chasing each other over a display of 2 disks moving independently (Rochat, Morgan, & Carpenter, 1997) which could indicate a preference for animate motion (although simpler interpretations, such as a preference for coordinated movement, are possible). We know that young infants can recognize biological motion given a point-light walker display, and evidence shows that infants as young as 3 months prefer to look at the biological motion of a walking figure compared to carefully controlled motion stimuli (Bertenthal, 1993; Bertenthal, Proffitt, Spetner, & Thomas, 1985). Taken together this evidence suggests that young typically developing children may develop the ability to perceive animacy in visual displays at an early age. Furthermore, animacy perception makes an integral contribution to social information processing and social cognition.

Autism

Autism is a developmental disorder characterized by three clusters of symptoms: (1) specific impairments in social interactions, especially involving joint attention and shared experiences (Baron-Cohen, 1989, 1991; Mundy, Sigman, & Kasari, 1990; Mundy, Sigman, Ungerer, & Sherman, 1986) (2) delay or impairment in the development of communication (Mundy et al., 1990; Ricks & Wing, 1975; Ungerer & Sigman, 1981), and (3) stereotyped or ritualistic behavior, including attachment to routines or object placement as well as extreme interest in a peculiar topic and compulsive mannerisms (Cuccaro et al., 2004; Lord et al., 2000; Miles, Takahashi, & Mudrick, 2000). For most individuals with autism the most profound and characteristic cognitive deficits are the social cognitive deficits. The most reliably measured deficits in early autism are those in social areas such as joint attention, communication and imitation. In fact, perhaps the most reliably measurable deficits in autism is a deficit in joint attention (Baron-Cohen, 1989, 1995; Buitelaar, van Engeland, de Kogel, de Vries, & van Hoof, 1991; Mundy et al., 1986; Mundy & Sigman, 1989), and this deficit appears as early as 18 months (Baron-Cohen, Allen, & Gillberg, 1992) or even 12 months (Osterling & Dawson, 1994).

Social dysfunction in autism may have its roots in social perceptual difficulties. One prominent model of social development, the ''theory of mind'' theory, proposes that the developing mind has an ''intentionality detection'' mechanism, which is an early precursor to other social cognitive development. This intentionality detection mechanism relies primarily on visual input to perceive intentional beings. This cognitive ability appears to be dissociable, since children with autism do not show social cognitive deficits in some other domains (such as understanding reciprocity and relationships) (Baron-Cohen, 1991).

The Perception of Social Motion in Autism

There is some evidence that individuals with autism spectrum disorders fail to see social motion as typical people do. Moore, Hobson, and Lee (1997) found that 14-year-old individuals with autism have deficits in perceiving emotion-related attitudes and subjective states (though not detecting biological motion), given the motion cues of a point-light-walker display (Moore et al., 1997). This finding reveals a deficit in perceiving mental states based on motion cues. This finding was recently replicated and expanded upon with individuals in middle childhood, in a study which demonstrated a relative deficit in the perception of biological motion itself (Blake, Turner, Smoski, Pozdol, & Stone, 2003). This later study showed performance that was above chance, but still well below typical performance among people with autism spectrum disorders. In addition, Klin (2000) found autism specific differences in people's descriptions of the classic Heider and Simmel task (1944) in which subjects are ask to narrate the actions of simple geometric figures (Klin, 2000). He found deficits at this higher level of interpreting social motion, suggesting the important developmental question of whether people with autism would have typical precursors to this ability to perceive social information in motion cues. This is an important question since this early perceptual ability would be needed for understanding other aspects of human action.

Evidence from brain imaging research also suggests that in autism, many specific social cognitive deficits might be attributable to specific brain areas known to be involved in social cognition. One group of researchers found decreased gray matter volume in individuals with autism in brain structures centered around the amygdala (Abell et al., 1999), the very same brain structures that past research has implicated in social cognition, including theory of mind (Happe et al., 1996). Another study, this one using a PET scan, showed that compared to control participants, individuals with autism showed less activation in the ''mentalizing network'' area of the brain while watching socially complex (coaxing or tricking) displays (Castelli, Frith, Happe, & Frith, 2002).

