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Ambiguous figure perception and theory of mind understanding in children with autistic spectrum disorders

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Running Head: Ambiguous figures and autism

Abstract

Researchers in early social cognition have become interested in children's perceptions of ambiguous figures. The ability to perceive both interpretations of these figures is similar to the abilities that allow children to take the perspective of others. Children's performance illuminates several issues about adult perception, specifically the development of spontaneous (i.e., uninformed) reversals. In earlier studies, preschool children never made spontaneous reversals and there was a strong positive correlation between the child's ability to make informed reversals and their success on first-order theory of mind tasks. In the current study, the relation between reversals and theory of mind abilities was explored in older children and in children with autism as compared to typically developing children. The first experiment found that approximately one-third of 5- to 9-year-olds did spontaneously reverse the figures. There was also a significant correlation between spontaneous reversals and success on a second-order theory of mind task. The second experiment considered these representational abilities in non-retarded children with autism and Verbal IQ matched controls. While children with autism were able to make spontaneous reversals, they did so less frequently than comparison children. A significant correlation was found within the autistic group between spontaneous reversals and performance on advanced theory of mind tasks, even when controlling for the effects of VIQ. These data support the idea that reversals of ambiguous figures are linked to high-level cognitive abilities that are also involved in theory of mind tasks and suggest that these abilities might be impaired in individuals with autism.

The relationship between perception of ambiguous figures and theory of mind development in typically developing children and children with autism

Researchers in early social cognition have been interested in when children begin to understand mental representation (Astington, Harris, & Olson, 1988; Flavell & Miller, 1998). In particular, researchers have investigated when children understand that different people may view or represent the same object from different perspectives. For example, by the age of three, children are able to understand that a blue car will appear green if placed behind a yellow filter or an object placed behind an opaque screen will be visible to a person facing the object, but not another person facing the screen (Flavell, Everett, Croft & Flavell, 1981; Gopnik, Slaughter, & Meltzoff, 1994). Between the ages of three and five, these representational abilities become more sophisticated. For example, at this age, children who know that a crayon box contains candles recognize that another person who does not know what is in the box will think the crayon box contains crayons (Perner, Leekam & Wimmer, 1987; Gopnik & Astington, 1988). Even later, by about the age of six, children realize that ambiguous objects might be interpreted differently by two different people (Taylor, 1988; Carpendale & Chandler, 1996, Ruffman, Olson, & Astington, 1991).

One way of measuring children's representational ability is to consider when children are able to hold multiple representations of a single object. The most obvious case of this is in pretend play, where a child may substitute a representation of an object in the world for a made-up representation, such as pretending that a banana is a telephone (Leslie, 1987) Although children begin to engage in pretense by 18 months (Piaget, 1962) and understand other's pretense by 28 months (Harris & Kavanaugh, 1993), there is much debate over exactly when children understanding pretense as involving mental representations (see

Lillard, in press, for a thorough discussion). Another, perhaps clearer means is to study children's visual perspective taking ability. Work by Flavell (1988; Flavell, Flavell & Green, 1986; Flavell et al., 1981) has shown that by the age of four, children begin to exhibit "level-2" perspective taking abilities in which they demonstrate that one person may be able to perceive an object one way and that another person would perceive it another. For example, given two people sitting opposite one another, four-, but not three-year-olds would respond that a drawing of a turtle is right-side-up to one of the people, but upside-down to the other. (Flavell et al., 1981). Furthermore, four-, but not three-year-old children shown a sponge that has the appearance of a rock will be able to distinguish between what the object looks like and what it really is (Flavell et al., 1987). These and other correlational studies (CITATIONS) suggest that by the age of five, children understand that there are cases where a single object can have multiple representations.

One area in which there has been renewed interest is children's perception of ambiguous figures (Rock, Gopnik & Hall, 1994; Gopnik & Rosati, 1999). These figures are of a single object, such as Jastrow's (1900) "duck/rabbit" (see Figure 1) can be interpreted in two distinct ways, although this is not necessarily obvious to a naïve viewer. Previous research with these figures (Girgus, Rock & Egatz, 1977; Rock, Hall, & Davis, 1994; Rock & Mitchener, 1992) has shown that not all adult viewer spontaneously generate both interpretations of the figures and has focused on what conditions are necessary for such a spontaneous reversal.

Rock, Gopnik, and Hall (1994) presented 3- and 4-year-old children with these types of figures, without initially informing them that the figures were ambiguous.

Unlike adult viewers, none of the children spontaneously generated both interpretations and only a handful reversed even after they were informed of the ambiguity. Gopnik and Rosati (1999) presented 4- and 5-year-old children with these types of figures and also found no spontaneous reversals. Importantly, they found correlations between children's reversals and the "deceptive container" false belief task (Gopnik & Astington, 1988). Children who passed the crayon-candle box task were much more likely to make a reversal of the figure after being informed of its ambiguity than children who failed the false belief task.

In a second experiment, slightly older children were presented with a version of the "droodle" task, adapted from Taylor (1988), which tested children's understanding of ambiguous representations. Children were shown a picture that was partially occluded in a way that did not reveal the identity of the full picture. For example, children would see a portion of the picture that looked like random angular lines, and when they removed the occluder and saw the whole picture they would realize that those lines were the center of a sunflower. Then children were asked what another person would think if they only saw the occluded ambiguous portion of the picture. Children who correctly said that the other person would not know the full picture depicted a sunflower were significantly more likely to make an informed reversal of the ambiguous figures.

