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SAGE Publications
and The National
Autistic Society,
Vol 4(2) 147–171;012565
1362-3613(200006)4:2

Attribution of mechanical and social causality to animated displays by children with autism

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ABSTRACT Two studies are reported that compare the descriptions given by children with and without autism of animated stimuli depicting mechanical launching effects, intentional reactions or sequences of mechanical and intentional reactions. Children were matched on chronological age, verbal mental age and IQ. The children with autism were as able as the control groups at differentiating mechanical launches from intentional reactions. Moreover, their descriptions of the longer action sequence were significantly different neither in length nor in their use of mental state language from those of the controls. However, finer-grained analyses of the accounts showed that the children with autism involved themselves more in the narrative than did control children. They also made less reference to episodes showing actions between animate objects, especially when the objects were not in contact. The implications of these findings for theories of autistic social dysfunction are discussed.

KEYWORDS *animation; autism; causality*

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Introduction

Recent research into the syndrome of autism has centred on attempts to explain the social and affective impairments that are characteristic of this condition. Foremost among these psychological accounts are those of Leslie (1987; 1994a; 1994b) and Baron-Cohen (1995). Leslie's position, which may be referred to as the 'theory of mind deficit' account, proposes that individuals with autism lack a cognitive module that enables them to understand mental states in others. This hinges crucially on the child's possession of a 'theory of mind mechanism' (ToMM), which develops during the second year of life and mediates an understanding of the attitudes of agents to objects. It is this ability to understand objects in terms of their 'agent-centredness' that is central to the development of symbolic play and, in turn, to the understanding of mental states in others.

In parallel with Leslie, Baron-Cohen (1995) developed an account of the development of 'theory of mind' in which he argued for a developmental unfolding of modular systems that are sensitive to the detection of intentions (intention detector, ID), eye direction (eye direction detector, EDD) and shared attention (shared attention mechanism, SAM). He argues that EDD is impaired in autism and this in turn affects the development of shared attention.

Both Leslie's and Baron-Cohen's positions were reinforced by evidence that children with autism have impairments in symbolic play (see Jarrold et al., 1993 for review) and by Baron-Cohen et al.'s (1985) seminal study using the Sally–Anne task, first developed by Wimmer and Perner (1983) with children with autism. However, although this study has been replicated a number of times, the results are not always consistent (see Happé, 1995 for review). For example, the success rate has varied between 15 and 55 percent in child samples and may be as high as 100 percent in studies of higher-functioning or older individuals with autism (Baron-Cohen, 1989). Bowler (1992) also found that adults with Asperger syndrome performed at a similar level to non-clinical controls on second-order false belief tasks (John thinks that Mary thinks that . . .).

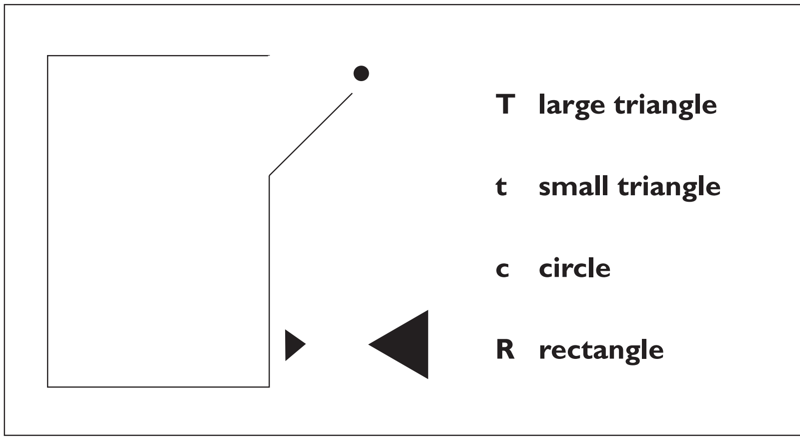
Findings such as these raise a number of issues. First, they show that the 'theory of mind deficit' account of autism may not be as straightforward as is sometimes claimed. Second, the mismatch between task performance and actual social behaviour requires reassessment of the paradigms typically used in research and the conclusions that can legitimately be drawn from the findings. For example, 'theory of mind' tasks are usually conducted in highly structured experimental settings and have a rather 'offline' nature which contrasts with the very 'online' nature of spontaneous social interactions. Although there is some evidence that performance on such tasks correlates with measures of everyday social functioning (Frith et al., 1994), it is not uncommon for individuals who show marked signs of autistic social impairment to perform relatively well in more structured test settings (e.g. McDonough et al., 1997).

More recently, Leslie (1994a) has attempted to refine his analysis of the developing child's understanding of agents by positing three independent systems. The first of these, ToBY, interprets agents in terms of their being capable of autonomous movement; the second, ToMM1, interprets the goal-directedness of agents; and the third, ToMM2, enables the child to understand agents in terms of attitudes or mental states – hypothetical, unobservable entities that nevertheless direct the actions of an agent.

Although the 'theory of mind deficit' account proposes that people with autism would be impaired on ToMM2, to date Leslie has not made specific predictions about which of the other two mechanisms might be impaired in this population.