Current Study

The primary aim of this project is to test whether children with autism can use motion to identify animacy in the same way that typical children do. It is possible that an early ability to discriminate animate from inanimate motion is a precursor to further social development for typical children, and a causal deficit in children with autism. This would predict that an early measurable deficit in autism would be a failure to discriminate animate motion. The intention of this study is to test the hypothesis that young children with autism are less able to discriminate animate from inanimate objects based on motion cues, compared to mental age matched controls. In particular, we defined as animate any figure that appeared to accelerate, decelerate, or propel itself in such a way as to suggest an internal energy source (Dittrich & Lea, 1994; Scholl & Tremoulet, 2000). Research in this tradition suggests that the perception of animacy is produced if an object starts from rest, changes direction or moves towards a goal. In this experiment, young children saw a circle moving as if it were animate, contrasted with a circle moving only in response to impact or gravity. These circles were presented on a computer touch screen, and children were rewarded for touching the animate circle.

Methods

Participants

The participants in this experiment were 23 children (21 boys and 2 girls) with autistic disorder (AD), 18 children (7 boys and 11 girls) with other developmental disorders (DD) and 18 typically developing children (7 boys and 11 girls), matched on overall mental age (see Table 1). The average chronological age of the children with autism was 70.7 months, 68.2 months for the children with other developmental disorders, and 46.4 months for the typically developing children.

The children with autism and other developmental disorders were recruited from various health and early education agencies, as well as parents' support and information organizations. The typically developing children were recruited from pediatrician's offices and through a university developmental subject pool. The children with autism were free from any other medical condition, had no visual or hearing impairment, had been diagnosed with autism by an outside agency, received current clinical diagnoses of autism, and met criteria for autism on at least two of three diagnostic systems: DSM-IV, ADI-R and ADOS-G. In addition, all of these children had a current clinical diagnosis of autism.

Table 1 Demographic information on participants

Diagnosis	*n*	CA	Overall MA
Autistic	23	Mean 70.74	6.8
Disorder		s.d. 15.41	2.2
Developmental	18	Mean 68.2	40.3
Delay		s.d. 11.8	7.8
Typical	18	Mean 46.4	40.6
		s.d. 11.2	10.7

The children with developmental disorders (DD) all had normal vision or vision corrected to normal, had unimpaired hand use, and were mobile. None was considered by any clinician, past or present, to have symptoms of autism. None of the DD group met criteria for autism on the DSM-IV, the ADOS-G, or on the ADI-R. This group of 18 children included 5 children with Down syndrome and 13 children with different idiopathic developmental disorders.

Measures

Autism Diagnostic Interview—Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994)

The ADI-R is a structured, standardized parent interview developed to assess the presence and severity of symptoms of autism in early childhood across the three main symptom areas in autism: social relatedness, communication, and repetitive, restrictive behaviors. The ADI-R has been carefully psychometrically validated across a wide range of ages and severity levels in autism.

An algorithm has been established that differentiates autism from other developmental disorders at high levels of sensitivity and specificity (over .90 for both) for subjects with mental ages (MA) of 18 months and older. Raters in this project were reliable to 85% or better item agreement.

Autism Diagnostic Observation Schedule—Generic (ADOS-G; Lord et al., 2000)

The ADOS-G is a semi-structured standardized interview using developmentally appropriate social and toy-based interactions in a 30–45 min interview to elicit symptoms of autism in four areas: social interaction, communication, play, and repetitive, restrictive behaviors. The ADOS-G consists of four different modules, each directed at a particular level of language ability.