That such a correlation exists is not surprising as the ability to reverse a figure after being informed of its ambiguity resembles that of Level 2 perspective taking. Success on both tasks requires that one considers two different representations of the same object and be able to flip back and forth between the two representations. Spontaneously reversing an ambiguous figure requires not only this ability, but also the ability to recognize that the figure could have another interpretation after a first, veridical, interpretation has been determined.

Thus, in order to spontaneously reverse, the child must not only have the ability to hold multiple interpretations of an object, but also the ability to recognize that any one interpretation may not be the only way one could interpret the object. This ability is similar to some of the experiments done on children's understanding of ambiguity in other domains in which by age six, children have the ability to recognize that two different people may have different interpretations about the nature of an ambiguous figure or situation (Carpendale & Chandler, 1996).

Several researchers have suggested that children's understanding of ambiguity involves several stages of development (Chandler & Helm, 1984; Forguson & Gopnik, 1988; Taylor, 1988; Wellman, 1990; although see Ruffman, Olson, & Astington, 1991 for a one-stage model). One change between roughly the ages of three and five involves understanding simply that there are multiple representations of an object or event. The visual perspective taking and appearance-reality results support this hypothesis. This is also consistent with the previous findings on children's perception of ambiguous figures (Gopnik & Rosati, 1999), that by age five, they can make a reversal when informed about the ambiguity and are more likely to do so if they can successfully pass a false belief task.

In the second stage, which occurs after the age of five, children develop a deeper appreciation of the fact that people can interpret the same stimuli differently, and may even be inclined to seek out multiple perspectives. This ability seems necessary for spontaneous reversals. Several researchers have looked beyond first order theory of mind tasks to explore the development of knowledge about thinking (Carpendale & Chandler, 1996; Perner & Wimmer, 1985; Wellman, 1990). One way of measuring this has been to consider what children know about the recursive nature of thinking. By age seven, children are able to pass a "second order" theory of mind task, in which they have to understand that a character will act on what they think another character thinks, which is contrary to what is really the case (Perner & Wimmer, 1985). Thus, at this age, children will understand that although John knows the truck is at the park, but thinks that Mary thinks the truck is at the school he will go to the school if he wants to find Mary, even though in reality, Mary also knows the truck is at the park and has gone there because John does not know that Mary knows the truck is at the park. Children's success on this task indicates that they can recognize that each character may have a belief about the world that is true (to them) and those beliefs may be different (because of each characters particular knowledge base). This seems similar to what is necessary for a spontaneous reversal: putting aside a character's veridical interpretation of events in favor of what they believe another character thinks is actually the case, even though it is not. One then would expect a relationship between the emergence of spontaneous reversals and children's success on second order theory of mind.

The first experiment had two goals. The first objective was to consider at what point, if any, children begin reporting spontaneous reversals. The second objective was to see if spontaneous reversals are related to more advanced theory of mind abilities. Children were given an ambiguous figures interview and second order theory of mind task similar to previous research as well as a set of other tasks that served as controls.

Experiment 1

To compare the two phenomena in question, children were run on five separate tasks. A replication of Perner and Wimmer's (1985) "ice cream truck" task was used as a measure of second-order theory of mind. The Gopnik and Rosati (1999) interview was administered to test whether children would make informed and spontaneous reversals of ambiguous figures. The droodle task, used by Taylor (1988), was given to assess first-order theory of mind abilities. Also, children were given a classic Piagetian number conservation task as a control.

Method

Participants. Thirty-seven children were recruited from two preschools and a YMCA after school program located in an urban area. Two children's data were eliminated due to previous experience with ambiguous figures (see below). The remaining 35 children ranged in age from 61 to 107 months (5 to 9-year-olds) and the average age was 83 months. Nineteen of the participants were male, 16 were female.

Materials. Two sets of line drawings were used for the ambiguous figure task. The figures were approximately 12x12cm in length and were drawn with black ink on standard 20x28cm white paper. Each set consisted of the ambiguous figure as well as two additional unambiguous pictures. Figure 1 shows the two ambiguous figures (duck/rabbit and vase/faces) used in this experiment as well as the third figure used in Experiment 2. Figure 2 shows both unambiguous interpretations of each of the three figures.

Insert Figures 1 and 2 approximately here

For the "ice cream" task, a model village was erected on a wooden board approximately 30x53cm. The park was located in one corner. The church was located on the opposite side of the board. Mary's house was located halfway between. The park consisted of an area painted green covered with five small wooden trees. 'John' and 'Mary' were approximately 2cm tall.

The droodle task consisted of a line drawing of a sunflower measuring approximately 15x23cm drawn on a standard 20x28cm white paper. The drawing was covered with a manila folder with a circle approximately 4cm in diameter cut out of it. The hole was positioned so that the only visible surface was the center of the sunflower, which consisted of angular lines.

Finally, twelve 2cm washers were used for the number conservation task.

Procedure. Children were tested at a small table in a quiet room by a male experimenter with whom they were familiar. Each child participated in all five tasks. The order of presentation was randomly determined for each child. The entire session took approximately 15 minutes and was audio taped. Details of the five procedures are below.

Ambiguous Figures. Children received an interview similar to that of Gopnik and Rosati (1999). Children were shown one of the ambiguous figures. The child told the child to look at the picture and asked the child, "what is it?" After the child responded s/he was encouraged to continue to look at the image for 30 seconds. After 15 and 30 seconds the child again was asked, "What do you see?"

