Attributing social and physical meaning to ambiguous visual displays in individuals with higher-functioning autism spectrum disorders

Ami Klin *, Warren Jones

Yale Child Study Center, New Haven, CT, USA

Abstract

The weak central coherence (WCC) account of autism characterizes the learning style of individuals with this condition as favoring localized and fragmented (to the detriment of global and integrative) processing of information. This pattern of learning is thought to lead to deficits in aspects of perception (e.g., face processing), cognition, and communication (e.g., focus on disjointed details rather than "gist" or context), ultimately leading to social impairments. This study was carried out to examine whether WCC applies to social and to non-social aspects of learning alike, or, alternatively, some areas of learning (e.g., physical reasoning) are spared in autism. Heider and Simmel's (1944) classic social animation as quantified in the Social Attribution Task (SAT) (Klin, 2000) and a novel animation involving physical reasoning (the Physical Attribution Task; PAT) were used to test the domain specificity of the WCC hypothesis. A pilot study involving a reference group of typically developing young adults and a group of individuals with higher-functioning autism spectrum disorders (ASDs) revealed gender differences in the reference group in regards to performance on the PAT (males outperformed females). In a follow-up case-control comparison involving only males where the ASD group was matched on age and IQ to a typically developing (TD) group of children, adolescents, and adults, the ASD group showed lower SAT scores and comparable PAT scores relative to the TD group. The interaction of diagnostic group by task was highly significant, with little overlap between the groups in the distributions of SAT minus PAT scores. These results indicated preserved integrative skills in the area of physical attribution in the ASD group, thus failing to support the WCC account as a domain-independent (or more general) model of learning in autism, while highlighting the centrality of the social deficits in the characterization of learning style in the autism spectrum disorders.
© 2006 Published by Elsevier Inc.

Keywords: Autism; Weak central coherence; Social attribution; Physical attribution

1. Introduction

Given the heterogeneity in manifestation of the autism spectrum disorders (ASDs), neurobiological research requires the isolation of more specific phenotypes that can be pursued with neuroscience tools (Dawson et al., 2002). Among the most influential psychological phenotypes available is the weak central coherence (WCC) account of autism (Happé, 1999). In a seminal contribution, Frith (1989) suggested that individuals with autism have a marked tendency to process incoming stimuli in a frag-

mented fashion, focusing on details (localized processing) rather than integrated and meaningful wholes (configural processing), failing, as it were, to interpret stimuli in terms of gist and context. This hypothesis has strong face validity given that over-focus on details to the expense of integrated meaning and context is one of the hallmarks of autism in multiple domains. This has been experimentally shown in a number of areas, ranging from perception and grapho-motor execution (e.g., Mottron & Belleville, 1993; Plaisted, 2001; Plaisted, Saksida, Alcantara, & Weisblatt, 2003), to visual-spatial constructional tasks (e.g., Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983, 1993) to language understanding (e.g., Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999) and memory (e.g., Hermelin & O'Connor, 1967; Tager-Flusberg, 1991).

* Corresponding author. Fax: +1 203 737 4197.
E-mail address: ami.klin@yale.edu (A. Klin).

The WCC hypothesis has several implications to our understanding of autism. First, it delineates an internal social world that is piecemeal and disjointed, lacking the overall coherence that defines social context and social meaning. Therefore, while the account concerns all domains of learning in autism, it also has immediate relevance to the core social disability in autism. Indeed, WCC reflects the first clinical observations (Kanner, 1943) and experimental findings (Scheerer, Rothmann, & Goldstein, 1945) of children with autism. Second, contrary to psychological theories that focus only on deficits in autism, this account also allows to examine assets commonly seen in individuals with this condition, that is in situations in which a preference for detailed or localized processing can be seen as an advantage in task performance. This is the reason why Frith and Happé (e.g., Frith & Happé, 1994; Happé, 1999) prefer to call WCC a cognitive style rather than a cognitive deficit. In fact, several studies examining WCC in individuals with autism tend to report superior abilities in some areas of task performance such as the Wechsler subtest of Block Design or the Embedded Figures Test (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1993). The WCC hypothesis also provides a theoretical framework to examine extreme cases of special abilities in individuals with autism, such as savant skills (see Hermelin, 2001). Third, WCC provides a psychological framework to examine new neurostructural and neurofunctional findings in autism, including findings of accelerated brain growth in autism (e.g., Courchesne, Carper, & Akshoomoff, 2003), of larger brains with abnormal morphometric distributions (e.g., Courchesne, Redcay, & Kennedy, 2004), and of reduced functional connectivity and synchronization in key psychological domains (e.g., Just, Cherkassky, Keller, & Minshew, 2004).

Despite the accumulating body of evidence in support of the WCC hypothesis, it has not gone unchallenged. Some studies have failed to corroborate the local vs. global cognitive style in visual-spatial constructional tasks (e.g., Mottron, Burack, Stauder, & Robaey, 1999; Ozonoff, Strayer, McMahon, & Filloux, 1994), whereas other studies helped refine the hypothesis, particularly in the perceptual domain (e.g., Mottron & Burack, 2001; Plaisted et al., 2003). It is now clearly the case that individuals with autism are able to process more integrated meaning in some cases (e.g., Snowling & Frith, 1986), particularly if the task is made explicit to them. This led Happé (2005) to suggest that the WCC cognitive style in individuals with autism is best characterized as the "spontaneous approach or automatic processing preference of people with autism," and is thus "best captured in open-ended tasks" (p. 641). This is critical since (1) individuals with autism are known to perform better in explicit tasks that can be reduced to a "close domain" problem-solving situation than in more naturalistic, spontaneous or "open domain" situations (e.g., Klin, Jones, Schultz, & Volkmar, 2003), and (2) real-life learning about the inanimate as well as the social world takes place in situations that are much more similar to "open domains," which is

where individuals with autism show their greatest degree of disability (Klin, Jones, Schultz, Volkmar, & Cohen, 2002a). In other words, the fact that they may be able to process information more holistically in some situations does not invalidate the hypothesis.

Nevertheless, most studies of WCC in autism have involved just such "close domain" situations. And yet, the clinical literature is replete with examples of fragmented processing in real-life adaptation of individuals with autism. For example, going into a high-school cafeteria and trying to make sense of what is going on there, there is a need to listen to what people are saying (i.e., their words), how they are saying it (e.g., their facial and bodily gestures, voice inflection, stress, and volume), what are the reactions of others to the people speaking, are there any particular props contextualizing the setting, background information about the situation (e.g., people's typical intentions, date and time in the day) among a host of other factors. Individuals with autism are very likely to overly focus in a number of isolated features of this complex situation, thus failing to infer overall context, responding in irrelevant or overly literal fashion, or otherwise ignoring essential elements.

It is of interest that a similar situation applies to another influential psychological hypothesis of autism, namely theory of mind (ToM) (Baron-Cohen, 1995). While a large number of individuals with autism fail ToM tasks, some, particularly those without cognitive deficits, can solve such problems at relatively high levels (e.g., Bowler, 1992; Dahlgren & Trillingsgaard, 1996), and yet have more difficulty with less explicit tasks (Volkmar, Lord, Bailey, Schultz, & Klin, 2004). One study (Klin, 2000) utilized a classic animation in which geometric shapes moved and acted like humans (Heider & Simmel, 1944) in order to measure how salient the social meaning of this array of ambiguous visual stimuli was to higher-functioning adolescents and adults with autism. Typical viewers immediately recognize the social nature of the cartoon and provide narratives that include a number of social attributions involving relationships portrayed there (e.g., being a bully, being a friend), the meaning of specific actions (e.g., trapping, protecting), and attributions of mental states (e.g., being shy, thinking, and being surprised) to the geometric shapes. By contrast, this study showed that individuals with autism had great difficulty in doing so despite having demonstrated the ability to "pass" higher-order (i.e., "second order"; e.g., Tager-Flusberg & Sullivan, 1994) ToM tasks. Other studies using similar animations reached similar conclusions (Abell, Happé, & Frith, 2000; Bowler & Thommen, 2000). These results have been interpreted to suggest that individuals with autism do not spontaneously search for social meaning in the environment (Klin et al., 2003) or that they may be lacking an "intuitive" theory of mind (Frith & Happe, 1999).