Mullen Scales of Early Learning (MSEL; Mullen, 1989)

The MSEL is a standardized developmental test for children ages 3 months to 60 months consisting of 5 subscales: gross motor, fine motor, visual reception, expressive language, and receptive language. The MSEL allows for separate standard verbal and nonverbal summary scores to be constructed. The MSEL demonstrates strong concurrent validity with other well-known developmental tests of motor, language, and cognitive development. The MSEL was administered to subjects according to standard instructions. Reinforcers were used at times to reward cooperation and attention.

The participants in this study were part of a larger longitudinal study on the development of autism (Rutherford, Young, Hepburn & Rogers, in press; Rutherford & Rogers, 2003; Scambler, Rogers, Rutherford, & Wehner, in press). The above measures were taken together in the third author’s clinic at the University of Colorado Health Sciences Center in Denver, Colorado. The current experiment, involving just the animacy discrimination procedure, took place in the homes of the participants, and was administered by the first author. No other measures were administered concurrently with the Animacy Discrimination Procedure.

Before the procedure itself started, but after the experimental computer was set up in the home, the experimenter (M.D.R.) interacted with the child in order to put the child at ease. The experimenter then guided the child to the computer, while saying ‘‘we’re going to play a game on the computer’’ but did not say anything about the nature of the game, nor anything more about what would be on the computer. The experimenter was careful, throughout this more casual, unscripted interaction, not to mention animacy or the idea of something being ‘‘alive.’’ Each of the children seemed comfortable with the experiment, and with the idea of interacting with the computer, and a parent was present throughout the procedure. Once the child was comfortably seated at the computer screen, the Animacy Discrimination Procedure began.

Animacy Discrimination Procedure

Animacy discrimination in this experiment was assessed using a novel paradigm in which children watched balls move about on a computer touch screen. Children were rewarded for touching the one that was ‘‘animate’’ in the experimental condition, or in the control condition the one that appeared heavier. In a series of scenarios, two black circles with a diameter of 3 cm moved, but only one moved around the screen as if self-propelled; the other seemed to move only in response to gravity or being touched (See Table 2).

The control test was procedurally very similar to that described just above. In the control trials, different scenarios were presented, and the scenarios were constructed such that an adult could tell which of the two balls was heavier based on its movements. For example, on ball might break through a horizontal barrier while the other bounces off of it, or one ball might push down one side of a teeter–totter, lifting the other up into the air. The order of the animacy set and the control set was counterbalanced across subjects.

There were two sets of scenarios: 8 training and 12 test scenarios (See Figs. 1, 2). The test scenarios were 6 pairs of temporal mirror images of each other. That is, the scenario could be played either forward or backward, and when it was reversed, the foil ball became animate and the animate ball became the foil. This reversal was meant to control for factors such as the amount of time the ball was in motion, left-right position, etc. The pairs of scenarios that were temporal images of each other were never played one after the other; other unrelated trials always intervened (Table 3).

The subject sat facing a 15-inch Micro-Touch computer touch screen. Experimental and control conditions were both presented to each participant, and the order was counter balanced across participants. Training scenarios

Table 2 Examples of training trials

Experimental: One ball is seen as animate	Control: One ball is seen as heavier
One ball rolls down hill, the other jumps out of the way	One ball falls onto the ground and makes a small indentation; the other falls and makes a much deeper indentation
One ball rolls down a ramp and to a stop; the other rolls up to it, expands and contracts, and rolls away	Two balls roll down a hill and hit a barrier. One breaks through, the other does not.
One ball rolls off edge of box and to the ground. Other ball opens side of another box, approaches, expands and contracts, and retreats back into box.	Two balls sit on a perch, and one breaks through and falls to the ground.
One ball falls off box. The other ball jumps over chasm onto the box, then moves to the edge of the box closest to the fallen ball.	Each ball rolls diagonally to a barrier at the same speed and only one push through it.
One ball climbs a hill and hit the other, which rolls down the other side.	Two balls fall onto a plank. One pushes the plank down and both balls fall of in that direction.
One ball approaches the other, jumps over it, and hits the ball on the far side, making it roll back.	Two balls roll onto a platform. One ball pushes the platform down, the other remains suspended in the air.