If the child generated both interpretations of the figure, the child was asked to point to specific parts of each interpretation, such as point to the rabbits ears and the duck's bill. If the child did not generate both interpretations of the figure, the experimenter then asked the child if there was anything else the ambiguous figure could be. If the child still did not generate both interpretations of the figure, the experimenter suggested the other interpretation and showed the child the two unambiguous pictures. The child was then asked if the ambiguous figure could be the interpretation they did not generate, like in the unambiguous picture. If the child assented, the experimenter asked the child to point to the various parts of the two alternate perceptions on the ambiguous figure. If the child did not the experimenter suggested that the ambiguous figure actually could be the second interpretation.

Finally, the child was shown the ambiguous figure accompanied by the two unambiguous versions. The experimenter suggested the reversibility by saying "Look, this is funny. This picture might change back and forth from a (rabbit) to a (duck) or from a (duck) to a (rabbit). But it might just stay a (duck) or it might just stay a (rabbit). Now I want you to look at this picture. Remember, it might or it might not change." The unambiguous versions were removed and the experimenter asked the child what he or she saw at 0, 15, and 30-second intervals.

Although children were not specifically asked whether they had seen the pictures before, two spontaneously generated this information. They were excluded from the analysis.

Ice Cream Task. For the ice cream truck task, the experimenter brought out the model of the town and pointed to two small dolls and told the child they were John and Mary. The experimenter also pointed out the park, the church, and Mary's house. The child was then asked which doll was John and which was Mary. If the child did not give the correct answer, then feedback was given. The experimenter then acted out a story, following Perner and Wimmer (1985). The story involves John and Mary at the park. While they are there, the ice cream man comes. Mary wants to buy ice cream, but has no money. The ice cream man tells her that he will be at the park all day, so she goes home to get her money. While she is away, the ice cream man tells John that he will go to the church because there is no one in the park to buy ice cream. The ice cream man leaves and John waits for Mary. While the ice cream man is driving to the church, he meets Mary walking on the street and tells her that he is going to the church to buy ice cream. She follows him. John, still in the park, is tired of waiting, so he goes to Mary's house and asks for Mary. Mary's mother tells John that she just left to buy ice cream.

The child was then asked where John will look for Mary. Children were asked to justify their response and were asked two control questions: "Where did Mary really go to buy ice cream?" and "Where was the ice cream man in the beginning." During the course of the story, children were asked control questions to see if they followed the story. Feedback for these questions were given, but not for the two control questions at the end.

Droodle task. Children received a similar interview to that of Taylor (1988). The experimenter placed the covered picture (of angular lines) in front of the child and asked, 'What do you think this is a picture of?' After the child responded, the experimenter uncovered the picture to reveal the drawing of the sunflower. With the picture fully exposed, the experimenter asked, "What is this really a picture of?" After the subject had identified the flower, the experimenter re-covered the drawing and asked the subject, "Do you remember what you thought this was a picture of before we uncovered it?" After the subject responded to the question, the experimenter asked "Let's say that [classmate's name] came in here now. What would [classmate's name] think this was a picture of, if he could only see it all covered up like this and didn't know what the drawing really was of?"

Number Conservation. The child was shown twelve washers laid out in two lines of six each. The washers were evenly spaced so that they were matched exactly. The experimenter labeled the line closest to the child as "your line" and the line closest to him as "my line." The experimenter then asked, "Does your line have more, less, or the same as my line?"

Then the experimenter spread out the washers in the child's line such that they were further apart than the washers in the other line. Again, the experimenter asked, "Does your line have less, more, or the same as my line?" The ordering of the words 'more,' 'less' and 'same' was changed between subjects and between the two questions for the same subject.

Results

If children reported seeing both interpretations of the picture before they were informed about its ambiguity they were coded as spontaneous reverser. If children only reported reversals after they were informed about the ambiguity they were coded as informed reversers. Finally, children who did not see that the ambiguous figure could be both interpretations were coded as single interpreters. For the ice cream task, children were scored as passing if they indicated that John would think Mary was at the park and correctly justified this response using an explanation that appealed to his mental states. Children were scored as passing the droodle task if they answered both questions correctly, stating that they did not know the picture was a flower before it was exposed and that another person would also not have this knowledge. Finally, if children stated there were the same number of washers for each question, they were scored as passing the number conservation task. Table 1 reveals children's performance on all of these tasks as a function of their success on the ice cream task.

Insert Table 1 approximately here

Table 1 shows that 12 of the 35 children spontaneously reversed the ambiguous figure. Of these children, eight had seen the vase/faces and four the duck/rabbit, not a significant difference (Binomial test, p = .39, ns.). Twenty children reversed the figure after they were told of its ambiguity and only three children gave the figure a single intepretation. This response pattern was not the result of chance performance: $\chi^2(2) = 12.40$, $p < .002$.

If children's ability to spontaneously reverse an ambiguous figure is tied to their overall theory of mind ability in general one would expect children passing the ice cream task to make more spontaneous reversals than those who failed. Likewise, children who failed the ice cream task should make more informed reversals than those who passed, as "passers" may make either a spontaneous or informed reversal, but "failers" should only make informed reversals. This is exactly the pattern found in the data. Children who passed the ice cream task were more likely to make a spontaneous reversal (Fisher Exact Test $p < .003$), while the reverse pattern was shown for informed reversals (Fisher Exact Test, $p < .006$).