What is of interest is that this set of results could also have been predicted from the WCC hypothesis. But in

contrast to the other accounts which define the deficits in the social domain, WCC would see this as only one instance in which deficits in integrative processing led to a lack of ability to construct (social) meaning from its (geometric) component parts. In sum, WCC predicts deficits in processing of information in *all* domains, not only the social one. Whether or not a psychological phenotype in autism is defined in more general cognitive terms or more specifically in the social domain has profound implications for neurobiological studies. While the former leads research in the direction of brain mechanisms involved in integration of information (Happé, 2005), the latter places much greater emphasis on basic adaptive mechanisms of socialization (Insel & Fernald, 2004; Klin et al., 2003), or on innate social cognitive mechanisms required for the emergence of intersubjectivity (Baron-Cohen, 1994).

In this paper, we examined the domain specificity of the WCC account of autism by using Heider and Simmel's (1944) social animation to quantify spontaneous attributions of social meaning (as quantified in the Social Attribution Task; SAT; Klin, 2000) in conjunction with a novel geometric animation created to elicit spontaneous attributions of physical meaning, which we named the Physical Attribution Task (PAT). In the preliminary study, these tasks were administered to a group of typical college students and a group of individuals with autism spectrum disorders (ASDs) without mental retardation but within a broad range of ages and IQ. In this phase of the study, no attempt was made to match the samples given the primary goal to explore developmental or other variables impacting on task performance. Also, and importantly, given the novel nature of the PAT, it was necessary to obtain pilot data on the difficulty level of this task (relative to the SAT). This preliminary study was followed by a more controlled comparison in performance between a group of typical children, adolescents, and adults and an age and IQ-matched group of individuals with autism.

The PAT was modeled after the SAT in several ways: (1) the physical event was depicted through the movements of geometric shapes; (2) the use of geometric shapes required the participant's capacity for attributing meaning (in this case, physical rather than social) to the ambiguous visual displays; (3) it was presented as an open-ended task (Happé, 2005; Klin et al., 2002a) since the presentation of the animation was simply followed by the examiner's question "What happened there?"; and (4) the resultant spontaneous narratives were quantified for the presence of a set of physical attributions made by typical young adults in response to the animation. On the basis of the WCC account of autism, our major hypothesis predicted that the group with ASD would show deficits relative to controls in both the SAT and the PAT once comparability of the two tasks was ascertained. If, however, deficits on the SAT were greater than on the PAT, the WCC hypothesis would not be supported as a domain-independent cognitive style characterizing individuals with autism.

2. Pilot study

2.1. Methods

As noted, there was a need to conduct a pilot study given the novel nature of the Physical Attribution Task (PAT). This pilot study was meant to (1) explore the role of developmental and clinical factors such as age, IQ, and gender on the performance of the Social Attribution Task (SAT) and PAT in order to identify critical matching variables for these tasks; (2) to examine the extent to which the SAT and PAT had similar or different levels of difficulty; and (3) to ascertain that the set of physical attributions likely to be made to the physical animation, as identified a priori and examined in previous exploratory work, indeed captured the most frequent physical attributions made by viewers of this animation. A reference sample of young adults (college students) and a fairly large group of higher-functioning individuals with autism spectrum disorders (ASDs) were included in the preliminary study. All of them were able to provide informed consent or assent (if they were minors and their parents or legal guardians were able to provide consent) to participation in this study, which was approved by the Yale University School of Medicine Institutional Review Board. The reference group of college students was recruited from a local college through on-campus advertisements, whereas participants with ASD were participants of a large, federally funded study focused on the neuropsychology and neurobiology of higher-functioning ASDs.

2.1.1. Participants

There were 35 participants in the typically developing (reference) group (TD) (9 males and 26 females) and 40 participants in the group with autism spectrum disorders (ASDs) (38 males and two females). Intellectual levels were measures in the TD group with the *Kaufman Brief Intelligence Test* (K-BIT; (Kaufman & Kaufman, 1990)), which provides a well-standardized and researched short form for the estimation of full scale, verbal, and performance IQs. All participants in the ASD group completed a full intellectual battery: the Wechsler Intelligence Scale for Children, Third Edition (WISC-III; Wechsler, 1991) or the Wechsler Adult Intelligence Scale, Third Edition (WAIS-III; Wechsler, 1997). Data on social adaptive skills were collected with the *Vineland Adaptive Behavior Scales, Expanded Edition* (Sparrow, Balla, & Cicchetti, 1984). Diagnostic characterization included the *Autism Diagnostic Interview—Revised* (ADI; Lord, Rutter, & Le Couteur, 1994) and the *Autism Diagnostic Observation Schedule—Generic* (ADOS; Lord, Rutter, & DiLavore, 1996). These various components of the assessment were conducted independently, by different clinicians. The experimental procedures were conducted independently from the characterization procedures, by assistants in research who were blind to other aspects of the assessment. For the purpose of this study, diagnostic assignment was made entirely on the basis of the ADI and ADOS, although all participants in the ASD group

received a clinician-assigned diagnosis of autism, Asperger syndrome, or PDD-NOS made by two experienced clinicians. Characterization data on the two groups are provided in Table 1.

The TD and ASD groups differed in gender distribution, age, and IQ. The TD group had many more females, was older, and had higher Full Scale, Verbal, and Performance IQs. The TD group was a fairly homogeneous group of young male and female adults providing, therefore, an appropriate reference group to explore the nature of the PAT in a normative sample. The ASD group consisted of higher-functioning children, adolescents, and adults who were nevertheless very socially disabled in terms of both social adaptation and level of autistic symptomatology. Within these confines, however, there was broad distribution of age and cognitive level. Thus, the ASD group was appropriate to explore the impact of developmental and clinical variables on the experimental tasks. All participants in the ASD met criteria for the social cluster of the ADI (45% met all criteria for autism), and also met criteria for at least ASD on the ADOS (90% met all criteria for autism).

2.1.2. The Social Attribution Task

2.1.2.1. Overview.
The SAT requires the participant's ability to recognize visual stimuli as social phenomena and then to extract visual cues from the display in order to create a social context (i.e., make social attributions). It utilizes Heider and Simmel's (1944) classic silent animation which lasts about 50 s. The "cast of characters" are a rectangle that has a small opening that opens and closes (like a "door"), a big triangle, a small triangle, and a small circle or dot (see Fig. 1). The movements of the shapes are contingent upon one another, in that they move in synchrony, against one another, or as a result of the action of the other shape. Data obtained with this procedure are a series of narratives (Klin, 2000). The first narrative is obtained after
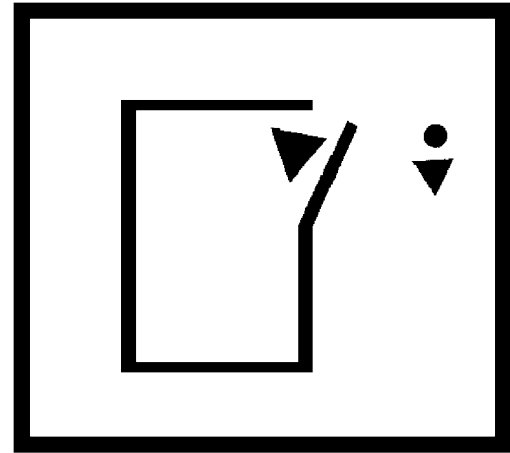

Fig. 1. The "cast of characters" in the Heider and Simmel (1944) cartoon.

the video sequence is shown twice (Narrative 1). The sequence is then broken down into six sequential, meaningful segments and presented one at a time. This is necessary in order to avoid placing too much burden on memory and narrative organizational processes, two factors that may place unnecessary demands upon individuals with developmental disabilities at different ages. In this way, the task is focused on the participants' ability to make attributions at varying levels of sophistication rather than on memory capacities. After each segment is shown, the participant is asked to state in as completely as possible fashion "what happened there" (Narratives 2–7). Narratives 1–7 represent spontaneous accounts of the visual display, with no explicit instruction as to the nature of the display.