Leslie's (1994a) theory remains largely untested in the context of autism, although there are some relevant studies of typically developing children and adults. There is now considerable experimental evidence that infants as young as 6–12 months of age can differentiate causal from non-causal events (Leslie and Keeble, 1987; Oakes and Cohen, 1990) and that 3-month-old infants can discriminate point-light displays of the human figure engaged in typical human locomotion from random but equally complex relative motions of the lights in the displays (Bertenthal et al., 1987). Gergely et al. (1995) and Gergely (1996) also found that 9-month-old but not 6-month-old infants were able to distinguish goal-directed actions of agents that followed rational principles of goal-directedness from those that did not. In a review of the literature, Legerstee (1992) concludes that there is also evidence that infants as young as 2 months can distinguish motions that differentiate animate from inanimate objects. However, Poulin-Dubois and Shultz (1990) did not find any evidence of discrimination of movements characteristic of social and non-social agents until 14 months of age. The ability of 1-year-old infants to recognize the goal-directed nature of the behaviour of self-propelled circles in a computer-generated display was demonstrated by Premack and Premack (1997). Similarly Rochat et al. (1997) found that 3-month-old infants could distinguish patterns of movements of two disks that were either dependent and seen by adults as a chase, or random and not seen as pursuits by adults. Rochat et al. argue that since this sensitivity emerges some time before the emergence of joint attention behaviours and communicative gestures, it may be a prerequisite for the emergence of such abilities. In the present context, the well-documented deficits in joint attention and communication in people with autism would lead us to predict that such individuals would be impaired in their differentiation of physical and social causality.

The film of animated geometric shapes developed by Heider and Simmel (1944) provides a way of exploring the basic determinants of social understanding in autism that helps to address some of the points just raised. This is a film in which two triangles and a circle execute a series of movements in relation to each other and to a rectangle. The triangles and circle are capable of independent movement, whereas the rectangle moves only when acted upon. (Figure 1 summarizes the main episodes contained in the film.) In an early study by Heider and Simmel (1944), all but one of the sample of 34 female undergraduate participants asked to describe the film used notions of intent, but Baron-Cohen (1995) speculated that



1 T moves towards the box, opens door, moves into house and closes door.
2 t and c appear and move around near the door.
3 T moves out of the box towards t.
4 T and t fight, T wins: during the fight c moves into the box.
5 T moves into the box and shuts the door.
6 T chases c within the house: t moves along to outside the box towards the door.
7 t opens the door and c moves out of the box and t and c close the door.
8 T seems to try to get out of the box but does not succeed in opening the door: t and c move in circles around the outside of the box and touch each other several times.
9 t opens the door and comes out of the box.
10 T chases t and c twice around the box.
11 t and c leave the field.
12 T hits the sides of the box several times: the sides break.

Figure 1 **Episodes in Heider and Simmel film**

people with autism would make less use of mental state or intentional language when describing it.

The content of the film contains a number of elements that relate both to Leslie's theoretical position and to the perceptual attributes of agents as described by other researchers (Mandler, 1992; Leslie, 1994a). The film depicts the movements of self-propelled and non-self-propelled objects (agents and non-agents), with the former capable of moving in irregular trajectories, of acting both on each other and on the non-agent, and of acting on and reacting to other entities at a distance. On the basis of this analysis, it can be argued that an important perceptual differentiation for the understanding of agents is that between self-propelled and non-self-propelled objects. The former are associated with intentional action and have been simulated by Dasser et al. (1989) and Kanizsa and Vicario (1969). Non-self-propelled objects are associated with physical causality and have been simulated by Michotte (1963).

The perception of causal interaction has also been studied in typically developing children by Olum (1958) and by Piaget and Lambercier (1958). Six- to eight-year-old children were compared with adults and found to differ in two ways; they produced less uniform descriptions and they attributed causal relations only when they described contact between figures (whether or not such contact had actually taken place). Research by Thommen (1991; 1992; Thommen et al., 1998) on the perception and attribution of intentionality, using Heider and Simmel's film as well as stimuli like those of Michotte and of Kanizsa and Vicario, has shown that children build up progressively more complex theories well past the age of 7 years. The ability verbally to describe even very simple situations calls upon complex reasoning abilities and the structure of children's descriptions provides clues to how they understand those events.

In the light of pre-existing studies on the perception of intentional and physical causality, we developed experiment 1, in which we asked children with and without autism to describe stimuli based on those devised by Michotte and by Kanizsa and Vicario. The stimuli are illustrated schematically in Figure 2.