Children's data can also be explored in a correlational manner. Table 2 shows a correlation matrix of children's pattern of response on ambiguous figures and their performance on all of the other tasks as well as their age. Consistent with the above results, a significant correlation was found between children's spontaneous reversals and their informed reversals and performance on the ice cream task. Likewise, a significant correlation between children's responses on the ambiguous figures interview was found, but these are due to their coding being mutually exclusive.

Insert Table 2 approximately here

Although there were no significant correlations between children's spontaneous reversals and age or number conservation, subsequent analyses were conducted to control for the possibility that success on the ice cream truck task and the tendency to make spontaneous reversals derived from advanced cognitive ability in general or increased chronological age. A hierarchial regression was performed on children's spontaneous reversals with the first factor being age and success on the number conservation task (a measure of cognitive function in general) and the second factor their performance on the ice cream task. The regression showed that the child's age and performance on the number conservation task did not predict children's spontaneous reversals: $\Delta r^2 = .045$, $\underline{F}(2,32) = 0.755$, <u>ns</u>. Children's performance on the ice cream task, however, did predict a significant amount of the variance in their spontaneous reversals after these two factors had been put into the model: $\Delta r^2 = .26$, $\underline{F}(1,31) = 11.623$, $\underline{p} < .002$. Thus, children's second order theory of mind ability predicted their ability to spontaneously reverse ambiguous figures above and beyond their age or general cognitive ability (as measured by the number conservation task). This is consistent with the idea that advanced theory of mind ability is a necessary, but not sufficient condition for spontaneous reversals of an ambiguous figure.

In addition, previous research (Gopnik & Rosati, 1999) had shown a relationship between preschooler's ability to make any kind of reversal (although children in the previous study only made informed reversals) and success on a first order theory of mind task. Further analysis of Table 2 is consistent with these findings. In this experiment, children's single interpretations are significantly correlated both with age and with performance on the droodle task. Although children's performance on the droodle task was almost at ceiling (89%), children who failed the droodle task were more likely (50%) to make a single interpretation of the figure than children who passed the droodle task: Fisher's Exact Test $\underline{p} < .029$. The analysis of single interpretations, rather than informed reversals is necessary as each type of reversal was mutually exclusive, that is, a child could not be categorized as both an informed and a spontaneous reverser. Thus, although there was not a relationship between children's performance on the droodle task and their informed reversals (Fisher

Exact Test p = .58, ns.), this was because a percentage of the children who passed the droodle task made spontaneous reversals. Further, those children who made the single interpretations were the youngest children in the sample.

Discussion

The current experiment was designed to test (1) whether children between the ages of five and nine would spontaneously generate both interpretations of an ambiguous figure and (2) if they did, whether this ability would be related to performance on theory of mind tasks. Children of this age did report spontaneous reversals and those reversals were related to their performance on a second order theory of mind task. In addition, children's ability to make any kind of reversal was related to their success on the "droodles" task, a first order theory of mind task. This is consistent with previous findings (Gopnik & Rosati, 1999).

These and the result of previous research suggest that children's ability to make spontaneous reversals emerges sometime after the age of five. Further, the fact that children's ambiguous figure reversals are related to their performance on theory of mind tasks suggests that reversing ambiguous figures is tied to a more general understanding of representation. This experiment replicates the earlier finding that the ability to make informed reversals is correlated with performance on simple measures of theory of mind (Gopnik & Rosati, 1999; Gopnik, Capps & Meltzoff, in press). Although the correlations were not as strong here as in Gopnik and Rosati (1999), this is probably due to the fact the children in the current study were older and were almost at ceiling on both the droodle task and their lack of a generation of a single interpretation. In addition, there was a positive and significant correlation between spontaneous reversals and success on a higher order theory of mind task.

The relationship between spontaneous reversals and performance on the measure of second-order theory of mind abilities raises interesting questions. First, not all adults spontaneously reverse ambiguous figures, but the vast majority of adults perform at ceiling level on second-order theory of mind tasks. Likewise, a small minority of children who failed the ice cream task did make a spontaneous reversal of the ambiguous figure. Success on a second-order theory of mind task may not fully measure representational abilities. Does performance on a more advanced theory of mind task, which is more variable among adults, predict spontaneous reversal of ambiguous figures in older children? Second, children with autism are a population known to have difficulty with theory of mind abilities (Baron-Cohen, 1995; Baron-Cohen, Tager-Flusberg & Cohen, 1993; Frith & Happe, 1994). Do these children show a similar relationships between theory of mind and ambiguous figures and do these children show an impairment in their perception of ambiguous figures? Finally, although no significant correlation between ambiguous figures and cognitive ability or age were found, a number conservation task might not be the test measure of this ability. Is the ability to reverse ambiguous figures related to cognitive ability in general or to theory of mind ability in particular? In Experiment 2 we endeavored to address these questions among older children and individuals with autism.

Experiment 2

Experiment 1 showed that, similar to research done on adult participants, a minority of school aged children (34%) spontaneously generated both interpretations of an ambiguous figure. In this group of children, spontaneous reversals correlated with success on a second order theory of mind task. Experiment 2 involved a sample of still older children ranging in age from 8 to 12. Given their age, we expected that most would perform at ceiling on the second-order theory of mind task used in Experiment 1 (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Bowler, 1992; Happe, 1994; Perner & Wimmer, 1985), but that they would display a range of abilities on a more advanced measure. In this experiment, we presented children not only with the "ice cream task" but also with Happe's (1994) "Strange Stories." This measure considers children's understanding of various forms of non-literal communication, such as jokes, lies, irony, and sarcasm, and their understanding of the motivations behind such practices.