2.1.2.2. Coding.
The development of the coding system for the SAT is provided in great detail in our previous work (Klin, 2000). For the purpose of this study, we utilized only one of the seven social cognitive indices described there,

Table 1
Characterization data on the typically developing (reference) group (TD) and on the group with autism spectrum disorders (ASDs)

	TD	ASD	t	Significance
N	35	40		
Gender	9 males, 26 females	38 males, 2 females		
Age (years) Mean (SD) [Range]	21.8 (1.9) [18–25]	13.0 (4.9) [8–35]	$t_{73} = 10.36$	$p < .001$
Full Scale IQ[a] [Range]	114.9 (6.2) [96–128]	100.2 (18.80) [66–141]	$t_{73} = 4.69$	$p < .001$
Verbal IQ[a] [Range]	116.7 (9.1) [94–132]	105.0 (18.9) [70–140]	$t_{73} = 3.46$	$p < .001$
Performance IQ[a] [Range]	110.6 (4.8) [100–120]	94.7 (19.5) [55–139]	$t_{73} = 4.97$	$p < .001$
Vineland Socialization Standard Scores[b] [Range]	—	51.5 (12.7) [22–75]		
ADOS[c] Communication Algorithm Total [Range]	—	4.3 (1.4) [2–7]		
ADOS[c] Social Algorithm Total [Range]	—	9.4 (2.6) [5–14]		
ADOS[c] Both Algorithm Total [Range]	—	13.52 (3.6) [7–21]		
ADOS[c] Meet criteria for autism (% of ASD sample)	—	90%		
ADOS[c] Meet criteria for ASD (% of ASD sample)	—	100%		
ADI[d] Meet criteria for autism (% of ASD sample)	—	45%		

[a] Kaufman Brief Intelligence Test (K-BIT) for TD group and the Wechsler Intelligence Scale for Children—third edition (WISC-III) or the Wechsler Adult Intelligence Scale—third edition (WAIS-III) for the ASD group.
[b] Vineland Adaptive Behavior Scales—Expanded Edition (Vineland).
[c] Autism Diagnostic Observation Schedule, Modules 3 and 4 (ADOS): Communication cut-off for autism is 3 (2 for ASD); Social cut-off for autism is 6 (4 for ASD); for both domains it is 10 for autism (7 for ASD).
[d] Autism Diagnostic Interview (ADI).

namely the Salience Index. This was necessary because we needed to make this procedure to be as comparable to its physical counterpart (the PAT) as possible, and the other social cognitive indices were not meaningful in that context. The Salience Index refers to the readiness with which a participant imposes a social interpretation to ambiguous visual stimuli. This index corresponds to the number of social elements (from a total of 20 items frequently mentioned by typically developing individuals) which the participant was able to identify in their spontaneous narratives. This score is expressed in percentages. Please see Appendix A for coding instructions.

2.1.2.3. Procedure. The SAT was presented to participants as an individually administered procedure, in a quiet room. The participant sat about 2 ft away from the computer screen where the cartoon was shown. The examiner operated the program by clicking on a button appearing before every segment to be presented, and also operated an audio recorder to record the participants' narratives. The initial instructions were as follows: "*You are going to watch a short videotape twice. The videotape lasts for less than a minute and it has no sound. If you have any questions please ask now. It is important that you pay attention while the videotape is showing. I will ask you a few questions about the videotape later. If you are ready we can start.*" After the complete animation is shown twice, the following instructions were given: "*Now, tell me what happened in the videotape. Please answer as completely as you can. There is no right or wrong answer. I will record your answer so that I can write it down later on. If you are ready, you can start.*" Narrative 1 was obtained. After the participant provided the first narrative, the following instructions were given: "*Now you will see clips of the videotape. They will be shown one at a time and only once, and then, after each one, I will ask you a question. Remember, please answer as completely as you can. If you are ready, we can start.*" Six video segments, corresponding to six sequential, meaningful segments of the animation, are then presented. After each segment, the participants were asked "*What happened here?*." Narratives 2–7 were obtained. Narratives 1–7 constituted the data to be quantified for this procedure.

The animation, coding directives, and procedure can be viewed at www.autism.fm/sat.html.

2.1.3. The Physical Attribution Task

The PAT requires the participant's ability to recognize visual stimuli as physical (not geometric) phenomena and then to extract visual cues from the display in order to create a physical context (i.e., make physical attributions). The PAT is presented as a silent computer display that lasts about 50 s. The group of "physical objects" consists of a large circle rotating like a planet (e.g., earth), a combination of an elongated rectangle, small triangle, and small circle together that is launched like a "spaceship" or "rocket" (the rectangle is like a "rocket booster," the small triangle and circle function like a "module"—like the module that landed on the moon—and the small circle is like a "capsule"—like the capsule that landed on the ocean after an Apollo mission), and a medium size circle that functions like an "orbiting moon." See Fig. 2 for the opening screen shot of the PAT. This animation was inspired by the work of Michotte (translated into English in 1963) who pioneered this line of work on causality. One difference between the SAT and the PAT is that the PAT has a black background and the shapes are white. Despite the authors' a priori concern that this animation might be too veridical, typically developing young adults were more likely to make physical attributions (rather than social) if the display was altered in this manner (see results for reference group).

For the purpose of description of the animation, the shapes are named as such:

Large circle: earth.
Rectangle + small triangle + small circle: rocket.
Rectangle only: booster.
Triangle + small circle: module.
Triangle alone: module booster.
Small circle alone: capsule.
Medium size circle: moon.

These geometric shapes move in a way that depicts the launching of a rocket into space from earth, following the earth's orbit before moving in the direction of the moon. The booster detaches from the rocket, becoming lost in space after briefly rotating around the earth's orbit. The module follows a trajectory to land on the moon, following a wide elliptical orbit, and sometimes disappearing off the screen (as it is completing the orbit out of the person's view). The module lands on the moon, and spends a whole (unseen) orbit there. Earth follows its own shorter orbit, and is always fully in view. Once one orbit of the moon is completed, the module is launched from the moon, and moves in the direction of earth. It initially goes around earth, the module booster detaches, and the capsule lands on earth. Both the capsule and the detached module booster move as if rotating around earth. The capsule
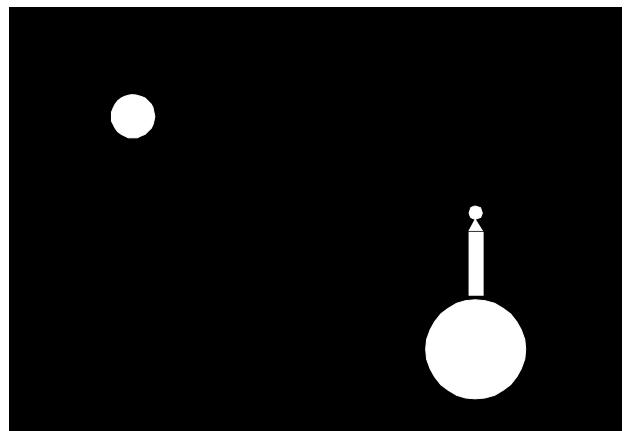

Fig. 2. The cast of characters in the PAT cartoon.

moves in a spiral motion (entering earth). This animation, as well as coding directives and procedures can be seen at www.autism.fm/pat.html.

2.1.3.1. Coding. The coding system for the PAT was created by generating, a priori, an exhaustive list of elements of the animation that could be interpreted as representing something physical. The list was modified after the preliminary coding of 32 pilot protocols obtained for typically developing young adults (these were college students whose protocols were used for the purpose of generating the coding scheme only. They were not part of the reference sample included in the study reported here). Elements that were not mentioned by any participant were eliminated, and elements mentioned consistently that had not been included in the preliminary list were appended. The criteria for each element's identification were also refined, producing a list of 22 elements that participants had to explicitly identify as physical in order to be counted. See Appendix A for the list of attributions and detailed directives for coding. In this manner, we created an index of physical attribution that could be compared to the Salience Index on the SAT. On the PAT, this index corresponds to the number of physical elements (from a total of 22 items) that a participant is able to identify in their spontaneous narratives. This score is expressed in percentages. We did not make any assumptions about the difficulty of the task relative to its social counterpart, preferring instead to assess comparability of the two tasks empirically. In this way we could avoid the vexing problems involved in creating a physical animation that would be comparable to Heider and Simmel's (1944) rich social plot, namely to portray a "physical plot" complex enough to elicit many related attributions at varying levels of complexity. Our main goal, therefore, was to create a level playing field for all participants completing the task, and to ascertain the distribution of performance results in a reference group of young college students as our starting point for examining results for clinical samples and younger participants.