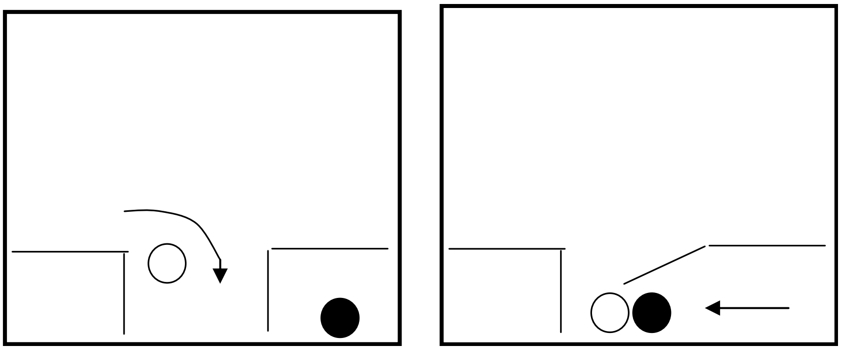

Fig. 1 A schematic example of a training trial. Simple geometric figures were presented on a touch screen. One moved as if self-propelled, the other only in response to gravity or contact. If the child touched the ''animate'' ball, the ball turned red and the child got praise and a reward. The animate ball is depicted here as a solid ball

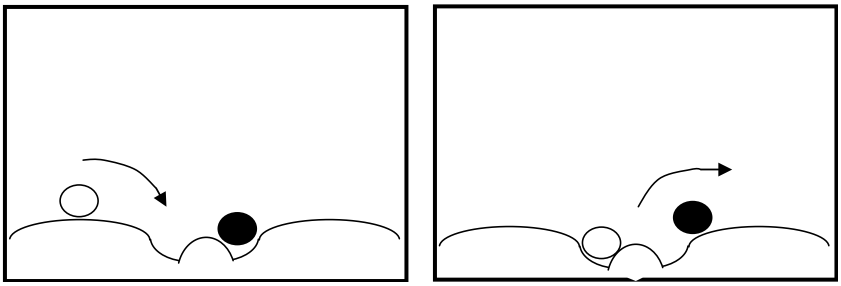

Fig. 2 A schematic example of a test trial. In the test phase, each trial was unique. Each test scenario could run forward and backward, reversing which ball was animate and which was the foil. The animate ball is depicted here as a solid ball

were presented in a random order. When the balls stopped moving at the end of the scenario, the experimenter prompted the child by saying ''pick one!'' or alternately, ''Which one?'' There were no other verbal instructions given to the children, and the word ''animate'' was never used with the children. If necessary, the experimenter would point to the two balls on the screen while prompting. If the child touched the correct circle, the ball turned red, the program paused and the child was given a food reward. If the child touched the other ball, or touched the screen anywhere else, the trial was counted as incorrect and the next scenario was presented without pause. Training scenarios continued to be presented in random order until the child has selected correctly 6 times in a row. The number of trials to criterion was recorded.

Once criterion was met, the program advanced to the test phase. There were 12 test scenarios. The first scenario was selected at random. The experimenter's prompts were the same as the training phase, and the child was again reinforced for selecting the animate (or heavier) ball. The significance of the test phase was twofold: First the child saw each scenario only once, whereas during the training phase a trial could be seen many times, depending up how long it took the child to reach criteria. Thus, each data point told how the child performed on a scenario that he or she had not seen before. Second, the trials were temporal reversals of each other, providing an opportunity to control for some low-level factors. Training trials lasted 8.6 s on average (range 4.7–11.2 s) and Test trials lasted 6.5 s on average (range 4.5–8.1 s).

