Published in final edited form as:

Res Autism Spectr Disord. 2013 ; 7(1): 9–16. doi:10.1016/j.rasd.2012.07.004.

Do Social Attribution Skills Improve with Age in Children with High Functioning Autism Spectrum Disorders?

Elgiz Bal^a, Benjamin E. Yerys^{a,1}, Jennifer L. Sokoloff^a, Mark J. Celano^b, Lauren Kenworthy^a, Jay N. Giedd^b, and Gregory L. Wallace^{b,2}

^aChildren's National Medical Center, Washington, DC, USA

^bNational Institute of Mental Health, Bethesda, MD, USA

Abstract

Age-related changes in social attribution skills were assessed using the “Triangles Playing Tricks” task in 7–17 year old high functioning children with ASDs (n=41) and in typically developing (TD) children (n=58) matched on age, IQ, and sex ratio. Children with ASDs gave responses that received lower intentionality and appropriateness ratings than did TD children in both the goal-directed and theory of mind (ToM) conditions. Results remained unchanged when the effects of verbal output (i.e., number of clause produced) and verbal IQ were included as covariates in the analyses. Whereas age was highly associated with ToM performance in the TD children, this relationship was not as strong among children with ASDs. These results indicate not only a diminished tendency among high functioning children with ASDs to attribute social meaning and intentionality to ambiguous visual displays of interactive forms but also an aberrant developmental trajectory. That is, children with ASDs may fall further behind their typically developing peers in social attribution abilities as they get older.

Keywords

Autism Spectrum Disorders; High Functioning Autism; Theory of Mind; Social Attribution

1. Introduction

Autism spectrum disorders (ASDs) are characterized by deficits in social cognition and understanding. Theory of mind (ToM), one component of social cognition and an area of difficulty for children with ASDs, describes the ability to think about thoughts and to attribute mental states, such as desires, beliefs, and intentions, to oneself and to others. False belief tasks are the most common way that basic ToM skills have been assessed both in typically developing (TD) children and in children with ASDs (Baron-Cohen, 2000). Several studies have documented that a majority of children with ASDs perform poorly on false belief tests; however, there is significant variability in performance with 15–60% of children passing the standard first-order ToM tasks (for review, see Happé, 1995). One of the reasons for this variability is that most false belief tests are designed for young children (Baron-Cohen, O’Riordan, Stone, Jones, & Plaisted, 1999). Understanding that others may have a

²Corresponding Author at National Institute of Mental Health (NIMH): 10 Center Drive, Building 10, Room 4C104, Bethesda, MD 20892, gregwallace@mail.nih.gov, Phone: 301-435-4947.

¹Present address: Children’s Hospital of Philadelphia, Philadelphia, PA, United States

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

false belief typically emerges around four years of age (Wimmer & Perner, 1983), an early developmental ceiling. Thus, older children with ASD can pass these tests despite having difficulty understanding others' thoughts, intentions, and actions in everyday situations. Further, performance on false belief tasks shows a strong relationship with verbal ability in early typical (Milligan, Astington, & Dack, 2007) and atypical (Happé, 1995) development, such that ASD children with solid verbal abilities can solve false belief problems successfully even though they exhibit social cognitive deficits in real-life scenarios and situations. As a result, capturing social deficits in verbally able children with ASDs has proven challenging.

Several story-like tasks assessing higher order ToM have been developed in an attempt to address these concerns, such as the 'Strange Stories' task (Happé, 1994) and the 'Faux Pas' test (Stone, Baron-Cohen, & Knight, 1998). More recently, nonverbal tasks have been adapted from the seminal work of Heider and Simmel (1944). They created a film of interacting geometric shapes that were shown to TD adults. In describing this animation, TD adults produced elaborate narratives, including a tendency to anthropomorphize, despite the relatively impoverished stimuli (e.g., no obvious cues such as facial expression). Using Heider and Simmel's silent animation, Klin (2000) developed the Social Attribution Task, in which the original animation sequence is broken down into six meaningful segments to reduce memory load. The results showed that adolescents and adults with ASDs obtained lower social cognitive ratings for narratives compared to age- and IQ-matched TD controls. Bowler and Thommen (2000) showed the original Heider and Simmel animation to children with ASDs and TD children. In this study, children with ASDs were able to distinguish intentional action from mechanical motion as well as TD children, but they less often described actions between agents. Interestingly, children with ASDs provided comparable amounts of mental state language (e.g., think, want, know) in their descriptions. However, it is important to note that near floor effects (i.e., low base rates of mental state language) were observed on these measures even among TD individuals, raising questions about whether the film was an effective instrument to elicit mental state language.