2.1.3.2. Procedure. The PAT was presented to participants in exactly the same way that SAT was presented.

2.1.3.3. Note on the overall procedure. The SAT and PAT animations were presented following a counter-balanced, random order.

2.2. Results

2.2.1. Reliability issues

The written transcription of the recorded narratives was performed by a professional transcriber. Although inter-rater reliability of the transcriptions was not assessed, the transcriber was unaware of the purpose of the study or the identity of the participants. Sixty of the 75 protocols (80%) were rated by at least 2 raters of a total of 3 raters. Transcriptions were de-identified for the purpose of coding.

Thus, the coders were blind to the identify of the protocol. In order to maximize inter-rater reliability (1) raters were trained together on the scoring of 15 protocols before scoring the protocols included in this study, with a view to clarify frequent scoring issues and to learn explicit scoring guidelines; (2) both SAT and PAT coding criteria were sufficiently detailed (Appendix A); (3) ratings followed a procedural flowchart; and (4) for PAT ratings, a precise description and visual rendition of the geometric forms and combinations thereof were created to guide coding. Inter-rater reliability was computed for the overall scores of the SAT and PAT. The intraclass correlation coefficient for the SAT (Salience Index) score was $r = .87$ (thus comparable to $r = .90$ obtained in our previous work; Klin, 2000). The intraclass correlation coefficient for the PAT was $r = .96$. Thus, inter-rater reliability coefficients can be characterized as excellent (Cicchetti & Sparrow, 1981).

2.2.2. Subject variables impacting on SAT and PAT performance

2.2.2.1. TD group. Given the exploratory nature of this phase of the study, correlations that were significant at $p < .05$ or below were reported here (in the subsequent case-control study, only correlations at the $p < .01$ were reported in order to minimize spurious findings). In the TD group, the SAT was inversely correlated with FSIQ ($r = -.42$, $p < .05$), VIQ ($r = -.34$, $p < .05$), and PIQ ($r = -.36$, $p < .05$), but not with age or gender, whereas the PAT was only (but strongly) correlated with gender ($r = -.52$, $p < .01$), with males outperforming females. While the age and IQ correlations for this group were less important because of the restricted distribution in both variables (only young adults and an IQ standard deviation of 6 points), the highly significant correlation between the PAT and gender was surprising. In fact, of 18 participants in the TD group who were unable to make any physical attributions and received a score of 0% only 2 were males (thus 61% of females, contrasting with only 22% of males, received a score of 0% on the PAT). These results suggested, therefore, that a direct comparison between the TD and the ASD groups would have to be matched on gender distribution. Finally, SAT and PAT results were not significantly correlated in this group, suggesting that the performance on these two tasks was fairly unrelated for subjects in this group ($r = .19$).

2.2.2.2. ASD group. A Pearson correlation matrix was created for the experimental variables (SAT and PAT) and the characterization variables (age, FSIQ, VIQ, and PIQ) for the ASD group in order to examine the impact of age and IQ on SAT and PAT performance. Gender was not included in the matrix because there were only two females in this group. SAT results were not correlated with age or IQ. PAT results were positively correlated with age ($r = .34$, $p < .05$), and PIQ ($r = .39$, $p < .05$), but not with FSIQ or VIQ (although PIQ was strongly correlated, as expected, with both FSIQ and VIQ). SAT and PAT results were positively correlated ($r = .41$, $p < .01$) for this group.

2.2.3. Within group performance on the SAT and PAT

The Median SAT and PAT for the TD group was 65 and 0%, respectively, whereas the Median SAT and PAT for the ASD group was 25 and 30%, respectively. A within group comparison of means for the SAT and PAT revealed a significance difference in the TD group [SAT Mean = 65.3% (22.2%) and PAT Mean = 20.3 (28.9%); $t_{34} = 8.08$, $p < .001$] but not for the ASD group [SAT Mean = 27.2% (19.4%) and PAT Mean = 35.3% (32.5%)].

2.3. Discussion of pilot study

A typically developing (TD) group and a group with autism spectrum disorders (ASDs) completed the SAT and PAT procedures. The TD group served as a reference sample of male and female young adults, whereas the ASD group was characterized by a wide span of ages and IQ. This pilot study was necessary to explore the impact of non-experimental variables on SAT and PAT performance and to gauge difficulty level between the two tasks. Inter-rater reliability coefficients were excellent for both tasks.

For the TD group, the SAT correlated with IQ but not with age or gender, though the narrow IQ distribution in this group, and the fact that the correlation IQ was negative signify that, like in our previous study (Klin, 2000), higher IQ does not facilitate SAT performance. In contrast, the PAT was strongly correlated with gender and not with age or IQ. The fact that 61% of females in this group did not spontaneously make any physical attributions to the PAT (score of 0%) was highly surprising, particularly given the fact that these 18 females had a mean SAT score of 63% (23%). Among these 18 female participants, 10 had seen the SAT before the PAT and eight saw the PAT before the SAT. Typical PAT narratives by these participants were long geometric narratives interspersed with very few social attributions (e.g., "hitting," "hiding underneath") that were used whenever the participant appeared to be struggling to fully articulate a geometric movement. One typical 21-year-old female with a FSIQ of 112 offered a stark example of this. The following is the beginning of her PAT and SAT narratives:

PAT narrative: "*There was a big white circle, and attached to it was like a rectangular shape with a triangular shape attached to the end of that and another circle. To the left of it, floating around at first, was a smaller white circle, which then went off the screen to the left. At the same time, the big white circle separated, but the rectangular structure and the triangle and the little circle were all attached as one unit …*"

SAT narrative: "*It seems like little kids playing to me. The big guy was trying to beat up the little guy. It ran away. It sort of first said "hello," and then the smaller guy realized the bigger guy was being aggressive and was backed into the lower right hand corner of the house. At that point, the circle sort of escaped into the house. As the little triangle escaped from the bigger bully, the bigger guy went inside the house and cornered the little circle. The little circle managed to*

escape, closing the door behind him and locking the bully inside. The little circle and the little triangle were like 'wee-eee!'. They were happy because …"

The vast majority of these female participants were able to "see" the plot in the physical animation once they were told about it, but they showed no spontaneous tendency to see the PAT as a rocketship event at all. Thus, their cognitive style was such that they readily integrated ambiguous visual displays into social sequences but did not spontaneously do so when the animation was of a physical nature. This strong gender finding is partially consistent with Baron-Cohen's (2002) gender predictions reflected by the terms "systemizing" (thinking about systems) and "empathizing" (thinking about mental states). According to this hypothesis, males are much more likely to engage in the former whereas females are more likely to engage in the latter. However, gender was not correlated with performance on the SAT; thus this model's prediction that females would outperform males on this task was not supported. More generally, it is important to emphasize that what was measured on the PAT was not a skill (both males and females appeared to be able to integrate the geometric elements into the physical event once they were told what this event was). Rather the gender difference referred, as noted, only to the spontaneous readiness with which they made social and physical attributions. Thus, it is very likely that besides any nature-given proclivities to empathize and systemize, there are powerful cultural forces, including gender-related personal experiences shaping spontaneous attribution formation processes.

The TD group as a whole had much higher SAT scores than PAT scores, and performance on the two tasks was fairly dissociated (with a correlation of only $r = .19$). However, gender played an important role in these results, and should, therefore, be an important variable to be controlled in the subsequent case-control study.

For the ASD group, the SAT scores were not correlated with age, IQ, or gender, whereas PAT scores correlated positively with age and PIQ. The fact that age correlated positively with the PAT but not with the SAT scores suggests that, for this population, level of social attribution skills seems to be stable over time, whereas level of physical attribution seems to improve over time. Also for this group, SAT and PAT scores were positively correlated (thus appearing to share some skills) and at similar levels. On the basis of these results, there was a need to consider age and IQ in the subsequent case-control study. Finally, although PIQ (and not VIQ) scores were correlated with PAT performance, a decision was made to match the groups on VIQ because (1) the raw data for both the SAT and PAT are spontaneous narratives. Therefore, control for verbal abilities was fundamental in a study of this nature; and (2) VIQ and PIQ were very highly correlated in the ASD group ($r = .59$). Because of the typical scatter in IQ profiles obtained for individuals with ASD, it was necessary to create a hierarchy rule for matching. For the purpose of the case-control study we, therefore, adopted age and VIQ, and

then PIQ. Since there were only a few females in the ASD group, we had to eliminate females entirely from the subsequent study.