This group also constituted a comparison for a group of high-functioning individuals with autism/Asperger Syndrome matched on verbal IQ. Researchers have suggested that individuals with autism suffer from a specifically impaired understanding of other's mental states (Baron-Cohen, 1995; Baron-Cohen, Tager-Flusberg, & Cohen, 1993; Leslie & Thaiss, 1992). Young children with autism show specific deficits on false-belief tasks. Older high-functioning persons with autism may pass these tasks and even pass second-order false-belief tasks but still have specific difficulty with tasks like the "Strange Stories." However, even people with autism who pass these higher-order theory of mind tasks seem to labor their way to success in a manner that differs from that of typically developing persons. This is manifest in a strong correlation between mind reading and verbal abilities that is specific to this group (Bowler, 1992; Eisenmajer & Prior, 1991; Happe, 1995). If there is indeed a relation between theory of mind understanding and ambiguous figure reversal we might expect that people with autism would be less likely to reverse such figures than typically developing controls.

Thus, Experiment 2 aimed to consider 1) whether the distribution of spontaneous reversals of ambiguous figures among typically developing pre-adolescents would resemble that of adults; 2) whether those who spontaneously reversed ambiguous figures would be more adept at advanced theory of mind tasks than those who did not; 3) whether pre-adolescents with autism would be able to reverse the ambiguous figures in the informed condition; 4) whether they would spontaneously reverse the figures; 5) whether performance on ambiguous figures would relate to performance on theory of mind tasks among individuals with autism; 6) whether the strength of the correlation, if present, would differ between groups.

Method

Participants. The sample included 54 children: 31 non-retarded children with autism or Asperger's Disorder, and 23 typically developing comparison children. Participants with autism were recruited through clinicians affiliated with several hospitals in two different urban areas Diagnoses were confirmed using the Autism Diagnostic Interview-Revised (ADI-R; Le Couteur, Rutter, Lord, et al, 1989). On the basis of the interview, 11 children clearly met diagnostic criteria for autism. Each of them had received a prior diagnoses of autism. Twenty individuals reportedly suffered early and ongoing social and communicative deficits and the restricted/repetitive behaviors that characterize autism, but did not unequivocally manifest language delays, and were therefore met criteria for Asperger's Disorder.

Only children whose current Verbal, Performance, and Full Scale IQ scores were 75 or higher were included in the study. Twenty-nine of the 31 target children were being educated in mainstreamed school environments. Two attended a private school for children with learning disabilities.

Comparison children were recruited from local schools and recreation programs in an urban area. As indicated during a telephone screening, none of the children had prior psychiatric history and none were being treated for a psychological difficulty of any kind. In addition, the presence of a Pervasive Developmental Disorder was ruled out using a parent-report questionnaire, the Pervasive Developmental Disorder Screening Test (Siegel, 1996). Comparison children and target children were matched on Verbal IQ, as indicated by performance on the Weschler Intelligence Test for Children, Edition III (WISC-III, Weschler, 1974). Table 3 shows average scores on the WISC-III for both target and comparison children. All participants received $10/hour in appreciation of their participation.

Insert Table 3 approximately here

Materials. The same two ambiguous figures from Experiment 1 were used. A third, the man/mouse (Bugelski & Alampay, 1961) as well as pictures of each unambiguous interpretation was also used (see Figure 2 above). A similar "town" and dolls as in Experiment 1 was used for the theory of mind tasks.

Procedure. Each child was brought into the lab by their parents and tested alone. The testing was administered over two sessions. In the first session, children received the ambiguous figures interview and the ice cream task. After this, they were also tested on the WISC-III to evaluate their IQ scores. In the second session, they were tested on the strange stories, along with several other unrelated experiments. Both sessions took slightly over 100 minutes. Ample breaks were provided between procedures. The ambiguous figures and ice cream task each took approximately 5 minutes to complete. The strange stories required approximately 10 minutes. The WISC-III required approximately 90 minutes to complete.

Ambiguous Figures. The coding and administration of this task are detailed in Experiment 1 with a few slight modifications. First, all of the delays between the questions about the perception of the figures were shorter (approximately 10 seconds). Second, at the end of the procedure, children were told "Its funny. When I look at this picture, sometimes it flips back and forth from a <duck> to a <rabbit> and from a <rabbit> to a <duck>. Can you look at the picture and tell me if that happens for you?" Children were given a brief delay to respond. Finally, children received this interview for all three ambiguous figures, always in the order: duck/rabbit, man/mouse, vase/faces.

Ice Cream Task. The coding and administration of this task are the same as in Experiment 1. If children passed this task, they were then given the strange stories in the follow-up visit.

Strange Stories. A binder containing the stories was brought out and the subject was told, "Now here are some stories and some questions. I'm going to read out stories. Listen carefully and after each story I'm going to ask you some questions." Each story was read aloud, with the story and picture facing the child. Following Happe (1994), at the end of the story, the child was asked two or three questions. The first question was always of the form, "Was it true, what X (a character in the story) said?" The second was "Why did X say that?" Positive comments were made throughout the testing, but no feedback as to the validity of the answers was given.