Heider and Simmel's original animation was not designed as a ToM task and therefore did not explicitly elicit mental state descriptions. In an attempt to build upon previous work and to better assess ToM abilities, Abell, Happé, and Frith (2000) adapted the "Triangles Playing Tricks" task from Heider and Simmel's animation. The Triangles Playing Tricks task included two key conditions: A goal-directed condition, which elicits a description of action without mental state inferences (e.g., two characters "dancing" together), and a ToM condition, which elicits a description of action with complex mental state attribution (e.g., one character "tricking" another). In the first use of this modified task, Abell and colleagues showed that lower functioning children with autism (M Full Scale IQ = 74, SD = 21) provided fewer mental state descriptions than did TD children and children with general intellectual impairment. Moreover, even those individuals with autism who passed standard false belief tasks provided inappropriate descriptions to ToM animations. Similarly, high functioning adults with ASDs (with average verbal and nonverbal ability) used fewer and less appropriate mental state descriptions in response to the Triangles Playing Tricks animations than did typical adults (Castelli, Frith, Happé, & Frith, 2002). Subsequently, Campbell and colleagues (2006) administered this novel task to TD adolescents and high functioning adolescents with ASDs (M Verbal IQ = 96, SD = 18). They replicated earlier findings in that adolescents with ASDs received lower appropriateness ratings in the ToM condition than did TD adolescents. Most recently, Salter, Seigal, Claxton, Lawrence, and Skuse (2008) assessed ToM skills in high functioning children with ASDs (M VIQ = 99, SD = 19; M NVIQ = 101, SD = 19) and TD children. This research also replicated earlier findings and showed that children with ASDs were less able to accurately describe ToM animations than TD children. The length of descriptions did not differ between the groups,

and verbal ability was not related to performance on the ToM animations in the ASD group. However, verbal ability correlated significantly with the appropriateness and intentionality scores in the ToM condition in the TD group.

Previous studies using the Triangles Playing Tricks task have mostly been limited to either lower functioning children with ASDs (Abell et al., 2000) or high functioning adolescents (Campbell et al., 2006) or adults (Castelli et al., 2002). To our knowledge, there is only one study looking at ToM skills in high functioning children with ASDs using the Triangles Playing Tricks task (Salter et al., 2008). Assessing the social attribution skills of specifically high functioning children with ASDs (free from intellectual impairment) allows investigation of ASD-specific deficits. Further, because childhood is a time of significant improvement in the tendency to attribute social meaning to impoverished visual displays (Hu, Chan, & McAlonan, 2010), investigating performance among particularly high functioning children with ASDs and age-related changes remains a significant gap in our knowledge.