3. Case-control study

3.1. Methods

This case-control study was intended to directly test the hypothesis that, following the WCC hypothesis, individuals with ASD would have generalized difficulties in integrating the ambiguous visual stimuli into coherent social and physical events. Specifically, we expected them to have lower scores than controls on both the SAT and PAT procedures. Another working hypothesis was suggested by the preliminary data. Given that PAT scores were much lower than SAT scores in the reference group, and that performance on these tasks was comparable in the ASD group, the alternative hypothesis was that there is domain specificity in regards to the spontaneous use of integrative skills (for the ASD group, lower skills in the social domain and higher skills in the physical domain). If corroborated, this trend of results would be inconsistent with the WCC account of autism.

3.1.1. Participants

There were 20 typically developing children, adolescents, and young adults in the typically developing group (TD) (only males) and 34 individuals with autism spectrum disorders (ASDs) (only males) matched on age and verbal IQ (VIQ). The TD group was formed by eliminating females from the original TD sample, and adding 11 younger boys and adolescents (who completed this protocol as part of an unrelated project). The additional participants were recruited from a local public school. The ASD group was formed by removing the two females as well as five males

with the lowest VIQ scores and one male whose age was an outlier in the pilot study. Characterization procedures were the same as described for the pilot study. These data are provided in Table 2.

The TD and the ASD groups consisted, therefore, of children, adolescents, and young adults who were matched on age, FSIQ, VIQ, and PIQ. The ASD group was a high functioning group of males with high levels of social disability and autistic symptomatology. All ASD participants met criteria on the social cluster of the ADI (50% met all criteria for autism) and the ADOS criteria for ASD (88% met all criteria for autism).

3.1.2. Experimental tasks and procedures

All methodological aspects of this study were exactly the same as the ones adopted in the pilot study. In fact, as noted, this study is better conceptualized as the creation of a well-matched case-control sample. This was important in order to make possible a direct comparison between the TD and the ASD groups.

3.2. Results

A repeated measures ANOVA was performed with Group (diagnosis, TD and ASD) by Task (SAT and PAT) set of comparisons. There were significant effects for Group ($F_{1,52} = 4.27$, $p = .043$), and for Task ($F_{1,52} = 5.80$, $p = .019$), and there was a significant interaction of Group by Task ($F_{1,52} = 19.74$, $p = .000$). Follow-up within group comparisons revealed a significant difference for tasks for the TD group ($F_{1,19} = 32.53$, $p = .000$) but not for the ASD group ($F_{1,33} = 2.24$, $p = .143$). These results are illustrated in Fig. 3.

These results indicate that the pattern of performance on the SAT and PAT in the two groups was very different. While between group comparison for the SAT was highly significant, performance on the PAT was not significantly

Table 2
Characterization data on the typically developing (reference) group (TD) and on the group with autism spectrum disorders (ASDs)

	TD	ASD	t	Significance
N	20	34		
Age (years) Mean (*SD*) [Range]	15.4 (5.8) [8–24]	13.0 (5.4) [8–35]	$T_{52} = 1.60$	NS[e]
Full Scale IQ[a] [Range]	109.6 (8.2) [88–124]	104.5 (16.0) [78–141]	$t_{52} = 1.33$	NS[e]
Verbal IQ[a] [Range]	109.1 (9.8) [92–127]	108.7 (16.2) [80–140]	$t_{52} = 0.10$	NS[e]
Performance IQ[a] [Range]	106.9 (8.7) [85–120]	100.1 (16.7) [72–139]	$t_{52} = 1.85$	NS[e]
Vineland Socialization Standard Scores[b] [Range]	—	53.4 (11.9) [32–75]		
ADOS[c] Communication Algorithm Total [Range]	—	4.1 (1.2) [2–7]		
ADOS[c] Social Algorithm Total [Range]	—	9.0 (2.4) [5–14]		
ADOS[c] Both Algorithm Total [Range]	—	13.1 (3.4) [7–21]		
ADOS[c] Meet criteria for autism (% of ASD sample)	—	88%		
ADOS[c] Meet criteria for ASD (% of ASD sample)	—	100%		
ADI[d] Meet criteria for autism (% of ASD sample)	—	50%		

[a] Kaufman Brief Intelligence Test (K-BIT) for TD group and the Wechsler Intelligence Scale for Children—third edition (WISC-III) or the Wechsler Adult Intelligence Scale—third edition (WAIS-III) for the ASD group.
[b] Vineland Adaptive Behavior Scales—Expanded Edition (Vineland).
[c] Autism Diagnostic Observation Schedule, Modules 3 and 4 (ADOS): Communication cut-off for autism is 3 (2 for ASD); Social cut-off for autism is 6 (4 for ASD); for both domains it is 10 for autism (7 for ASD).
[d] Autism Diagnostic Interview (ADI).
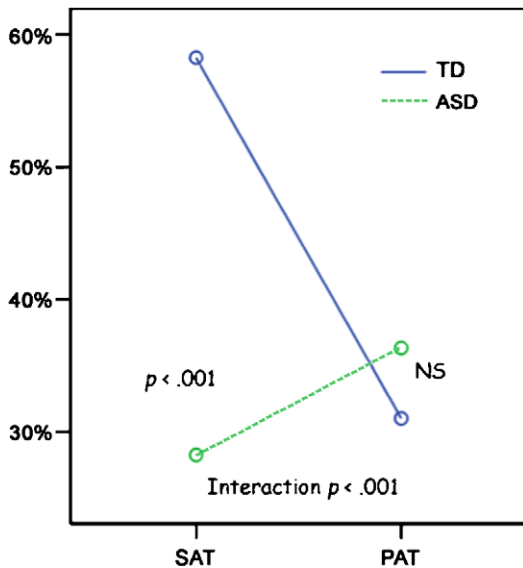[e] Not statistically significant.

Fig. 3. Between and within group comparisons for Group (TD and ASD) and Task (SAT and PAT).

different across the two groups [for the TD group SAT Mean = 58.2% (16.9%) and PAT Mean = 31.0% (28.6%); for the ASD group SAT Mean = 28.2% (18.8%) and PAT Mean = 36.3% (32.4%)]. The significant interaction illustrates this profile best. These results are inconsistent with the WCC prediction that performance on both tasks in the ASD group would be lower than in the TD group. However, the lack of significance in the between group PAT comparison also indicates that the individuals with ASD were not superior on this task relative to the TD group.

What these results do indicate very strongly is that the social vs. physical domains of the procedures mattered the most. This is illustrated in Fig. 4, which provides boxplots for the differences within groups between performance on the SAT and on PAT (i.e., SAT − PAT).
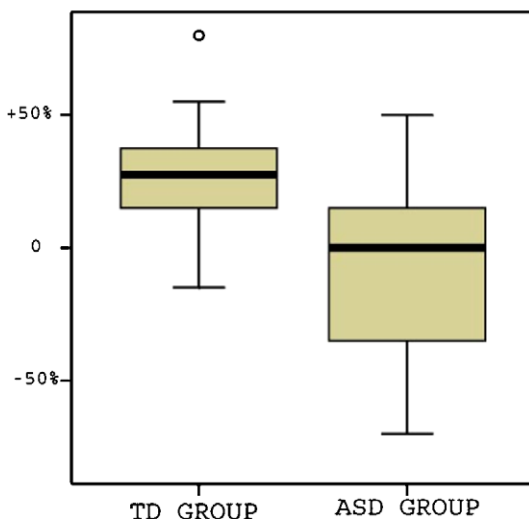

Fig. 4. Boxplot for SAT − PAT for the matched two groups (TD and ASD).

While most of the distribution of SAT − PAT results for the TD group falls in the positive side (i.e., favors the SAT), the opposite was obtained for the ASD group (i.e., favors the PAT). In fact, there is very little overlap between the distributions.