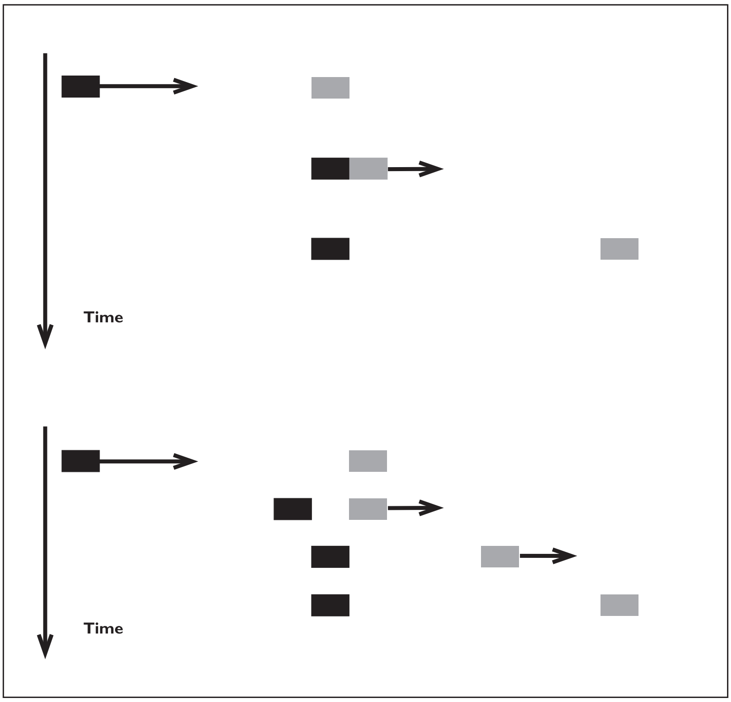


Figure 2 **Launching and reaction effects used in experiment 1**

Table 1 Chronological and mental ages in months of children who participated in experiment 1 (for the CA and VMA controls, mental age taken to be equivalent to chronological age)

	With autism (N = 10)	*CA matches* (N = 10)	*VMA matches* (N = 10)
CA (months)			
Mean	125.5	124.0	90.9
(SD)	(41.9)	(34.4)	(26.3)
Range	86–187	85–183	63–132
VMA (months)			
Mean	90.3		
(SD)	(26.2)		
Range	63–132		

Experiment 1

Participants

Three groups of 10 children were involved in this study: one group with autism selected according to DSM-III-R criteria and two groups of typically developing children whose chronological ages (CAs) were matched individually with either the CAs of the children with autism or with their verbal mental age (VMA) as measured by the Test for the Reception of Grammar (TROG: Bishop, 1982). Details of the three groups of children are set out in Table 1.

Stimuli

Children were seated approximately 60 cm from a 20 × 27 cm computer monitor and shown a sequence of 12 computer-generated films showing either launching or reaction effects (see Figure 2). In launching films, the black square (1 cm × 1 cm) was on the left of the screen and the grey square was 10 cm to the right, in the middle of the screen. The black square started to move towards the grey at a speed of 4 to 36 cm s^{-1} depending on the film and stopped the moment it touched it. The grey square then moved immediately in the same direction for a distance of 10 cm and stopped on the right of the screen. The grey square moved either three or nine times more slowly than did the black square.

In reaction films, the squares did not touch and the speed ratio was the reverse of that in the first film, with the grey square moving either three or nine times faster than the black square. The initial display was the same as in the first film but the grey square started moving when the black one was still 1 cm away from it. The black square continued moving until it was 5 mm from the grey square's initial position, while the grey travelled for a distance of 10 cm as in the launching film. Each film lasted only 1 to 2 seconds.

Procedure

After seeing four warm-up films, each child was shown eight test films: four launches and four reactions presented in a different order for each child. Children were asked to watch the screen and to tell the experimenter what they saw happening on the screen after each film was presented. Their responses were tape recorded and transcribed later for analysis.

Analysis of children's descriptions

The analysis of children's accounts was developed by Thommen and colleagues (1995; 1998) and determines whether or not the subjects give descriptions that are specific to launching or reaction films. (The same analysis was used for both of experiments 1 and 2.) The following example (excerpt from the protocol from a child with autism) shows that the child gave a differentiation criterion for reaction by mentioning a chase between the figures.

Launching	the grey square moved
Reaction	the black square chased the grey square
	the grey square ran . . .
Reaction	and the grey square went to the side
	because the black square was chasing it
Launching	the grey square moved
	to the black square
	and moved to the side

A differentiation criterion is an accurate and specific description, applied to one type of film and to that type only. For example, if the subject correctly described one or more launchings by mentioning a contact between the two figures, this description was taken as a differentiation criterion for launchings. But if, in addition, the subject mentioned a contact in a reaction film, contact was no longer considered as a differentiation criterion for launchings.

The results are based on the number of children who gave at least one specific description to differentiate launching and reaction films. This is a generous measure, but if a child is able to master a particular type of description that s/he uses only for one type of film, we can say that s/he can tell the two kinds of stimuli apart.

Results

Seven children with autism, eight CA controls and seven VMA controls used at least one criterion to differentiate between launching and reaction films, suggesting that the children with autism were as able as the controls at differentiating self-propelled from non-self-propelled motion. A quantitative score based on the subtlety of differentiation of the film (as in the original analysis: Thommen et al., 1998) was also calculated, but again no significant group differences were found. According to Leslie (1994a), these children would appear to have an intact ToBY, in that they understand the fact that agents are capable of self-propelled motion. Overall, this finding shows that the children with autism are not impaired in their production of descriptions that mirror differentiation between mechanical and intentional causality

Experiment 2

To explore understanding of longer sequences of events involving movements that simulate those of animate and inanimate objects, we presented children with the animated film developed by Heider and Simmel (1944) (see Figure 1). The aim was to compare the responses of children with autism with those of typically developing children matched on chronological age, verbal mental age and IQ. We made no specific predictions, although both Leslie's and Baron-Cohen's theoretical positions would hypothesize that the descriptions of the children with autism would show less differentiation between animate and inanimate objects and show less evidence of mental state language.