There is growing evidence that age is highly correlated with the likelihood of making social attributions about interacting geometric shapes. Two studies corroborate the findings from Hu and colleagues in that TD adults outperformed TD 8-year-olds (Abell et al., 2000), and TD adolescents received higher scores than TD 7-year-olds (Campbell et al., 2006) on the Triangles Playing Tricks task. Similarly, Peterson and colleagues (Peterson, Wellman, & Slaughter, 2012) showed that children with ASDs were slower than TD children to master ToM skills, even after controlling for age and language skills. However, this study used a 6-step ToM Scale, and it is unknown whether this relationship between age and ToM performance holds within a sample of children with high functioning ASDs using the Triangles Playing Tricks task. In addition, previous studies (e.g., Abell et al., 2000) using the Triangles Playing Tricks animations primed subjects by assigning identities to the geometric shapes (e.g., animal roles in the goal-directed condition [“mother duck and duckling”] and people roles in the ToM condition [“grandmother and grandson”]) or through instructions on alternate items (e.g., presenting animations displaying “an interaction with feelings and thoughts” [ToM] or “a simple interaction” [goal-directed]) in order to elicit a social attribution. Therefore, it remains unclear how high functioning children with ASDs and TD children respond to relatively *uncued* animations. Lastly, not all previous studies examining ToM skills using the Triangles Playing Tricks task in individuals with ASDs evaluated the relationship between verbal ability, verbal output (the length of descriptions), and ToM skills.

The present study aims to address current gaps in the literature by assessing ToM abilities in a large sample of children and adolescents with high functioning ASDs and a TD group matched on age, IQ, and sex ratio using uncued instructions with the Triangles Playing Tricks test. By including a relatively large sample size and a wide age range, the current study will extend prior work and evaluate age-related changes in social attribution in high functioning children/adolescents with ASDs. Further, in the current study, verbal abilities (VIQ) are assessed, and language output for each of the animations is quantified to explore whether these affect ToM performance. Based on the previous literature, we hypothesize that children/adolescents with ASDs will receive lower appropriateness and intentionality ratings on the “Triangles Playing Tricks” animations, especially in the ToM condition, than TD children/adolescents. In addition, we hypothesize that there will be a stronger positive relationship between age and performance on ToM animations among TD children than children with ASDs.

2. Method

2.1. Participants

Participants included 58 TD children (7–17 years old) and 41 high functioning children with ASDs (6–15 years old) matched on age, Full Scale IQ, and sex ratio (see Table 1 for details). TD children were screened and excluded if they or a first-degree relative were found to have developmental, language, learning, neurological, or psychiatric disorders or psychiatric medication usage. Children with high functioning ASDs were excluded if they had any parent-reported history of co-morbid genetic or neurological disorders (e.g., Fragile X syndrome, Tourette's syndrome) or if they had a FSIQ < 80. Children with high functioning ASDs were diagnosed by expert clinicians using DSM-IV criteria (23 Asperger's disorder, 11 autism, 7 pervasive developmental disorder-not otherwise specified) and through use of the standard instruments in the field (i.e., the Autism Diagnostic Interview-Revised [Lord, Rutter, & Le Couteur, 1994] and the Autism Diagnostic Observation Schedule [Lord, Rutter, DiLavore, & Risi, 1999]). Verbal and non-verbal intelligence were assessed with the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) for all TD children/adolescents and the majority of children with ASDs (n=34). Wechsler Intelligence Scale for Children-III (Wechsler, 1991) or Wechsler Intelligence Scale for Children-IV (Wechsler, 2003) were used to assess IQ in the remainder of the ASD sample (n=7). There were no statistically significant differences on verbal and non-verbal IQ scores between the groups. Sample characteristics are reported in Table 1. Informed assent and consent were obtained from all participants and their parent/guardian.

2.2. Experimental Stimuli

The “Triangles Playing Tricks” task was administered as part of a larger neuropsychological battery. The animations showed one large red and one small blue triangle moving around the screen displayed using Powerpoint software. The animations involve rather impoverished scenes, which prevent subjects' reliance on overlearned social cues. The task is composed of three conditions (i.e., goal-directed, ToM, and random) and includes ten animations (i.e., four goal-directed, four ToM, and two random) presented in a pseudo-randomized and fixed order. Across the conditions, direction and type of movements of the triangles were matched to avoid providing additional unintended cues in completing social attributions (Abell et al., 2000). The goal-directed condition involves interactions between triangles that do not require ‘insight’ into the mental state of the agent (e.g., chasing). Conversely, the ToM condition shows interactions between triangles where one responds to the mental state of the other (e.g., persuading). The goal-directed condition, therefore, served as a relatively conservative control task for the ToM condition. Random sequences involve the two triangles moving around independently from one another without interaction. Because responses to the random sequences were rather limited in length and depth, they were not included in the final data analysis.