Results

Children's performance on each of the strange stories was coded using a slightly different system from that of Happe (1994). For each story, if the child generated the correct answer to the truth question and explained their answer referring to the social process involved, they received full credit and a score of 2. If the child generated the correct answer, but did not explain their answer referring to incorrect social processes or to perceptual features of the story, they received partial credit and a score of 1. If the child generated the incorrect answer, explained their correct answer referring to no process, or said “I don’t know”, they received no credit and a score of 0. Children’s scores were then summed, yielding an overall strange story score that ranged from 0 to 24. All of the Strange Stories were coded by one of the authors (D.S.), based on transcriptions which did not reveal the child’s diagnostic group or their performance on the ambiguous figures task. Eight children in each diagnosis group were also coded by an undergraduate assistant, also blind to the child’s performance on the ambiguous figures task. Overall agreement between the two sets of scores were approximately 95% (Cohen’s Kappa = .869). Disagreements were resolved by the second author.

Table 4 shows children’s performance on the three tasks as a function of their diagnosis group. Comparison children scored higher on all three tasks. 100% of the control children passed the ice cream task, while only 68% of the target children did so: $\chi^2(1) = 9.106$, $p < .003$. Only children who passed the ice cream task were subsequently given the strange story task. 23 control children and 21 of the target children did so. However, due to experimental error, one control child and one target child was not administered this task, so that Strange Stories data was collected for 22 comparison children and 20 children with autism. These two subgroups also did not differ in age, verbal IQ, or full scale IQ (t-tests, all p’s > .05). Overall, comparison children scored higher on the strange story task than did target children: $t(1,40) = 3.378$, $p < .002$.

Insert Table 4 approximately here

Finally, children's responses on the three ambiguous figures were first analyzed to see if there were individual differences across the figures. A Chi-squared analysis between response type (spontaneous reversal, informed reversal and single interpretation) and the three figures types revealed that there was no difference in response between the three figures: $\chi^2(4) = 8.285$, ns. Given this finding, children's individual responses on each figure were treated independently. A Chi-squared was performed between children's response types and their diagnosis, revealing that the target children showed a different pattern of response on the ambiguous figures task than the control children: $\chi^2(2) = 9.642$, $p < .002$. Subsequent analysis revealed that target children made fewer spontaneous reversals than did control children, $\chi^2(1) = 5.703$, $p < .017$, and more single interpretations than did control children, $\chi^2(1) = 5.428$, $p < .02$. Target and control groups did not differ with respect to their number of informed reversals.

As in Experiment 1, the relationship between children's tendency to make spontaneous reversals and their theory of mind abilities was examined. Since all of the control children passed the second order theory of mind task, only the target children were considered for this analysis. A t-test was performed considering the number of spontaneous reversals target children made as a function of whether they passed the ice cream task. Results showed a trend for children who passed the ice cream task to make more spontaneous reversals (1.00 out of a possible 3) than did those who failed the ice cream task (0.4 out of a possible 3): $t(1,29) = -1.777$, $p < .083$.

Given that target children who passed the ice cream task tended to have higher Verbal IQ scores than those who failed (106.2 vs. 90.2, $t(1,29) = -2.797$, $p < .009$), subsequent analyses were conducted to test whether the correlation between performance on the ice cream task and spontaneous reversals of ambiguous figures was mediated by Verbal IQ. A hierarchical regression indicated that performance on the ice cream task did not significantly increase the amount of explained variance after VIQ was factored out: $\Delta r^2_{\text{ice cream}} = 0.022$, $F(1,28) = .762$, ns).

In Experiment 1 there was a significant relation between number of spontaneous reversals and performance on the second order theory of mind task in younger typically developing children. Here, this finding was not obtained. However, the typically developing children in Experiment 2 were older than those in Experiment 1. Not surprisingly, given their age, comparison children performed at ceiling on the ice cream task and therefore no such correlation emerged.

Children's Strange Story scores were examined across both groups. A stepwise linear regression was performed on children's spontaneous reversals with Diagnostic Group, Strange Story score, VIQ and a Group x Strange Story score interaction. This analysis revealed that VIQ explained the greatest amount of variance in children's spontaneous reversals: $\Delta r^2_{VIQ} = 0.180$, $F(1,40) = 8.753$, $p < .005$. In addition, scores on the Strange Stories task explained a significant additional amount of variance: $\Delta r^2_{SS} = 0.110$, $F(1,39) = 6.021$, $p < .019$. Neither the group, nor the group x strange story score interaction predicted a significant amount of the variance in children's spontaneous reversals beyond that. It is worth noting, however, that when all the factors were forced into the regression, the Strange Story Score x Group interaction tended to predict a significant amount of the variance beyond all the other factors: $\Delta r^2_{SSxGroup} = .068$, $F(1,37) = 3.893$ $p < .056$.

Given the main effect of strange story score and VIQ and the trend for the significance of the interaction, we investigated the role of Strange Story Scores and verbal IQ in predicting the number of spontaneous reversals within the two diagnostic groups. Two separate hierarchical linear regressions were performed measuring children's spontaneous reversals as a function of their verbal IQ first, then Strange Story Score. For the control children, spontaneous reversals was predicted by their verbal IQ scores: $\Delta r^2 = .187$, $F(1,20) = 4.612$ $p < .044$. Strange story scores did not predict a significant amount of variance beyond this ($\Delta r^2 = .005$). Target children, in contrast, showed the reverse pattern. Verbal IQ only showed a trend to explain spontaneous reversals $\Delta r^2 = .181$, $F(1,18) = 3.975$ $p < .062$, while strange story scores did predict a significant amount of the variance beyond verbal IQ: $\Delta r^2 = .377$, $F(1,17) = 14.515$, $p < .001$. This suggests that the main effect of the Strange Story Scores was mediated mostly by the target children.