Table 3 Examples of test trials

Experimental: One ball is seen as animate	Control: One ball is seen as heavier
One ball accelerates towards and hits other ball, which rolls away	A ball rolls towards another at a high velocity and hits it. The other rolls off very slowly.
One ball bounces off wall and through a vertical trap door and hits other ball, which rolls through a trap door and bounces off a wall	Two balls are on a ''teeter–totter'' and one ball tips the teeter–totter, raising the other ball into the air.
One ball teeters at top of an incline, and falls down into a valley. The other ball rolls up out of a different valley and to the top of an incline	A ball rolls towards another at a high velocity and hits it. The other rolls off very slowly.
One ball bounces and then ''jumps'' up to edge of a chasm. The other ball falls off the other edge of the chasm, into the chasm and bounces once.	One ball is perched on a large circle. The other ball gets lodged on the other side, rotating the circle, and pulling the other ball up.
One ball rolls down a hill and to a stop. The other accelerates and rolls up the same hill.	One ball starts in a deep well with smooth sides. The other ball rolls the bottom, hits the first ball, and causes it to fly out of the well.
One ball rolls to a stop. The other accelerates away from it.	One ball is on a plank and the other ball falls onto the far end of the plank, sending the first ball flying into the air.

Results

First, demographic information was analyzed to see if the different groups were different on chronological age or mental age (See Table 1 for demographic information). A one-way ANOVA revealed no difference on overall mental age $F(2,44) = 1.9$, n.s., which was expected since the groups were matched on mental age. Another ANOVA revealed significant differences in chronological age ($F(2,53) = 18.9$, $P < .001$), which was not unexpected. Post-hoc Tukey tests showed that the autism group was significantly older than the typical group ($P < .001$) and the DD group was also significantly older than the typical group ($P < .001$).

Next, we examined the theoretically relevant measures. The first measure was the number of training trials participants needed to reach criterion. Table 4 shows the means and standard deviations for each of the three groups. A 3 × 2 [group by trial type (animate or control)] ANOVA was performed to compare the groups' relative performance on ''animate'' trials and control (weight) trials. This ANOVA revealed a significant interaction ($F(2,56) = 3.65$. $P = .03$) that is, the groups performed relatively differently on animate and control trials. Post-hoc Tukey tests revealed that the AD group need more trials to reach criterion for the animate trial types, compared to the typical group ($P = .01$) and compared to the DD group ($P = .05$). Figure 3 illustrates these group differences.

The other interesting measure was the number of correct trials during the test phase. Again, there was no effect of order so the orders were collapsed for further analysis. In this case, an ANOVA revealed no significant interaction between trial type and diagnosis $F(2,56) = .53$, n.s.). There were no group differences in performance during the test phase. Figure 4 illustrates results for the test phase.

During the test phase, more children in each of the groups got the majority of trials correct for both the animacy and control conditions. Among the 23 children with autism, 17 got more than half of the animacy trials correct, and only 4 got less than half correct during the test phase. Of these children, 16 got more than half of the control trials correct, and 7 got less than half the control trials correct. Of the 18 children with developmental delays, 10 got more than half of the animacy trials correct and 8 got fewer than half of the animacy trials correct during the test phase. Similarly, 13 of these children got more than half of the control trials correct and 4 got fewer than half of the control trials correct. Of the 18 typically developing children, 15 got more than half of the animacy trials correct and only 2 got fewer than half of the animacy trials correct during the test phase. Of these children 14 got more than half of the control trials correct and 3 got fewer than half of the control trials correct.