2.3. Procedures

After being administered verbal and non-verbal intelligence measures, participants were told that they were going to watch a series of cartoons (lasting approximately 40 seconds each) on the computer screen. After each animation was played on the computer, participants were asked to describe what was happening between the triangles in that cartoon. The experimenter wrote down participants' responses verbatim. To familiarize the participants with the task, two practice animations were shown¹. For these items, after providing their

¹These practice items were included in the final data analyses, as inclusion or exclusion of these items from the analysis did not affect the results.

own description of each sequence, participants were given a verbal explanation of what the cartoon actually depicted. Any questions or concerns regarding the task were addressed at this time. For the remaining eight items, no other verbal instruction was given other than general encouragement. Unlike the administration methods of past studies using similar stimuli (Abell et al., 2000), participants were not primed with character-based social scenarios to aid their interpretation of action sequences.

2.4. Scoring

Responses were scored by two blind raters according to three separate dimensions: intentionality, appropriateness, and length (adapted from Castelli, Happé, Frith, & Frith, 2000; Castelli et al., 2002). Intentionality was defined as the level of mental state attribution given in descriptions. Intentionality scores ranged from 0 to 5, with higher scores reflecting increasingly complex mental state descriptions. For example, from the ToM animation labeled “Mocking,” a response rated as a 0 was “The triangles are just bouncing around in circles,” and a response rated as a 5 was “The smaller triangle is making fun of the big triangle. Every time the big one turns around, the smaller one pretends like he isn’t doing anything. At the end, the big triangle catches the small one, and the small one runs away.” Appropriateness was defined as the level of overall accuracy in describing the action sequence. Appropriateness scores ranged from 0 to 2, representing incorrect, partially accurate, and completely accurate descriptions of the action sequence. For example, from the ToM animation labeled “Mocking,” a response rated as a 0 was “The two triangles get bigger and smaller and blink around the screen,” and a response rated as a 2 was “The small triangle is making fun of the big one behind his back.” The number of clauses in each response determined length scores. A clause was defined as any subject-predicate pairing. Additionally, any other word or phrase that represented an independent action or idea but did not fit the traditional definition of the word was counted as its own clause (e.g., running). In summary, four primary dependent variables of interest were quantified: appropriateness and intentionality ratings in the goal-directed and the ToM conditions; all were expressed as mean ratings (ranging from 0 to 2 for appropriateness and from 0 to 5 for intentionality ratings). Two additional nuisance variables were also quantified to serve as potential covariates: number of clauses in the goal-directed and ToM conditions. Two blind raters produced comparable intentionality ($Kappa=.74$) and appropriateness ($Kappa=.71$) ratings, indicating good inter-rater reliability.

3. Data Analysis

Data were inspected for outliers, skewness, and kurtosis, and no issues were noted. An initial 2×2 mixed model ANOVA was run in order to assess the effects of group (TD vs. ASD) and animation condition (goal-directed vs. ToM) on verbal output (i.e., number of clauses produced) and to determine whether this variable should be used as a covariate in later analyses. A significant main effect of condition, $F(1,97)=108.59$, $p<.001$, and a significant group by condition interaction, $F(1,97)=5.57$, $p=.020$, were found, indicating that greater verbal output was provided to ToM animations than to goal-directed animations and that children with ASDs provided a fewer number of clauses to ToM animations than goal-directed animations compared to TD children. The analyses did not indicate a significant main effect of group ($p>.05$). Therefore, four one-way ANCOVAs (two for goal-directed and two for ToM animations), controlling for verbal output (number of clauses), were run for appropriateness and intentionality ratings.

The main analyses involved additional 2×2 mixed model ANOVAs (one for intentionality scores and one for appropriateness scores) that were run in order to assess the effects of group and animation condition on the two ratings of performance. Animation condition was the within subjects factor and group was the between subjects factor.