To re-examine the relationship between performance on the SAT and PAT and developmental factors, a new correlational matrix was created using the experimental tasks and age and IQ. As noted, only correlations at the $p < .01$ level are reported here in order to avoid Type I error. For both the TD and the ASD groups, neither the SAT nor the PAT performance was significantly correlated with age or IQ. Of importance, performance on the SAT and PAT was significantly and positively correlated for the TD group ($r = .67$, $p < .01$), suggesting that the lack of association obtained in the pilot study was due to the inclusion of females in the reference sample, for whom there was the greatest dissociation between performance on these two tasks. In contrast, the correlation between SAT and PAT performance for the ASD group was not statistically significant.

3.3. Discussion of the case-control study

Result of the case-control study indicated that the spontaneous ability to attribute meaning to ambiguous visual displays portraying social and physical events are significantly different in males with higher-functioning ASD relative to age and IQ-matched controls. Consistent with previous results, the ASD group has significant deficits in making social attributions but is at least as competent as controls in making physical attributions. The choice of matching the samples on VIQ (because of the need to generate spontaneous narratives) rather than on PIQ made the TD vs. ASD comparison even more conservative since PIQ was somewhat lower in the ASD group relative to the TD group. The fact that the two groups showed different abilities in creating meaningful context of the ambiguous animations in the social vs. physical domain was highlighted by the highly significant Group (TD and ASD) by Task (SAT and PAT) interaction. This pattern of results was also illustrated by the fact that there was very little overlap in the distribution of scores in the two groups resulting from the subtraction SAT − PAT. Thus, the hypothesis derived from the WCC account of autism that predicted generalized deficits in integrative thinking regardless of attribution domain was not supported. Instead, the deficits were confined to the social domain only. The fact that both of these tasks involved spontaneous use of cognitive style (i.e., a predisposition to interpret ambiguous visual displays in a particular way as measured through spontaneous narratives and without any form of explicit instruction) adds credence to these results (Happé, 2005; Klin et al., 2002a).

In several ASD cases, the contrast between the inability to interpret Heider and Simmel's (1944) classic animation as a social plot and the sophisticated ability to reconstruct

the PAT as a physical event was extreme. The following is the beginning of the SAT and PAT narratives provided by a 35-year-old man with autism:

SAT narrative: "*Starts when a small equilateral triangle breaks out of a square. A small sphere or circle appears and slides down the broken rectangle. The triangles were either equilateral or isosceles. Later the small, I think, isosceles triangle and sphere bounce around each other, maybe because of a magnetic field …*"

PAT narrative: "*The rocket is being launched and is in preliminary orbit around the earth, winding around the moon at the appropriate distance so that the satellite can be released. The satellite was launched from the rocket, and it actually landed on the moon. The satellite was actually more like a lunar module …*"

4. Overall discussion

The fact that the results of this study did not support the WCC account of autism in its more sweeping implication, namely that deficits in integrative skills apply to all domains of learning and functioning, does not invalidate this extremely heuristic hypothesis. The strong face validity and accumulating empirical evidence suggesting that individuals with autism experience fragmentation in perceptual, cognitive, language, and social adaptation are very strong (Happé, 2005). And yet, the domain specificity revealed in the data reported in this study does beg the need for additional studies examining the predictions of this theoretical framework.

Of importance in this context is the need for increased attention to its developmental aspects. As recently noted by Happé (2005), predominance of global (vs. localized) processing appears to be present from infancy (e.g., Bhatt, Rovee-Collier, & Shyi, 1994; Freedland & Dannemiller, 1996). Indeed, one may search for evidence of integrative skills in basic perceptual phenomena, such as "binding," by which the brain brings together separately coded stimulus features to form unitary representations of objects. Evidence for binding phenomena as indexed by 40-Hz (gamma-band) oscillations have already been reported in infants as young as 8 months of age (Csibra, Davis, Spratling, & Johnson, 2000), and preliminary disruptions of this system in developmental disabilities (autism and Williams syndrome) have already been documented (e.g., Grice et al., 2001). Whether the "binding" phenomena applies in multiple domains (Lachaux et al., 2000) and whether disruption of this system could have any syndrome specificity (Haig et al., 2000) are still unanswered questions. But these are important lines of future research.

Of equal importance is an elucidation of the relationships between integrative skills and the development of sociability. The present study highlighted the need to consider the WCC hypothesis in multiple (e.g., social vs. physical) domains in order to examine the extent to which the general cognitive predictions apply regardless of the domain being studied. This is critical as evidence continues to accumulate as to the centrality of the social domain in autism (Insel & Fernald, 2004). Clearly, social adaptation is an extremely conserved reaction to the environment that does not require integrative processes to exist. For example, affiliative behavior can be triggered by extremely specific stimuli in many non-primate species (Insel & Young, 2001). The WCC hypothesis makes a cogent argument for the need for integrative skills for social cognitive understanding to emerge and serve social adaptation. But given the early onset of autism (e.g., Klin et al., 2004), and the extremely early onset of critical social responses such as the detection of and acting upon another person's eye contact (Farroni, Csibra, Simion, & Johnson, 2002; Farroni, Mansfield, Lai, & Johnson, 2003) which can be highly disrupted in autism (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b), the radical consideration that integrative skills might in fact not *lead to* but *result from* meaningful social experiences cannot be seen as too outlandish. If cognition trails experiences as described in the neuroscience framework called embodied cognition (e.g., Klin et al., 2003), a powerful force requiring the need for integrating multiple sources of information into holistic meanings might be social approaches (e.g., the repeated demanding contact made by caregivers). When the infant learns to seek the meaning of a new (and potentially threatening stimulus) by looking at the caregiver's reactions for clues (as in social referencing; Campos & Sternberg, 1981), this relationship between social adaptation and integrative processing (e.g., new stimulus, facial gestures, bodily gestures, voice inflection, among other elements) certainly appears to be at play. Of course, this speculation suffers from the converse limitation that we were able to identify in the WCC, namely it fails to account for the emergence of integrative skills in autism (at least in some domains such as the physical one) despite lifelong social disabilities. While we can consider the possibility of compensatory forms of learning in either theoretical scenario (e.g., acquisition of integrative skills/social skills in the physical/social domain by means other than the ones postulated in typical development), the question remains as to the primacy and causative direction of these two constructs (coherence skills and social adaptation). In many ways, the currently underway prospective work on infant siblings of children with autism (Volkmar et al., 2004) will likely elucidate some of these questions.

The relative preservation of physical attribution skills in autism demonstrated in this report relative to deficits in social attribution skills support renewed consideration of the social vs. physical duality in stimulus processing and reasoning in autism (Baron-Cohen, 2002; Klin et al., 2003). In this study, the dichotomy between social and physical thinking was clear, once again demonstrating the pervasive effects of the social features in autism, which over 60 years since Kanner's (1943) original hypothesis of "disturbances of affective contact," remain one of the strongest, if still ill-defined, candidate phenotypes in this syndrome.

Acknowledgments

Appendix A. Scoring criteria for the Social Attribution Task and the Physical Attribution Task

A.1. Social Attribution Task

As described in detail in Klin (2000) (www.autism.fm/sat), the SAT consists of a presentation of Heider and Simmel's (1944) classic animation and modifications thereof in order to obtain spontaneous narratives describing the ambiguous visual displays. The narratives are scored according to six indices of social attribution. Only the Salience Index was utilized in this study. Based on Heider and Simmel's (1944) work and our own (Klin, 2000), a number of salient items of social attribution made to the animation are typically included in SAT narratives. Twenty high-frequency attribution were previously identified in adult narratives. The Salience Index is calculated in terms of the percentage of such attributions included in the participant's narrative. The index is meant to capture the extent to which typical invariances in SAT attributions are detected by a given participant. There is no need for explicit use of the words describing a given element of the story; the item is scored as present or absent in terms of whether or not the idea is represented, explicitly or implicitly, in the participant's narrative. The 20 items are:

(01) Rectangle is human enclosure.
(02) Recognition of three actors (rectangle not an actor, three agents throughout).
(03) Little triangle and circle are together (may be implicit).
(04) The big triangle and the small triangle fight.
(05) Indication of the direction of hostility: The big triangle is the aggressor, the little triangle is resistant.
(06) The little triangle is overwhelmed by the big triangle (e.g., the big triangle wins, the big triangle scares off the little triangle).
(07) The little circle tries to avoid conflict (e.g., hides, cowers, seeks protection).
(08) The big triangle searches for the little circle (e.g., entraps, tries to catch).
(09) The little circle panics (e.g., is afraid, scared, terrified).
(10) Indication that the little triangle comes to the little circle's aid (e.g., save, rescue, help).
(11) The little circle escapes the big triangle (e.g., evades, flees, gets away from).
(12) The big triangle is trapped inside the enclosure.
(13) The little circle and the little triangle celebrate (e.g., are happy, dance, rejoice).
(14) Proposition explaining the reason for celebration (e.g., escaped from the big triangle, are free).
(15) Indication that the big triangle chases the little triangle and the little circle (e.g., goes after, pursues them).
(16) Indication that the big triangle momentarily does not know where the little triangle and circle are (as a result of the big triangle's momentary search of the two other shapes inside the rectangle).
(17) The little triangle and the little circle are successful at evading the big triangle (e.g., they escape, ran away).
(18) The big triangle is frustrated (e.g., mad, angry).
(19) Proposition of explanation for the big triangle's anger (e.g., because he failed to catch them).
(20) The big triangle breaks the enclosure.