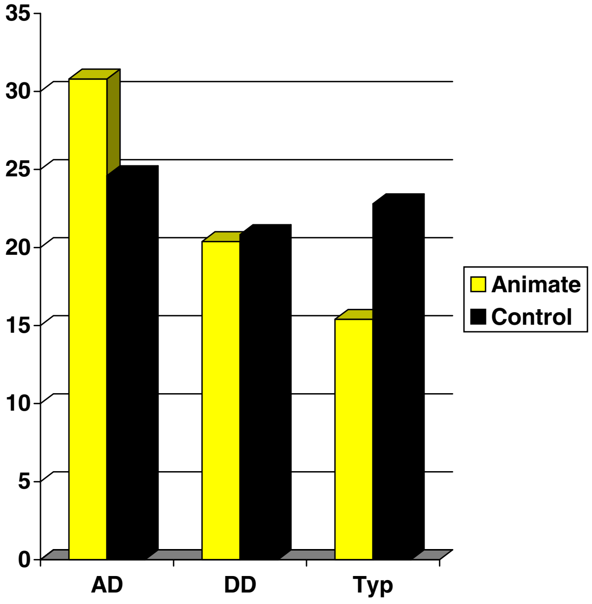

Fig. 3 The number of training trials each group needed, on average, to reach criterion of 6 consecutive correct answers, in the animacy detection task and the control task, which required subjects to judge relative weight

Correlational analyses revealed few statistically significant relationships between chronological age and our theoretically relevant measures. When all three groups were combined, there was a significant negative relationship between chronological age and the number of training trials participants took to make it to criterion given the control trials ($r = -.28$, $P = .04$, two-tailed). No other outcome measure was significantly correlated with chronological age. No outcome measure was significantly correlated with mental age.

Table 4 Performance on animacy detection test

Group		Trials to criterion		Test trials correct	
		Animacy	Control	Animacy	Control
Autistic	Mean	30.8	24.6	7.6	8.3
Disorder	s.d.	14.4	13.7	3.3	3.0
Devt.	Mean	20.4	20.1	9.6	8.0
Delay	s.d.	13.4	15.7	2.8	2.3
Typical	Mean	15.4	22.8	8.2	8.7
	s.d.	7.0	14.8	2.4	2.6

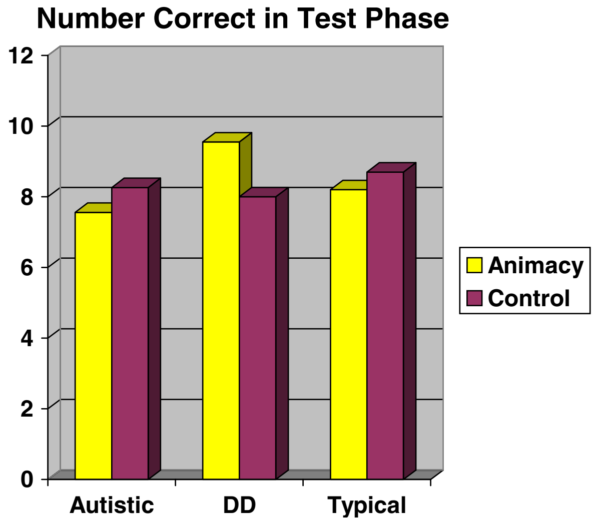

Fig. 4 The number of test trials that each group got correct, on average

Given that there was a significant group difference, and those with autism performed differently on training, a sex difference analysis was performed to compare all the males in the two control groups with all the females from these two groups. This analysis revealed no sex difference for training trials (*F*(1,34) = .08, n.s.) and no sex difference for test trials (*F*(1,34) = .46, n.s.). Therefore, we found no evidence of a significant sex differences on performance among these children.

In addition, because there were more males in the group with autism than in the other groups, the original ANOVAs (group by trial type) were repeated with males only, and the same trial type by group interaction was present during the training phase (*F*(2,32) = 5.15, *P* = .01) but there was still no interaction in the test phase (*F*(2,32) = 1.39, *P* = .26). The results, therefore, were essentially the same when just the male participants in each group were included in the analysis.