Pearson correlations were run to examine the relationship between age and intentionality and appropriateness ratings in the ToM condition in each group separately. Follow-up hierarchical linear regression analyses were run to examine how well not only age and group alone but also the interaction term of age $\times$ group predicted performance in the ToM condition of the Triangles Playing Tricks task.

4. Results

Results of the intentionality ratings ANOVA indicated a main effect of group, $F(1,97)=11.11$, $p=.001$, a main effect for animation condition, $F(1,97)=30.62$, $p<.001$, but no significant condition by group interaction, $F(1,97)=0.45$, $p=.51$. Follow-up one-way analyses showed that children with ASDs gave responses that received lower intentionality ratings than did TD children in both the goal-directed, $F(1,97)=6.47$, $p=.013$, and ToM, $F(1,97)=7.98$, $p=.006$, conditions (see Figure 1). A follow-up paired samples t-test indicated higher intentionality scores in the ToM condition than the goal-directed condition, $t(98)=-5.75$, $p<.001$. Results of the appropriateness score ANOVA also indicated a main effect of group, $F(1,97)=13.36$, $p<.001$, a main effect for animation condition, $F(1,97)=69.85$, $p<.001$, but no significant condition by group interaction, $F(1,97)=0.01$, $p=.92$. Follow-up one-way analyses showed that children with ASDs gave responses that received lower appropriateness ratings than did TD children in both the goal-directed, $F(1,97)=6.97$, $p=.010$, and ToM, $F(1,97)=9.45$, $p=.003$, conditions (see Figure 2). A follow-up paired samples t-test in the combined sample of TD and ASD children indicated higher appropriateness scores in the goal-directed condition than the ToM condition, $t(98)=8.51$, $p<.001$.

To be conservative in follow-up to these analyses, we ran four separate one-way ANCOVAs, covarying the effect of verbal output (i.e., number of clause produced), for the intentionality and appropriateness ratings in the ToM versus the goal-directed conditions. Results remained unchanged in that significant group differences were found for intentionality ratings in both the goal-directed, $F(1,96)=5.67$, $p=.019$, and ToM, $F(1,96)=4.28$, $p=.041$, conditions as well as for appropriateness ratings in the goal-directed, $F(1,96)=7.57$, $p=.007$, and ToM, $F(1,96)=6.34$, $p=.013$, conditions. Similarly, we ran four separate one-way ANCOVAs, covarying the effect of verbal IQ, which did not alter any of the findings (intentionality ratings in the goal-directed, $F(1,94)=7.47$, $p=.008$, and ToM, $F(1,94)=7.42$, $p=.008$, conditions; appropriateness ratings in the goal-directed, $F(1,94)=7.50$, $p=.007$, and ToM, $F(1,96)=8.77$, $p=.004$, conditions).

Next, we examined the influences of age on ToM performance. A significant positive correlation between age and appropriateness scores was found among TD children ($r=.49$, $p<.001$) as well as among children with ASDs ($r=.33$, $p=.035$) (see Figure 3). Within the group of TD children, there was a significant positive correlation between age and intentionality ratings ($r=.29$, $p=.026$); however, this relationship was not noted within the ASD group ($r=.18$, $p=.26$) (see Figure 4).

In follow-up to these correlations, hierarchical linear regression analyses were conducted to examine how well group membership alone, age alone, and the interaction of age and group predicted intentionality and appropriateness ratings in the ToM condition. As depicted in Table 2, group membership alone was a significant predictor of intentionality and appropriateness ratings for ToM animations ($p<.01$). Further, the entry of chronological age as a separate predictor resulted in a significant increment in prediction of intentionality and appropriateness ratings ($p<.05$). The addition of the group by age interaction term did not significantly affect the prediction ($p>.05$).