Scoring: Number of elements of the story included in the participant's narration divided by 20 and multiplied by 100 to obtain percentage score.

A.2. Physical Attribution Task

The PAT is a novel task involving the presentation of a video animation consisting of geometric shapes that display a sequence of physical events, namely the launching of a rocket from the earth to a moon and its return to earth. Twenty-two high-frequency attributions of physical meaning were revealed in pilot work with typically developing adults. The scoring of this task was modeled after the scoring of the Salience Index of the SAT. The PAT score is meant to capture the extent to which typical invariances in PAT attributions are detected by a given participant. As with the SAT, there is no need for explicit use of the words describing a given element of the story; the item is scored as present or absent in terms of whether or not the idea is represented, explicitly or implicitly, in the participant's narratives. Some of the items require that another, typically simpler attribution has also been made or has been implied in order for credit to be given. Items required such prerequisites list the items that should be positive for it to be credited. The narratives are more easily scored with the use of Fig. 5, which defines and gives abbreviations to the various geometric shapes and combinations thereof that are typically included in participants' narratives.

1. The event depicted in the cartoon takes place in outer space. [Even if "outer space" was not used, but was implied by references to celestial bodies.]
2. **BC** is a planet, star, moon, Earth, or other celestial body.
3. **SC** is the Moon, a moon, planet, star, or other celestial body.
4. **R + T + VSC** is a spaceship, or other space-cruising machine (e.g., space probe).
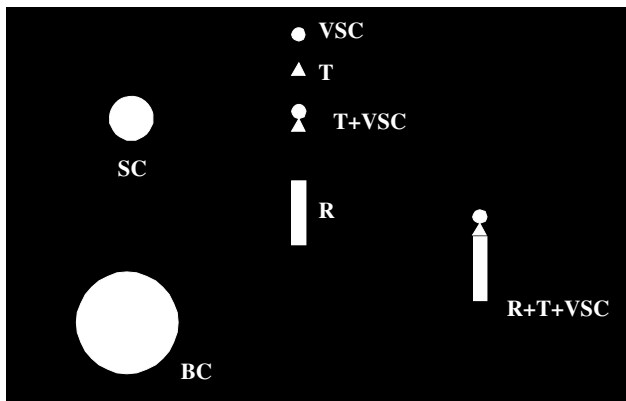5. **R** is a booster to the spaceship mentioned in # 4.

Fig. 5. Geometric forms and combinations thereof needed for coding of narratives in the PAT. BC, Big circle; SC, small circle; VSC, very small circle; T, triangle; R, rectangle; T + VSC, triangle + very small circle; T + VSC + R, triangle + very small circle + rectangle.

6. **T + VSC** is a "lunar module," space probe, or other manned or unmanned spaceship with clear reference that **R** was its booster.

7. **VSC** is a "space capsule," or some description to say that this was "were the astronauts or men were," or the "probe that really collected the material," etc., acknowledging implicitly or explicitly that this was the only part of the original spaceship (**R + T + VSC**) that came back to the original planet. [Some attribution that gives the VSC a space-like identity separate from the **T + VSC + R** combination (e.g., people there, capsule). Not simply a geometric description.]

8. **T** was a booster to the capsule or an equivalent attribute mentioned in # 7.

9. **BC** rotates around its own axis or "rotates" only, BUT # 2 HAS TO DO BE +.

10. **SC** has an orbit [word "orbit" or some equivalent].

11. A rocket, or other kind of spaceship or space probe is launched from the **BC**. ["launched," "took off," "blasted off," or "shoots off," or some equivalent term to a rocket being launched. "Fell off," "dove off," or "detached" are not given credit.]

12. The rocket or spaceship "orbits" (or similar term) the earth or planet (**BC**), BUT # 4 HAS TO DO BE +.

13. The rocket's or spaceship's booster detaches, BUT # 5 HAS TO DO BE +.

14. The rocket's or spaceship's booster disappears into space following a trajectory that is influenced by the gravity field of the big celestial body (Earth or planet) associated with the **BC**. [This trajectory has to be described as a physical event, not simply geometric (e.g., "disappears off screen").]

15. The "lunar module" or equivalent attribute given to **T + VSC** follows a trajectory towards the Moon, or equivalent attribute given to the **SC**. [Unless "trajectory" has clear outer space meaning, a purely geometric account of "trajectory" would be scored + ONLY IF # 16 IS +.]

16. The "lunar module" or equivalent attribute given to **T + VSC** lands on the Moon, or equivalent attribute given to the **SC**. ["lands" or "touches down," or a similar description implying that a spacecraft is getting to a large celestial body.]

17. The "lunar module" or equivalent attribute given to **T + VSC** completes one full orbit of the Moon, or equivalent attribute given to the **SC**. [If something other than the word "orbit" is used, THEN # 3 HAS TO BE + OR # 6 HAS TO BE +.]

18. The "lunar module" or equivalent attribute given to **T + VSC** leaves the Moon, or equivalent attribute given to the **SC**, back to Earth, or equivalent attribute given to the **BC** ["launched," "took off," "blasted off," or "shoots off," or some equivalent term to a rocket being launched. "Fell off," "dove off," or "detached" are not given credit].

19. The "lunar module" or equivalent attribute given to **T + VSC** enters the orbit of Earth, or equivalent attribute given to the **BC**. [If something other than "orbit' is used, e.g., goes around, THEN # 2 HAS TO BE + .]

20. The booster (**T**) of the "lunar module" or equivalent attribute given to **T + VSC** detaches from the capsule, or equivalent attribute given to the **VSC**. [ITEM # 8 HAS TO BE + .]

21. The booster (**T**) of the "lunar module" or equivalent attribute given to **T + VSC** disappears in a trajectory influenced by the gravity of Earth, or equivalent attribute given to the **BC**. [This trajectory has to be described as a physical event, not simply geometric (e.g., "disappears off screen").]

22. The "capsule" or equivalent attribute given to the **VSC** lands on Earth, or equivalent attribute given to the **BC**. ["lands" or "touches down," or a similar description implying that a spacecraft is getting to a large celestial body.]

Scoring: Number of elements of the story included in the participant's narration divided by 22 and multiplied by 100 to obtain percentage score.

References

Abell, F., Happé, F., & Frith, U. (2000). Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. *Journal of Cognitive Development, 15*, 1–20.

Baron-Cohen, S. (1994). How to build a baby that can read minds: Cognitive mechanisms in mindreading. *Cahiers de Psychologie Cognitive, 13*(5), 513–552.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind.* Cambridge, MA: MIT Press.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences, 6*, 248–254.

Bhatt, R. S., Rovee-Collier, C., & Shyi, G. C. W. (1994). Global and local processing of incidental information and memory retrieval at 6 months. *Journal of Experimental Child Psychology, 57*, 141–162.

Bowler, D. M. (1992). "Theory of Mind" in Asperger's syndrome. *Journal of Child Psychology and Psychiatry, 33*(5), 877–893.

Bowler, D., & Thommen, E. (2000). Attribution of mechanical and social causality to animated displays by children with autism. *Autism, 4*(2), 147–171.