Experiment 2 also involved the production of a narrative account of events. Existing studies of narrative or story production in children with autism have concentrated either on the production of spontaneous narratives (Baltaxe and Simmonds, 1977), or on the reproduction of narratives provided by the experimenter, often using dynamic stimuli such as puppets (Loveland et al., 1990), or on the production of stories in response to static stimuli (Baron-Cohen et al., 1986; Tager-Flusberg, 1995). However, the use of data from spontaneous narratives gives rise to problems since any deficits found may be a result of motivational factors. Methods that assess the re-presentation of experimenter-provided stories are as much tests of memory as of narrative ability, and studies using static stimuli lack the perceptual information that could cue the child to focus on the operation of agents in the story. The present experiment overcomes these difficulties by asking children to describe a series of ongoing events that are almost invariably described by non-autistic individuals in terms of social interactions (Heider and Simmel, 1944).

Participants

Four groups of 11 children took part in this study: one group of children with autism selected according to DSM-III-R criteria and three groups of typically developing children. The CAs of the first two groups were individually matched with either the CAs (CA controls) or the VMAs (MA controls) of the children with autism as measured by the TROG. Children from the third control group (IQ controls) were individually matched with the children with autism on CA and VMA. Details are set out in Table 2.

Procedure

Children were seated in front of a computer monitor, as in experiment 1, and told that they were going to watch a very short (90 second) animated cartoon film. They were asked to watch it once in silence and then once again, during which they had to describe what they saw on the screen as it was happening. Their utterances were tape recorded for later transcription.

Qualitative analysis

Each child's set of descriptions was first divided into propositions, consisting of a subject and a verb, with predicates being included when uttered. A qualitative analysis of these propositions was then conducted according to a step-by-step method developed by Thommen (1992) (summarized in Appendix 1). This analysis generated the typology of propositions set out

Table 2 **Chronological and mental ages in months of children who participated in experiment 2 (for the CA and VMA controls, mental age taken to be equivalent to chronological age)**

	With autism (*N* = 11)	*CA matches* (*N* = 11)	*VMA matches* (*N* = 11)	*IQ matches* (*N* = 11)
CA (months)				
Mean	127.5	126.4	97.1	120.7
(SD)	(38.6)	(39.4)	(30.3)	(31.3)
Range	82–174	78–169	63–130	83–176
VMA (months)				
Mean	94.7			103.4
(SD)	(30.0)			(39.0)
Range	63–132			60–152
IQ				
Mean	81.1			85.9
(SD)	(32.1)			(26.2)
Range	55–143			50–138

Table 3 **Examples of proposition types generated by qualitative analysis in experiment 2**

Proposition type	*Example*
Action (Act)	he's messing about and the circle bounces round
Action between animates (ActA)	then the big one's trying to hit the little one and chases after the little circle
Action on rectangle (ActR)	he's closing it up and then the little triangle opens it
Relation with rectangle (RelR)	circle is going to rectangle and then it went in the rectangle
Intentional (Int)	the big triangle looks confused the triangle knew the way
Neutral (Neu)	there's a small triangle and a big triangle and the little triangle is there

in Table 3. The typology described in this table and in Appendix 1 represents an analysis of all the possibilities inherent in the film. The resulting classes of events have been given names that reflect more or less what is going on in these events. So, for example, actions are differentiated into those that are undirected, directed towards an object or towards another agent. The last two could be considered as a subset of what might be called 'intentional acts' in the wider sense of the term. Here, the category Int (intentional) refers to all other intentional actions that do not fall into the ActA (action between animates) or ActR (action on rectangle) categories. As such, our analysis allows a finer-grained account of the understanding of intentional phenomena. All propositions were rated by another rater blind to the diagnosis of the participants, and an acceptably high level of inter-judge reliability was found (Cohen's kappa = 0.85).

Results

The mean numbers of times each type of proposition was used by children in the four groups are set out in Table 4 and illustrated in Figure 3.

A series of Kruskal–Wallis one-way analyses of variance was carried out on each of the six proposition types. These revealed significant differences among the four groups for ActA (action between animates) ($\chi^2 = 8.28$, d.f. = 3, $p < 0.05$) and RelR (relation with rectangle) ($\chi^2 = 12.16$, d.f. = 3, $p < 0.01$) as well as a marginally significant effect for Neu (neutral proposition) ($\chi^2 = 7.67$, d.f. = 3, $p < 0.053$). Differences among groups on the remaining three types of proposition were all non-significant ($\chi^2 < 4.1$, $p > 0.05$). *Post hoc* comparisons using the Mann–Whitney test indicated that the children with autism made fewer propositions describing

Table 4 **Mean numbers (SDs) of different types of proposition in experiment 2**

Type of proposition	*With autism* ($N = 11$)	*CA matches* ($N = 11$)	*VMA matches* ($N = 11$)	*IQ matches* ($N = 11$)
Actions	2.36 (3.17)	0.64 (0.67)	1.45 (1.29)	0.73 (1.19)
Actions between animates	2.09 (2.34)	3.91 (1.58)	3.55 (1.69)	3.91 (1.51)
Actions on rectangle	2.64 (2.34)	3.45 (2.16)	3.91 (2.74)	2.64 (2.38)
Intentional	2.00 (2.93)	1.09 (1.14)	1.64 (1.36)	2.55 (4.44)
Relations with rectangle	0.82 (1.08)	2.91 (2.02)	0.45 (0.69)	1.73 (1.85)
Neutral	6.91 (4.35)	3.73 (2.69)	4.36 (2.73)	2.55 (1.92)
Actions between animates for:				
Fight scene	1.27 (1.42)	1.73 (0.79)	1.55 (1.21)	2.09 (0.83)
Chase scene	0.18 (0.40)	1.18 (0.87)	1.00 (0.77)	1.18 (0.87)
Relation with rectangle scene	0.45 (0.69)	0.73 (0.79)	0.73 (0.65)	0.45 (0.69)