5. Discussion

The current study examined uncued social attribution to the Triangles Playing Tricks task and age-related changes in performance within relatively large samples of high functioning children with ASDs and TD children matched on age, IQ, and sex ratio. Because age-related changes in ToM skills beyond early childhood have received limited attention in the autism literature, one of the main goals of the current study was to investigate the relationship between age and social attribution abilities after controlling for verbal and language skills in children with ASDs compared to TD children.

Our main hypothesis that children with ASDs would receive lower appropriateness and intentionality ratings on the animations than TD children was supported. Consistent with previous research (Abell et al., 2000; Campbell et al., 2006; Castelli et al., 2002), in the current study, children with ASDs provided less appropriate responses to the animations of 'interacting' geometric shapes compared to the TD children in both the goal-directed and ToM conditions. Moreover, children with ASDs showed a reduced tendency to attribute intentionality to animations in both conditions, which is consistent with the findings from Castelli and colleagues' study (2002) conducted with high functioning adults with ASDs. Intentionality, *per se*, was not commonly assessed in other studies using Heider and Simmel-type animations (e.g., Bowler & Thommen, 2000; Klin, 2000; Klin & Jones, 2006). The animation sequences designed by Abell and colleagues (2000) were longer in duration, more complex, and more dynamic in motion properties (e.g., allowing the triangles to change shape periodically) than the original Heider and Simmel task. Further, Abell and colleagues' task included a ToM condition designed specifically to elicit mental state attributions with greater intentionality. All of these factors may have influenced the likelihood of participants attributing intentionality to the geometric shapes. Thus, the use of Abell and colleagues' task in the current study most likely increased our ability to assess group differences that may have been difficult to detect otherwise in this high functioning sample. Indeed, we documented higher intentionality ratings in the ToM animations compared to the non-ToM animations, which is also consistent with the previous literature (Castelli et al., 2002). In summary, the results of the current study are consistent with previous research assessing ToM skills in children with ASDs and add to the growing body of literature by demonstrating a diminished tendency to attribute social meaning to displays of interacting geometric forms among high functioning children with ASDs.

Our second hypothesis that the relationship between age and performance on ToM animations would be stronger among TD children than children with ASDs was partially supported. Although both groups showed age-related improvements in ToM performance, the correlation between age and appropriateness in the ToM condition was higher in the TD group than in the ASD group, and a significant correlation between age and intentionality was found only within the group of TD children. However, the group by age interaction term for both appropriateness and intentionality ratings did not significantly increase predictive power in regression analyses. Recently, Hu et al. (2010) demonstrated a steady improvement in social attribution skills with age in TD children using a modified version of the Social Attribution Task developed by Klin (2000). To our knowledge, the current study is the first to explore the relationship between age and ToM performance in high functioning children with ASDs who usually perform well on false belief problems despite having social cognition deficits in real life situations. It is possible that a nonverbal social attribution task that does not rely on increasingly complex syntax, as is the case for false belief paradigms, cannot be solved with compensatory verbal strategies by a subset of high functioning children with ASDs (Happé, 1995). Visual examination of our data showed that very young children (<8 years) in both ASD and TD groups received lower appropriateness scores in the ToM condition compared to older children (8+ years). Hu et al. (2010) reported similar

findings in TD children (i.e., children who are 7 and younger explain events in physical terms, whereas children between the ages of 8 and 10 begin to consider the intentions behind the motion). Taken together, these findings indicate that key components of social attribution ability may not begin to develop before age 8.

In summary, the present study adds to the existing literature by showing that even among high functioning children with ASDs there is a clearly diminished propensity to attribute social meaning to uncued animations of interacting geometric shapes. Moreover, whereas age is highly associated with ToM performance in the TD children, this relationship was not as strong among children with ASDs. These results suggest that with increasing age during childhood and early adolescence, individuals with ASDs may fall further behind their typically developing peers in social attribution abilities.