Campos, J. J., & Sternberg, C. R. (1981). Perception, appraisal, and emotions: The onset of social referencing. In M. E. Lamb & L. R. Sherrod (Eds.), *Infant social cognition*. Hillsdale, NJ: Erlbaum.

Cicchetti, D. V., & Sparrow, S. S. (1981). Development of criteria for establishing the interrater reliability of specific items in a given inventory: Applications to assessment of adaptive behavior. *American Journal of Mental Deficiency, 86*, 127–137.

Courchesne, E., Carper, R., & Akshoomoff, N. (2003). Evidence of brain overgrowth in the first year of life in autism. *Journal of the American Medical Association, 290*, 337–344.

Courchesne, E., Redcay, E., & Kennedy, D. P. (2004). The autistic brain: Brain through adulthood. *Current Opinion in Neurology, 17*(4), 489–496.

Csibra, G., Davis, G., Spratling, M., & Johnson, M. (2000). Gamma oscillations and object processing in the infant. *Science, 290*(5496), 1582–1585.

Dahlgren, S. O., & Trillingsgaard, A. (1996). Theory of mind in nonretarded children with autism and Asperger's syndrome. A research note. *Journal of Child Psychology and Psychiatry, 37*, 759–763.

Dawson, G., Webb, S., Schellenberg, G., Dager, S., Friedman, S., Alyward, E., et al. (2002). Defining the broader phenotype of autism: Genetic, brain, and behavioral perspectives. *Development and Psychopathology, 14*(3), 581–611.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America, 99*, 9602–9605.

Farroni, T., Mansfield, E. M., Lai, C., & Johnson, M. H. (2003). Motion and mutual gaze in directing infants' spatial attention. *Journal of Experimental Child Psychology, 85*, 199–212.

Freedland, R. L., & Dannemiller, J. L. (1996). Nonlinear pattern vision processes in early infancy. *Infant Behavior and Development, 19*, 21–32.

Frith, U. (1989). *Autism: Explaining the enigma*. London: Blackwell.

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

Frith, U., & Happe, F. (1999). Theory of mind and self-consciousness: What is it like to be autistic? *Mind and Language, 14*, 1–22.

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

Grice, S., Spratling, M., Karmiloff-Smith, A., Halit, H., Csibra, G., de Haan, M., et al. (2001). Disordered visual processing and oscillatory brain activity in autism and Williams syndrome. *Neuroreport, 12*, 2697–2700.

Haig, A. R., Gordon, E., De Pascalis, V., Meares, R. A., Bahramali, H., & Harris, A. (2000). Gamma activity in schizophrenia: Evidence of impaired network binding? *Clinical Neurophysiology, 111*, 1461–1468.

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

Happé, F. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Sciences, 3*, 216–222.

Happé, F. (2005). The weak central coherence account of autism. In F. R. Volkmar, A. Klin, R. Paul, & D. J. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders* (pp. 640–649). New York: Wiley.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *The American Journal of Psychology, 57*(2), 243–259.

Hermelin, B. (2001). *Bright splinters of the mind: A personal story of research with autistic savants*. Philadelphia: Jessica Kingsley Publishers.

Hermelin, B., & O'Connor, N. (1967). Remembering of words by psychotic and subnormal children. *British Journal of Psychology, 58*, 213–218.

Insel, T. R., & Fernald, R. D. (2004). How the brain processes social information: Searching for the social brain. *Annual Review of Neuroscience, 27*, 697–722.

Insel, T. R., & Young, L. J. (2001). The neurobiology of attachment. *Nature Reviews Neuroscience, 2*, 129–136.

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal on the Embedded Figures Test? *Journal of Child Psychology and Psychiatry, 38*, 527–534.

Jolliffe, T., & Baron-Cohen, S. (1999). A test of central coherence theory; linguistic processing in high-functioning adults with autism or Asperger's syndrome: Is local coherence impaired? *Cognition, 71*, 149–185.

Just, M. A., Cherkassky, V. L., Keller, T. A., & Minshew, N. J. (2004). Cortical activation and synchronization during sentence comprehension in high-functioning autism: Evidence of underconnectivity. *Brain, 127*, 1811–1821.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child, 2*, 217–250.

Kaufman, A. S., & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test manual*. Circle Pines, MN: American Guidance Service.

Klin, A. (2000). Attributing social meaning to ambiguous visual stimuli in higher functioning autism and Asperger syndrome: The Social Attribution Task. *Journal of Child Psychology and Psychiatry, 41*, 831–846.

Klin, A., Chawarska, K., Paul, R., Rubin, E., Morgan, T., Wiesner, L., et al. (2004). Autism in a 15-month-old child. *American Journal of Psychiatry, 161*(11), 1981–1988.

Klin, A., Jones, W., Schultz, R. T., & Volkmar, F. R. (2003). The Enactive Mind—from actions to cognition: Lessons from autism. *Philosophical Transactions of the Royal Society, Biological Sciences, 358*, 345–360.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002a). Defining and quantifying the social phenotype in autism. *American Journal of Psychiatry, 159*(6), 895–908.

Klin, A., Jones, W., Schultz, R., Volkmar, F. R., & Cohen, D. J. (2002b). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry, 59*(9), 809–816.

Lord, C., Rutter, M., & DiLavore, P. (1996). *Autism Diagnostic Observation Schedule-Generic (ADOS-G)*. Unpublished MS. University of Chicago.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnosis Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*, 659–685.

Lachaux, J.-P., Rodrigues, E., Martinerie, J., Adam, C., Hasboun, D., & Varela, F. J. (2000). A quantitative study of gamma-band activity in human intracranial recordings triggered by visual stimuli. *European Journal of Neuroscience, 12*, 2608–2622.

Michotte, A. (1963). *The perception of causality*. New York: Basic Books [translated].

Mottron, L., & Belleville, S. (1993). A study of perceptual analysis in a high-level autistic subject with exceptional graphic abilities. *Brain and Cognition, 23*, 279–309.

Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In J. A. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.), *The development of autism: Perspectives from theory and research* (pp. 131–148). New Jersey: Erlbaum.

Mottron, L., Burack, J. A., Stauder, J. E. A., & Robaey, P. (1999). Perceptual processing among high-functioning persons with autism. *Journal of Child Psychology and Psychiatry, 40*, 203–211.

Ozonoff, S., Strayer, D. L., McMahon, W. M., & Filloux, F. (1994). Executive function abilities in autism and Tourette syndrome: An information processing approach. *Journal of Child Psychology and Psychiatry, 35*, 1015–1032.

Plaisted, K. C. (2001). Reduced generalization in autism: An alternative to weak central coherence. In J. A. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.), *The development of autism: Perspectives from theory and research* (pp. 149–169). New Jersey: Erlbaum.

Plaisted, K., Saksida, L., Alcantara, J., & Weisblatt, E. (2003). Towards an understanding of the mechanisms of weak central coherence effects: Experiments in visual configural learning and auditory perception. *Philosophical Transactions of the Royal Society, Biological Sciences, 358*(1430), 375–386.

Scheerer, M., Rothmann, E., & Goldstein, K. (1945). A case of "idiot savant": An experimental study of personality organization. *Psychological Monographs, 58*(4).

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24*, 613–620.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the Block Design task? *Journal of Child Psychology and Psychiatry, 34*, 1351–1364.

Snowling, M., & Frith, U. (1986). Comprehension in 'hyperlexic' readers. *Journal of Experimental Child Psychology, 42*, 392–415.

Sparrow, S., Balla, D., & Cicchetti, D. (1984). *Vineland Adaptive Behavior Scales* (expanded ed.). Circle Pines, MN: American Guidance Service.

Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence for a cognitive deficit. *British Journal of Developmental Psychology, 9*, 417–430.

Tager-Flusberg, H., & Sullivan, K. (1994). A second look at second-order belief attribution in autism. *Journal of Autism and Developmental Disorders, 24*(5), 577–586.

Volkmar, F., Lord, C., Bailey, A., Schultz, R., & Klin, A. (2004). Autism and pervasive developmental disorders. *Journal of Child Psychology and Psychiatry, 45*(1), 135–170.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children* (3rd ed.). San Antonio, TX: Psychological Corporation.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale*. San Antonio, TX: Psychological Corporation.