Discussion

Results from the training phase of this study are consistent with the idea that young children with autism take longer to learn to consistently distinguish animate from non-animate moving geometric figures, compared to control groups. This deficit seems to be specific to autism, since results of the group with autism was significantly different from the group with other developmental disorders. In addition, this group difference does not seem attributable to simple factors such as motivation, attention, or an understanding of the expectations, since performance on the control task did not differ across groups.

Results from the test phase of the experiment, in contrast, suggest no reliable autism-specific deficit in animacy perception once criterion is reached. This is an intriguing contrast. It suggests that either the mechanisms that perceive animacy are functional in autism and perhaps need to be primed, or that these children are able to quickly develop compensatory strategies. One should, of course, consider whether alternative and unintended features might be attracting the attention of these participants. To the extent that it is possible, we have tried to ensure that the child is in fact discriminating the underlying attribute (in this case animacy) rather than surface features (such as expanding and contracting), by presenting a set of entirely novel stimuli in the test condition. No display in the test phase was the same as any display presented in the training phase. In fact, some types of motion (expanding and contracting) that occurred in the training phase did not occur in the test phase, so learning or attending to this particular motion could not account for performance in the test phase. Furthermore, an attempt was made to carefully control extraneous features of the test scenarios: each scenario was a displayed forward and backward, and switching between the two changed which circle appeared animate. In this way many simple features, such as left or right position, left or right motion, and duration of motion were controlled. If extraneous features were sufficiently controlled, then this study suggests that very young children with autism are capable of distinguishing animate from inanimate motion, at least under these specific conditions.

Children with autism show no measurable deficit in animacy perception during the test phase. Indeed, children with autism were able to choose the correct figure at the same rate as the control children. The fact that the perception of animacy is possible in autism is suggestive: It is possible that the neural mechanisms that allow for the perception of animacy are preserved in autism (but see below). This idea is strengthened by the fact that these children are sufficiently young that they are unlikely to have developed compensatory mechanisms for solving the same discrimination task using an artificial heuristic. There is some evidence that dedicated neural mechanisms are recruited during the perception of biological motion (Grossman et al., 2000; Wheaton, Pipingas, Silberstein, & Puce, 2001). Perhaps such mechanisms are functional in individuals with autism.

The results of this study have some similarity to early findings of Klin (2000). In both studies, a group of individuals with autism were less likely than control groups to perceive animacy given a display of very simple geometric figures in motion. One major difference in the current study is the age of the participants. These results suggest that the deficit Klin measured in adults is present or developing early in life for those with autism spectrum disorders. In addition, finding this deficit in a animacy perception early in life sheds light on developmental discussions of autism, as discussed above.

One obvious caveat to this study is that the sex ratios in the various groups were not equated. In the autism group, there were relatively more males, whereas each comparison group has a slight majority of girls. Indeed, girls are thought to mature early than, particularly in social domains. Furthermore, a recent model of autism proposes that autism may be an extreme form of the male mind (Baron-Cohen, 2002). In this particular study, there was no sex difference in performance in the test. The results were the same when only the male participants in each group were considered.

These results are consistent with the social orienting model of autism (see Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Mundy & Neal, 2001), although this experiment was not designed as a strong test of the model. The social orienting view of autism suggests that in early autism the cause of the social cognitive deficit is a result of the fact that children with autism fail to orient to social information (with the same preference that typical children orient to social information) and therefore fail to provide higher level social cognitive processes with relevant information. It does not posit a deficit in the ability to perceive social information, just in the likelihood that the child will orient to social information. In other words, neural mechanisms responsible for perceiving animacy may not be damaged or absent in autism, rather, those with autism may simply be less likely to orient to and attend to social information. According to the social orienting model, a failure to orient to social information early in life leads to later social deficits because the information necessary for social development has not been made available to the developing brain. The results from the training phase, which show significant group differences, suggest that upon arrival into the lab participants with autism are less attentive to, or less likely to use information about animacy, while the results from the test phase show that individuals with autism are capable of making the discrimination under optimal circumstances.