The results of the current study need to be interpreted cautiously for several reasons. First, the current study examined the development of social attribution skills using a cross-sectional design. Given that longitudinal designs are better suited to assess and understand developmental changes, future studies utilizing these methods to map the developmental trajectory of social attribution skills will be extremely important. Second, although the social attribution task used in the current study was nonverbal in nature, it required a verbal response from the participants. We controlled for verbal IQ and verbal output (i.e., number of clauses produced) when conducting data analyses; however, the task cannot be considered language-independent. Given this, it would be helpful for future studies to include additional tools to assess language skills in more depth. Further, developing new tasks assessing social attribution skills that rely less on language/verbal abilities will also be a valuable addition to the literature, as such tasks can be used with lower functioning children who may have poor language skills. Lastly, studying social attribution abilities concurrent with everyday social skills as well as other nonsocial cognitive abilities important in ASD, such as executive functioning skills (e.g., attention, impulsivity, organization, flexibility, etc.; for review, see Hill, 2004; Kenworthy, Yerys, Anthony, & Wallace, 2008) will provide useful information and add to the current body of literature.

Acknowledgments

This research was supported in part by the Intramural Research Program of the NIH, National Institute of Mental Health, the Frederick and Elizabeth Singer Foundation, and the Studies for the Advancement of Autism Research and Treatment (STAART: NIMH U54MH066417). We also thank the Intellectual and Developmental Disabilities Research Center at Children's National Medical Center (NIH IDDRC P30HD40677) for supplementary support. We would like to thank the children and families who participated in this research.

References

- Abell F, Happé F, Frith U. Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. *Cognitive Development*. 2000; 15:1–16.
- Baron-Cohen, S. Theory of mind and autism: A fifteen year review. In: Baron-Cohen, S.; Tager-Flusberg, H.; Cohen, DJ., editors. *Understanding other minds: Perspectives from developmental cognitive neuroscience*. 2. New York, NY: Oxford; 2000. p. 3–20.
- Baron-Cohen S, O'Riordan M, Stone V, Jones R, Plaisted K. Recognition of faux pas by normally developing children and children with asperger syndrome or high-functioning autism. *Journal of Autism and Developmental Disorders*. 1999; 29:407–418. [PubMed: 10587887]
- Bowler DM, Thommen E. Attribution of mechanical and social causality to animated displays by children with autism. *Autism*. 2000; 4:147–171.
- Campbell R, Lawrence K, Mandy W, Mitra C, Jeyakuma L, Skuse D. Meanings in motion and faces: Developmental associations between the processing of intention from geometrical animations and gaze detection accuracy. *Development & Psychopathology*. 2006; 18:99–118. [PubMed: 16478554]