actions between animates (ActA, $z = 2.39$, $p < 0.02$) and fewer describing a relation with the rectangle (RelR, $z = 2.56$, $p < 0.02$) than CA controls. In comparison with the VMA controls, the children with autism made significantly fewer propositions in the category describing actions between animates (ActA, $z = 2.04$, $p < 0.05$) and when compared with the IQ controls they made fewer statements describing actions between animates (ActA, $z = 2.41$, $p < 0.02$) and more neutral (Neu, $z = 2.45$, $p < 0.02$) propositions.

In view of the importance of describing actions between animates in the context of understanding social interactions, a further analysis of ActA propositions was made. It was possible to classify each child's ActA propositions according to whether they referred to the fight scene, the chase scene, scenes where there was a relation with the rectangle, or to none of these events. Mean numbers of ActA propositions in the first three categories are set out in Table 4 and illustrated in Figure 4 (the numbers in the fourth category were too small for analysis). Analysis of each of these

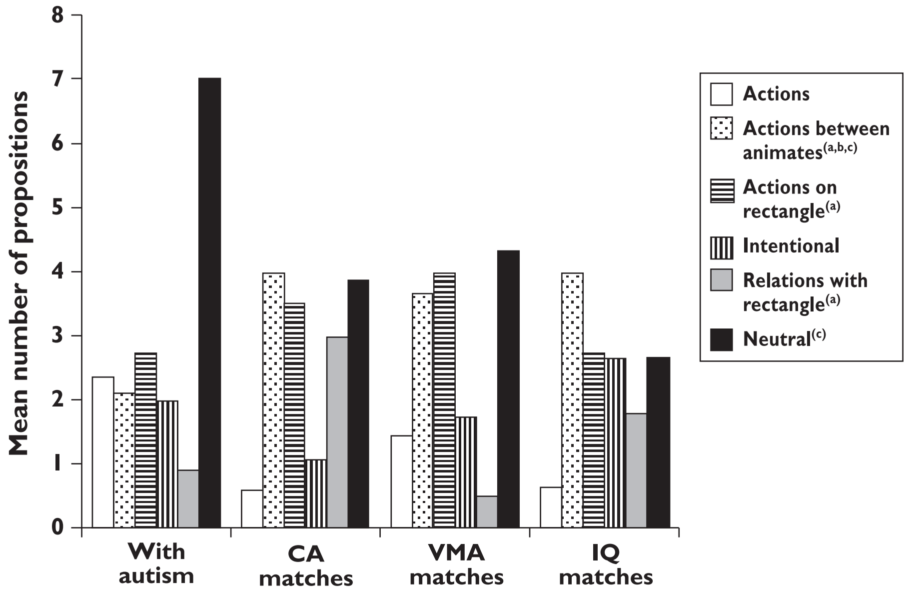


Figure 3 **Mean numbers of each type of proposition made by each of the four groups of participants**

[a] Significant difference between autism and CA matches.

[b] Significant difference between autism and VMA matches.

[c] Significant difference between autism and IQ matches.

three categories using a Kruskal–Wallis one-way analysis of variance revealed a significant difference among groups for the chase scene only ($\chi^2 = 10.75$, d.f. $= 3$, $p < 0.02$) *Post hoc* analysis of the data using Mann–Whitney U-tests revealed that the children with autism made significantly fewer ActA propositions for the chase scene than either the CA, VMA or IQ controls ($z = 2.76$, 2.64 and 2.62 respectively, all $p < 0.01$). In addition, the children with autism made fewer ActA propositions than the IQ controls for the fight scene. Inspection of Figure 4 shows that for the chase scene, the rate of ActA propositions made by the children with autism is between 15 percent and 18 percent of that of each of the control groups, whereas the effect for the fight scene is a reflection of the fact that the IQ controls produced more ActA propositions in this context than did the other groups. These results suggest that the children with autism have a particular difficulty in describing the coordinated actions of two animate agents when their interaction does not involve contact, yet they appear to show no difficulties in describing interactions that involve contact.

Implication of self and other in the description of the film

As was described earlier, children were also asked to give a verbal account

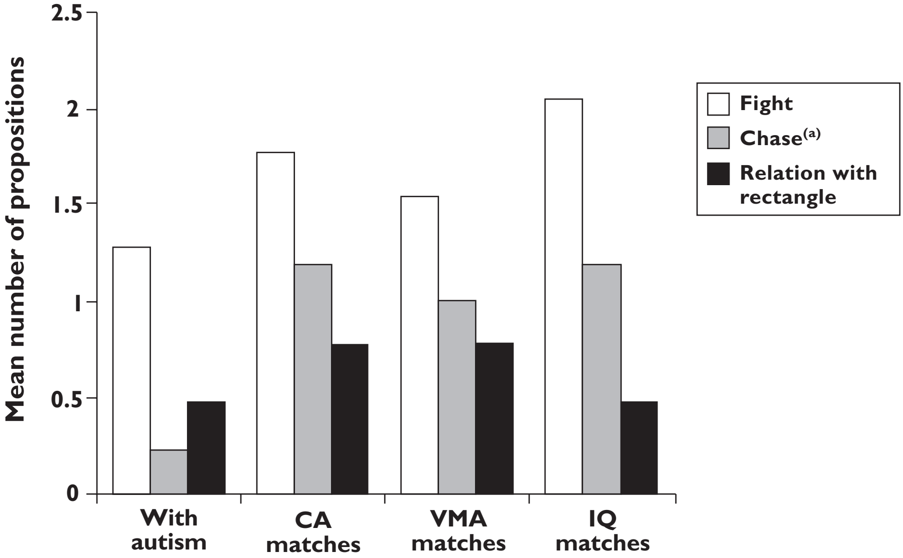


Figure 4 **Mean numbers of ActA propositions for scenes involving chase, actions on rectangle and fight**