Discussion

Non-retarded children with autism and Asperger's syndrome were interviewed about their perception of ambiguous figures to determine whether they could generate both interpretations of the figures spontaneously or when informed about the ambiguity. They were also given a second order theory of mind task, and if they succeeded on that task, Happe's (1994) "Strange Stories," a more subtle measure of their social understanding. Children with autism/Asperger's Syndrome were as capable as age and verbal IQ matched controls of reversing an ambiguous figure when both interpretations were pointed out to them. The target children, however, were less likely than the controls to make spontaneous reversals of these figures and more likely than the controls to perserverate on one interpretation.

Although the target children made fewer spontaneous reversals of the ambiguous figures than the comparison children, the two groups did not differ in their number of informed reversals. Given that all of the target children were in a high functioning group and that the majority of them passed a second order theory of mind task, it is not surprising that they can hold two alternative interpretations of the figure in mind, a skill found to be correlated with first order theory of mind.

In addition, for the target children, there was a relationship between spontaneous reversals and performance on both a second order theory of mind task and the higher order "Strange Stories" task. Although the correlation between success on the ice cream task and spontaneous reversals was mediated by children's VIQ scores, target children's Strange Story scores predicted children's spontaneous reversals after VIQ was factored out of the regression. In contrast to the group with autism and to findings reported in Experiment 1, a positive relationship between theory of mind tasks and spontaneous reversals was not obtained in the comparison group. In this experiment, however, the typically children were older (by approximately three years on average), and were at ceiling on the second order theory of mind task. In addition, although children were not at ceiling on the strange story task, their performance was very high. It is possible that the two theory of mind tasks used did not provide enough variance for children of this age to demonstrate the relationship between theory of mind and spontaneous reversals. The absence of a correlation between Verbal IQ and Theory of Mind abilities (both the Ice Cream Task and Strange Stories) for the comparison children, which is consistently reported in the literature (Happe, 1995; Yirmiya et al., 1998), lends credence to this hypothesis.

In the control group there was a significant correlation between verbal IQ and spontaneous reversals. An implication of this finding is that it might be that the significant minority of adults who make spontaneous reversals in Rock's and other's findings have a higher VIQ than those who do not. This remains, however, an empirical question.

General Discussion

In Experiment 1, approximately one-third of the children between the ages of five and nine showed the ability to spontaneously reverse ambiguous figures. Moreover, there was a correlation between children's ability to spontaneously reverse and their success on a second order theory of mind task, even when an index of general level of cognitive functioning was factored out. In Experiment 2, non-retarded children with autism and Asperger's syndrome between the ages of eight and twelve and made spontaneous reversals less frequently than verbal IQ matched comparison children. Although a correlation between success on the ice cream task and spontaneous reversals was found for the target children, it was mediated by their verbal IQ scores. However, for these children, a significant correlation was found between spontaneous reversals and scores on a more advanced measure of theory of mind (Strange Stories; Happe, 1994), even when verbal IQ was factored out. The comparison children, in contrast, did not show such a relationship. Instead, spontaneous reversals were predicted by verbal IQ and not theory of mind tasks.

Several issues emerge from these two experiments. The first concerns why the perception of an ambiguous figure reverses. Several researchers have suggested a bottom-up view involving neural fatigue in which a neural pathway representing one interpretation of the figure tires, thus allowing a second pathway representing the second interpretation to take over (Attneave, 1971; Köhler, 1960; Orbach et al., 1963). Other researchers have suggested a more top-down approach in which the perceiver approaches the stimuli with the goal of discerning what it is they are perceiving (Ammons, 1954; Long & Toppino, 1981). In addition to more recent research by Rock (Girgus, Rock & Egatz, 1977; Rock, Hall, & Davis, 1994; Rock & Mitchener, 1992) which provides support for the latter hypothesis, the results here support a top-down approach for two reasons. First, they contradict the notion of saturation in that spontaneous reversals only occurred in approximately one-third of the children. It is implausible that only a subset of the population is vulnerable to neural fatigue. Second, a bottom-up approach seems unlikely to support a relationship between reversals and theory of mind abilities.

Another issue concerns the data from the two groups of typically developing children. In the first experiment, typically developing children between the ages of five and nine showed a correlation between spontaneous reversals and success on the ice cream task. However, in Experiment 2, subjects were at ceiling on the theory of mind task, but a majority still did not spontaneously reverse, as in previous studies of adults. This suggests that once a child has reached a certain level of theory of mind ability, the minority of the population who reverse do so. From this perspective, theory of mind abilities are a necessary but not sufficient requirement for spontaneous reversals. That theory of mind abilities, or some general cognitive capacity from which they derive, act as an enabling mechanism for reversals is also consistent with the data obtained from the children with autism. In this group there was also a significant correlation between spontaneous reversals and scores on the Strange Stories, even when verbal IQ was factored out.

These experiments taken in conjunction with Gopnik and Rosati (1999) and Rock, Gopnik and Hall (1994), suggests that the ability to reverse ambiguous figures develops during childhood and that this ability is related to the development of theory of mind abilities. How can this relation be explained? There are several possibilities. One is that there is some other cognitive ability that mediates both reversals and theory of mind. For example, it is possible that some general increases in executive function or flexibility of representation are involved in both abilities.