It is important to keep in mind, however, that this experiment is not designed as a strong test of this hypothesis, and other interpretations are possible. In particular, it is very possible that the children with autism are learning to solve the problem through some compensatory strategy. This suggestion is not that they are learning the specific set of stimuli, since the test stimuli are novel and presented only once. Rather, it is possible that they are learning to perceive animacy based on motion cues, but are not using the same brain regions, or the same psychological processes as the control group. This possibility differs from the social orienting theory, and the current data cannot distinguish between these possibilities, but not that these children are learned to perceive animacy in one relatively short visit to the laboratory, which makes it unlikely that any elaborate compensatory strategy was created independently by each of these children.

Similarly, one might ask whether children in this experiment learned something about the task, rather than learning about animacy per se. Because children saw the test scenarios only once, and because the test scenarios were unique and were not seen during the training phase, it is not obvious what the children might have learned about the task during the training phase that would have led to their success during the test phase. That said, it would be very interesting in future research to see if any benefit could be seen in performance on a completely dissimilar animacy perception, or mentalizing task among young children with autism, once they met criteria in the training phase of the Animacy Discrimination Task. Such a transfer would be even more powerful evidence of a new skill.

Future research might test for deficits in the ability of individuals with autism to perceive more nuanced social information based on motion cues. We know that given point light walker displays, typical people can ‘‘see’’ sex, mood, weight, and even identity of particular individuals (Cutting & Kozlowski, 1977). Recent work has shown that adolescents with autism spectrum disorders see biological motion in point light displays at above chance but below typical performance (Blake et al., 2003). In the future, we wish to explore the difference in the perception of animate motion and goal-directed motion, especially in individuals with autism spectrum disorders. Intuitively, animacy perception seems simpler and easier. Perhaps individuals who can discriminate animate motion may still have trouble perceiving intentions in simple figures that are moving towards a particular goal. This remains an open empirical question.

One possible limitation of this study is that the number of training trials was finite and repeating, which means that it would be possible to advance to criterion in the training phase by memorizing the exact movements of the circles in each display. One hopes that this is not how participants were solving the problem in the training phase, since there were 8 training scenarios to rotate between, and participants took, on average about 23 trials to get to criterion. We know that this is not how participants were solving the task during the test phase since each scenario appeared only once. However, in future it would be helpful to be able to generate many more training scenarios so that they would not have to repeat, regardless of how many training trial the participant needed to achieve criterion.

One would want to know that the experimental task (animacy) and the control task (weight) were equivalent in difficulty. Based on performance on of the three groups in both the training phase and the test phase, these tasks appear to be equivalent. Since there was no main effect of trial type, we know that there was no statistically reliable difference between task difficult for these participants. In additions, inspection of performance leads one to believe that this failure to reach significance was not due simple to a lack of power. It appears that for this group of participants, these two tasks were roughly equivalent in difficulty.

One specific concern regarding the comparison of these tasks is the fact that this is a novel task; neither the children with autism nor the children in the control groups would have seen any sort of computer display like this before. One possible confound, therefore, is the fact that children with autism are known to have difficulty using feedback to modify their behavior, especially if they have happened upon an unsuccessful strategy [for example in the Wisconsin Card Sort Task (Rumsey & Hamburger, 1988)]. The fact that this task requires just such an ability on the part of participants may have disadvantaged the children with autism. For this reason, the inclusion of the control task is significant, and it is important to note that there were not group differences, either in the training or test phases for the control task.

In conclusion, we were interested in testing for a deficit in very early performance in the ability to discriminate animacy. If this ability is an early precursor to social cognitive development, then an early deficit in this ability might be causally related to later social cognitive deficits in autism. What we found was that there was a significant group difference in the training phase: children with autism took longer to perform at criteria. However, group differences disappeared during the test phase, apparently after the ability had been mastered.

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