[a] Significant difference between autism and other groups.

of what they saw in the film. Children with autism were more likely to use an 'involved' or 'implicated' style of description, either by placing themselves in the narrative or by explicitly soliciting the attention of the experimenter in ways that were not seen in the children in the other group. For example:

> I'm going to catch that grey
> and they say 'hooray, hooray', the big triangle
> Now you two little . . . now you tricksters . . . no more tricks, remember
> Look at the dot, it's trying to get into the square

Examples of distanced style, where the child distanced her/himself and the experimenter from the account, are:

> And like he's chasing them
> And the little circle looks like a little boy or something going inside

Complete protocols for a child who gave a distanced and an implicated account are set out in Appendix 2.

The mean numbers of the two styles of proposition for the four groups of children together with the numbers of children in each group who produced at least one involved style proposition are set out in Table 5.

Analyses of these data show that the children with autism made more

Table 5 **Mean numbers (SDs) of involved and distanced propositions in the four groups**

	With autism (N = 11)	*CA matches (N = 11)*	*VMA matches (N = 11)*	*IQ matches (N = 11)*
Involved	2.6 ($n = 6$)	0.1 ($n = 1$)	0.2 ($n = 1$)	0.0 ($n = 0$)
Distanced	2.4 ($n = 8$)	2.2 ($n = 6$)	0.8 ($n = 7$)	1.1 ($n = 8$)

frequent use of involved style expressions than the other two groups (autism v. CA, $z = 2.35$, $p < 0.02$; autism v. VMA, $z = 2.23$, $p < 0.03$; autism v. IQ, $z = 2.76$, $p < 0.01$, Mann–Whitney U-test). None of the between-group differences in distanced style accounts was significant ($p > 0.05$).

Account length, mental state terms and causal statements

Table 6 presents the mean numbers of propositions and mean numbers of mental state terms and causal statements made by the four groups of children. Analysis of these data using non-parametric analyses of variance and Mann–Whitney U-tests revealed no significant between-group differences (all p values > 0.05) on these measures.

Correlational analysis

In order to examine the relationship between chronological and verbal mental ages and the use of different categories in the typology as well as the use of distanced and involved narrative styles, we computed a series of

Table 6 **Mean numbers (SDs) of propositions, causal and mental state terms per group in experiment 2**

	With autism (N = 11)	*CA matches (N = 11)*	*VMA matches (N = 11)*	*IQ matches (N = 11)*
Overall propositions	21.7 (12.6)	17.6 (7.5)	16.3 (4.3)	16.0 (1.4)
‘Think/know’	0.18 (0.71)	0.10 (0.32)	0.00	0.18 (0.60)
‘Want’	0.36 (0.84)	0.00	0.36 (0.63)	0.09 (0.30)
‘Because/so that/for’	0.50 (1.08)	0.10 (0.32)	0.60 (0.52)	0.55 (0.82)

Pearson correlation coefficients between CA for the two control groups and CA and VMA for the children with autism and the frequency of use of these different categories of response. The only relationship to reach a Bonferroni-corrected value of 0.006 was for the children with autism, for whom the number of involved style statements correlated with the number of Act propositions ($r = 0.82$, $p < 0.003$).

Discussion

Although the findings reported here appear to go against the predictions of 'theory of mind deficit' accounts of autism in that they show that children with autism are not deficient in their use of mental state terms such as 'think', 'know', 'want' etc. the findings must be interpreted with caution. An inspection of Table 6 shows a near floor effect on these measures for all four groups, suggesting that the film used is not a good instrument for eliciting the use of mental state language. The present findings, however, do provide evidence that children with autism are able to discriminate animate from inanimate objects at some level and attribute intentionality to the animate figures.

The finer-grained, qualitative analyses of the two experiments also reveal theoretically important and illuminating similarities and differences between the groups. Although Leslie (1994a) does not make predictions about which of the mechanisms ToBY or ToMM1 would be impaired in autism, it is nevertheless reasonable to predict that the children with autism might not clearly distinguish agents from non-agents, i.e. show an impairment of ToBY, and that they would certainly show impairments in the other two systems. Yet in both of the experiments, the children with autism were able to distinguish movements characteristic of agents – self-propelled motion – from that typical of mechanical systems. Thus they would not appear to have an impairment of ToBY and as such are as capable as young (3-month-old) infants.