However, it is also possible that the ability to reverse is more specifically tied to theory of mind. This might seem odd at first, since theory of mind typically involves inferences about the mental states of others, while perceiving ambiguous figures involves a particular first-person experience of reversal. However, there are other examples in the literature of these relations. For example, the false belief task is correlated to a representational change task which involves reporting one's own immediate past beliefs. Children who say that another person will think there are candles in the crayon-box also report that they themselves thought there were candles in the crayon-box just a few moments earlier (Gopnik & Astington, 1988). The experience of our changing belief does not seem to be a matter of inference. Rather, it seems just as immediate as our experience of changing perceptions in the ambiguous figures case. Similarly, the appearance-reality task involves reporting how something appears to one at the moment rather than predicting how others will perceive it. Both these abilities, however, are highly correlated to the ability to predict the false beliefs of others and both are impaired in autism (Baron-Cohen, 1989). This suggests that there is a relation between the ability to infer the mental states of others and the ability to have certain kinds of related first-person phenomenological experiences, such as the experience of reversal.

These two possible explanations are also relevant to explaining the difficulties children with autism had with reversals which were discovered in this study. The first is that children with autism organize their knowledge differently in general. For example, it is possible that these difficulties reflect a broader executive function, control or flexibility problem (Courchesne et al., 1994; Ozonoff, Rogers, & Pennington, 1991; Ozonoff & McEvoy, 1994), or a problem in the integration of information in general (Frith, 1989; Frith

& Happe, 1994; Happe, 1997), or in the ability to construct theories (Gopnik, Capps, & Meltzoff, in press.)

As an alternative, it is also possible that the difficulty is more specific to the understanding of representation, but includes both the social ability to predict the representations of others and the ability to experience certain types of phenomena involved in self-representation (see Gopnik, 1993, for further discussion). This is consistent with Frith and Happe's (1999) argument that theory of mind and "self-consciousness" are linked. Individuals with autism, they suggest, have difficulty reflecting on their own mental states. This introspective process requires comprehending mental experience as it unfolds, rather than an effortful post-hoc analysis. In this way, it is similar to the on-line processing of perceptual representations that is necessary to reverse an ambiguous figure.

In conclusion, the ability to spontaneously reverse an ambiguous figure appears to emerge sometime between the ages of five and nine and appears to be related to children's advancing understanding of theory of mind. Across ages, there are correlations between the development of the ability to reverse and the development of theory of mind abilities. Children with autism appear to be impaired on both reversals and theory of mind abilities in comparison to control children. However, they show a similar relationship between these two abilities. This finding suggests that children possess an overall understanding of representation that affects their experience of the world quite broadly.

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Figure 1: Ambiguous Figures used in Experiments 1 and 2

Figure 2: Unambiguous Figures used in Experiments 1 and 2

Table 1: Performance of children on all tasks in Experiment 1.

Note: SR: Number of children spontaneously reversing.
IR: Number of children reversing after informed of ambiguity.
Single: Number of children who did not reverse.
Droodle: Number of children passing droodle task.
NC: Number of children passing number conservation task.
ML: Number of children succumbing to Muller-Lyer Illusion
Ponzo: Number of children succumbing to Ponzo Illusion

Percentage of responses shown in parentheses

Ice Cream	SR	IR	Single	Droodle	NC
Passed (n=16)	10 (63)	5 (31)	1 (5)	16 (100)	12 (75)
Failed (n=19)	2 (11)	15 (79)	2 (11)	15 (79)	12 (63)
Total	12 (34)	20 (57)	3 (8)	31 (89)	24 (69)

Table 2: Correlations between Experiment 1 Tasks

Notes: * indicates significance at .05 level
** indicates significance at .01 level
*** indicates significance at .001 level

	Age	Spont	Inform	Single	Ice Cream	Droodle	Number
Age	1.000	.209	.012	-.377*	.225	.237	.323
Spont	.209	1.000	-.834***	-.221	.545***	.259	.100
Inform			1.000	-.354*	-.480**	.052	.036
Single				1.000	-.076	-.532***	-.232
Ice Cream					1.000	.330	.127
Droodle						1.000	.144
Number							1.000

Table 3: Summary data for participants in Experiment 2

Notes: [a] Control group not significantly different from target group, $p > .10$.
[b] Control group significantly different from target group, $p < .01$.
Standard deviations given in parentheses

Group	Age	FSIQ	VIQ	PIQ
Control (n = 23)	10.46[a] (1.15)	108.26 [b] (7.83)	107.39 [a] (10.02)	106.70 [b] (8.25)
Target (n = 31)	10.94 (2.44)	98.19 (15.99)	101.03 (16.49)	95.90 (16.00)

Table 4: Performance of children on tasks in Experiment 2 as a function of diagnosis group

Notes: [a] Number of responses, percentage in parentheses
[b] Number of children passing, percentage in parentheses
[c] Overall score (out of 24), standard deviation in parentheses

Group	Spontaneous [a]	Informed [a]	Single [a]	Ice Cream [b]	Strange Story [c]
Control	31 (50)	31 (50)	0 (0)	23 (100)	19.50 (2.82)
Target	25 (27)	61 (66)	7 (7)	21 (68)	15.80 (4.22)