- Castelli F, Frith C, Happé F, Frith U. Autism, asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain*. 2002; 125:1839–1849. [PubMed: 12135974]
- Castelli F, Happé F, Frith U, Frith C. Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns. *Neuroimage*. 2000; 12:314–325. [PubMed: 10944414]
- Happé FGE. An advanced test of Theory of Mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped and normal children and adults. *Journal of Autism and Developmental Disorders*. 1994; 24:129–154. [PubMed: 8040158]
- Happé FG. The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*. 1995; 66:843–855. [PubMed: 7789204]
- Heider F, Simmel M. An experimental study of apparent behavior. *American Journal of Psychology*. 1944; 57:243–259.
- Hill EL. Evaluating the theory of executive dysfunction in autism. *Developmental Review*. 2004; 24:189–233.
- Hu Z, Chan RCK, McAlonan GM. Maturation of social attribution skills in typically developing children: an investigation using the social attribution task. *Behavioral and Brain Functions*. 2010; 6:1–8. [PubMed: 20047681]
- Kenworthy L, Yerys BE, Anthony LG, Wallace GL. Understanding Executive Control in Autism Spectrum Disorders in the Lab and in the Real World. *Neuropsychology Review*. 2008; 18:320–338. [PubMed: 18956239]
- Klin A. Attributing social meaning to ambiguous visual stimuli in higher-functioning autism and Asperger syndrome: The social attribution task. *Journal of Child Psychology and Psychiatry*. 2000; 41:831–846. [PubMed: 11079426]
- Klin A, Jones W. Attributing social and physical meaning to ambiguous visual displays in individuals with higher-functioning autism spectrum disorders. *Brain and Cognition*. 2006; 61:40–53. [PubMed: 16497422]
- Lord, C.; Rutter, M.; DiLavore, P.; Risi, S. Autism diagnostic observation schedule-WPS edition. Los Angeles, California: Western Psychological Services; 1999.
- Lord C, Rutter M, Le Couteur A. Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*. 1994; 24:659–685. [PubMed: 7814313]
- Milligan K, Astington JW, Dack LA. Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding. *Child Development*. 2007; 78:622–646. [PubMed: 17381794]
- Peterson CC, Wellman HM, Slaughter V. The mind behind the message: advancing theory of mind scales for typically developing children, and those with deafness, autism, or asperger syndrome. *Child Development*. 2012; 83(2):469–485. [PubMed: 22304467]
- Salter G, Seigal A, Claxton M, Lawrence K, Skuse D. Can autistic children read the mind of an animated triangle. *Autism*. 2008; 12(4):349–371. [PubMed: 18579644]
- Stone VE, Baron-Cohen S, Knight RT. Frontal lobe contributions to theory of mind. *Journal of Cognitive Neuroscience*. 1998; 10:640–656. [PubMed: 9802997]
- Wechsler, D. Wechsler Scales of Intelligence. 3. San Antonio, TX: Psychological Corporation; 1991.
- Wechsler, D. Wechsler Abbreviated Scales of Intelligence. San Antonio, TX: Psychological Corporation; 1999.
- Wechsler, D. Wechsler Intelligence Scale for Children. 4. San Antonio, TX: Harcourt Assessment; 2003.
- Wimmer H, Perner J. Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*. 1983; 13:103–128. [PubMed: 6681741]

Highlights

- Lower intentionality and appropriateness ratings were observed in the ASD group than the TD group.
- Children with ASDs had a diminished tendency to attribute social meaning and intentionality to ambiguous visual displays.
- Age was highly associated with ToM performance in the TD children, whereas this relationship was not as strong among children with ASDs.
- With increasing age, individuals with ASDs may fall further behind their TD peers in social attribution abilities.

Figure 1. Intentionality ratings across conditions for typically developing children and children with high functioning autism spectrum disorders.

Figure 2. Appropriateness ratings across conditions for typically developing children and children with high functioning autism spectrum disorders.

Figure 3.
Correlations between appropriateness ratings in the theory of mind condition and age for typically developing children and children with high functioning autism spectrum disorders.

Figure 4.
Correlations between intentionality ratings in the theory of mind condition and age for typically developing children and children with high functioning autism spectrum disorders.

Table 1Participant characteristics (*N*, mean age, mean IQ scores).

		ASD (n=41)	Control (n=58)	Statistics
Mean Age (<i>SD</i>)		10.46 (2.26)	10.77 (2.44)	$t(97)=-0.64, p=.52$
Mean IQ (<i>SD</i>)	Verbal IQ	114.95 (19.30)	115.17 (14.27)	$t(95)=-0.06, p=.95$
	Performance IQ	112.69 (18.13)	111.86 (14.37)	$t(95)=0.25, p=.80$
	FSIQ	113.41 (20.14)	115.16 (13.33)	$t(97)=-0.48, p=.63$
% Male		78%	71%	$\chi^2(1, N=99)=0.67, p=.41$

\$watermark-text

\$watermark-text

\$watermark-text

Table 2

Regression analyses: The contributions of group, age, and the interaction of group and age to performance on the Triangles Playing Tricks task.

	Theory of Mind Animations					
	Intentionality			Appropriateness		
	R	R Square	R ² Change	R	R Square	R ² Change
Group	.276	.076	.076**	.298	.089	.089**
Age	.366	.134	.058*	.509	.259	.170**
Group x Age	.369	.136	.002	.517	.267	.008

* $p<.05$,
** $p<.01$