In their accounts of the film in experiment 2, children with autism made significantly less use than all the other groups of propositions describing actions between animates, and less use than the CA controls of propositions involving relations with the rectangle. All of these differences relate to the goal-directedness of action: events that would be considered 'intentional' in the wider sense of the term. It is as if for children with autism, someone engaging in an action is doing just that; the consequences or directedness of that action, however immediate, are less likely to be taken into consideration. According to Leslie's (1994a) analysis, in order to understand other people, children have to understand the directedness of the actions of agents towards objects, events and other agents in the environment, an understanding that is mediated by his two ToMM systems. Our findings suggest that the first of these systems is impaired in children with autism; it provides no evidence either way on the functioning of ToMM2. According to Leslie's scheme, however, an impairment in ToMM1 is sufficient to affect the normal development of symbolic and propositional understanding that is a prerequisite for social functioning. Leslie's ToMM deficit account is given further support by an observation by McDonough et al. (1997) in their study of symbolic play and memory in children with autism. They argue that in order to engage successfully in symbolic play, children need not only to use the play object as a cue for action, but also to use potential recipients of the action as well. This implies an understanding of action–object relatedness which appears, on the basis of the results of the present study, to be impaired in children with autism.

However, the contradiction between the findings of the two experiments also needs to be addressed. In experiment 1, it was found that the children with autism were no different from controls in the ways they described launching (physical causality) from reaction (social causality) stimuli. Yet the difficulties identified in experiment 2 suggest that children with autism have problems with directedness of the action. As pointed out earlier, the stimuli presented in experiment 1 were of a relatively short duration (1–2 seconds) and were not embedded in any context. In contrast, experiment 2 presented a complex scenario involving the goal-directed actions of three agents in relation to an inanimate object. It is possible that children with autism have learned to make correct, simple social and non-social attributions to brief, uncomplicated stimuli depicting goal-directedness. However, when faced with more complex stimuli embedded in a richer context that unfolds over time, their performance declines. Leslie points out that the origins of 'theory of mind' lie in 'time-pressured, on-line processing to interpret an agent's behaviour' (1994b, p. 213), which is just what is tested in experiment 2. To give an intentional description of the action of one of the figures in the film in relation to another requires the subject to take the entire scenario into account. For example, the approach by the little triangle towards the opening of the rectangle involves no direct spatio-temporal relation with the circle. At this point, the motions of the circle are in relation to the large, not the small, triangle. Yet when a subject describes the little triangle's movement in terms of freeing the circle, s/he is taking the whole scenario into account, i.e. the fact that the circle is trapped in the rectangle by the big triangle, and is unable to get out unaided. Experiment 1 requires inferences to be made about events that are not set against a background scenario and participants merely have to differentiate launchings from reactions and to produce descriptions that mirror such differentiation.

Whatever the reasons behind them, the findings on goal-directedness are relevant to clinical accounts of the lack of sharing of interests in children with autism (Ricks and Wing, 1975; Curcio, 1978) and the experimental literature on the absence of protodeclarative pointing in this group (e.g. Mundy et al., 1986). We would suggest that it is the identification of agent–agent and agent–object relatedness on the basis of perceptual evidence that forms the foundation of the social difficulties experienced by children with autism. The finding by Rochat et al. (1997) that infants can distinguish patterns of movement characteristic of a chase by the age of 3 months, i.e. *before* they engage in joint attention, suggests that the capacity to identify these patterns of movement may be important for social development. This last point is further reinforced by the observation that the children with autism made fewer ActA (actions between animates) propositions than all three control groups when describing the scene where the large triangle chases the small triangle and circle. In order to see the chase scene as an action between animates, a child has to be aware of the fact that there is a coordination between the movements of spatially distant entities, all of which are capable of independent motion.

The significant correlation for the VMA group between chronological age and the number of RelR (relationship with rectangle) propositions suggests that younger children in this age group find such propositions difficult. Given that the VMA of this group was assumed to equal their CA, it is impossible to say whether this effect is due to age or verbal abilities. However, the similar correlation found in the IQ group for VMA suggests that the understanding of relational events is mediated by increasing verbal ability and not by greater chronological age, and may reflect a growing capacity to handle complex information that would drive both language development and an understanding of relationships over time between objects.

The data also indicate that the children with autism were more likely than all the control children to draw themselves or the experimenter into the narrative. For the typically developing children, such use of involved style narratives correlated negatively with developmentally more mature aspects of their discourse (such as greater numbers of propositions or descriptions in terms of actions between animates: Thommen, 1992). Similarly, involved style narratives were strongly correlated with the use of action-only propositions, which are a developmentally earlier phenomenon. These data cannot tell us about causal relationships between these phenomena, but in view of findings that an understanding of chase-like stimuli appears to develop prior to joint attention, the role of understanding the directedness of the actions of agents in the development of pragmatics would appear to warrant further investigation.

There are other possible reasons why the children with autism may have responded as they did. Perhaps, for example, they saw no need to tell the experimenter the full story, since the information was available to him on the screen. However, their use of involved narratives reflects the pragmatic impairments that are characteristic of autistic spectrum disorders (see Brook and Bowler, 1992; Boucher, 1998) which would lead us to expect that they would be less likely to take the knowledge of the listener into account. Moreover, Baron-Cohen and Goodhart (1994) have demonstrated experimentally that such children experience difficulty on a 'seeing-leads-to-knowing' task. In the context of the current experiment, this would have made them more likely to have told the experimenter about events that children should have known were available visually to them. Evidence of a pragmatic impairment is further supported by the significantly greater number of neutral statements made by the children with autism, especially when compared with the IQ matches. Neutral statements typically describe non-action-related aspects of the film, such as 'and circling round'. Whilst some use of such statements is necessary to make a coherent story, the children with autism seem to pepper their narratives with this sort of statement, as if the action of the characters was less important than their physical presence. The over-use of this category shows that the children with autism have a greater need to provide information about the elements of the film (rather than their actions) than did the other children.

A second possible explanation of the results of the second experiment is that the children with autism may display subtle language deficits that either impair their ability to generate complements, or slow down their responses so that they have to drop elements of the account in order to keep up with the demands of the task. It can be further argued that the tasks used here did not directly measure their perception of agent–object and agent–agent relations, but merely their ability to describe them. The inclusion of a range of individually matched comparison groups renders this interpretation less likely but future studies could consider including a further comparison group of children without autism but with specific language impairments, matched on a battery of language tests, in order to decide whether or not the effects reported here were due to language difficulties.

It might also be argued that the generation of complements of actions and the relating of actions to a wider scenario involve the ability to shift attention across a range of stimuli, to select out relevant material and to reject irrelevant but often salient stimuli. These are so-called 'executive functions', which are thought to be mediated by the frontal lobes (Stuss and Benson, 1986). There is now a large body of research that suggests that individuals with autism are impaired on a variety of executive function tasks (see Bishop, 1993 and Pennington and Ozonoff, 1996 for reviews). Dennis (1991) argues that early damage to the frontal lobes can affect what she refers to as 'social discourse' by impairing the ability to coordinate information across a range of sources and to monitor ongoing interactions. On this basis, it could be hypothesized that for children with autism, the numbers of ActA, ActR and RelR propositions would correlate negatively with measures of executive function. Given that children with autism have also been shown to have impairments on gazing behaviours and shifting of attention (see Burack et al., 1997 for review), future research could also explore relationships between the extent to which such impairments correlate with those reported here.

Finally, it is possible to argue that children with autism do not really experience difficulty in understanding the object-related nature of the actions of agents because there are experimental studies, such as that of Kavanaugh and Harris (1994), which show that they possess just such understanding. Kavanaugh and Harris carried out a study in which they assessed the abilities of children with autism to predict what would happen to an object as a result of certain pretend transformations, for example, whether a polar bear would become wet when a cup containing imaginary liquid was 'poured' over it. Kavanaugh and Harris's results showed clearly that the children with autism could understand the consequences of such pretend actions. However, such observations raise precisely the point developed in the discussion of 'theory of mind' in the introduction, namely the extent to which the structure of experimental situations can cue appropriate responses from children with autism. Given the highly structured nature of Harris and Kavanaugh's experiment, it is not so surprising that their participants performed well. By contrast, the present study was aimed to capture the 'online' nature of real life situations, which provide fewer cues to the 'right' response, and thus to tap into areas of difficulty that are masked by more structured experimental situations (cf. McDonough et al., 1997).

To conclude, the results of these two studies show that children with autism appear to be able to differentiate patterns of movement that characterize animate and inanimate objects. However, they appear to be specifically impaired when they have to describe the object-directedness of such activity, as when an agent acts on an inanimate object or when two animate objects interact. The latter deficit is particularly evident when the action between the animate objects takes place at a distance and is embedded in a stream of ongoing activity. The findings have important implications for how we conceptualize autism as a developmental disorder, for they demonstrate difficulties in just those areas that are thought to develop in infancy *prior* to the emergence of communication, joint attention and protodeclarative pointing (i.e. an understanding of the goal-directed nature of the behaviour of animate entities). As such they support theoretical accounts such as that of Leslie (1987), which relate autistic social dysfunction to a failure to understand the goal-directed actions of agents. At a more abstract level, it is possible to argue that the present findings also support symbolic or representational deficit theories of autism (Ricks and Wing, 1975; Perner, 1991; Leslie and Roth, 1993). Thus, symbolic understanding implies knowledge that symbols (including mental states) are in some way 'about' the world (Dennett, 1978), in the same way as a goal-directed action is 'about' its goal, whilst a similar but non-goal-directed pattern of movement is not. Yet the difficulties shown here by the children with autism in perceiving or conceptualizing certain kinds of agent–object and agent–agent relatedness and, by extension, their well-documented difficulties with joint attention, need not be considered in terms of the operation of dedicated modular systems, as some theorists (e.g. Baron-Cohen, 1995; Premack and Premack, 1997) suggest. It may equally well be the case that such difficulties are a function of attentional or executive dysfunction. Such an analysis takes the view that the social difficulties of people with autism are an emergent function of early impairment of more domain-general systems which operate over time to cause difficulties for the individual across a range of different areas of psychological functioning. This analysis also forces a truly developmental reconsideration of the phenomenon of autism, and serves to remind us that the difficulties experienced by individuals with autism go far beyond the social.

Appendix 1: summary of Thommen's (1992) qualitative analysis of propositions used in experiment 2

The typology of propositions was constructed on the basis of several indices contained in the propositions. Predicates were differentiated according to whether they referred to causal actions or movements or states. The *implicit* nature of the agents implied by the predicates (A animate, I inanimate and M mixed) were then categorized. For example, the predicate 'push' could equally well be used with animate or inanimate agents, and the agents are thus classified as mixed. By contrast, 'chase' is normally used with animates, whereas 'open' has an inanimate as a complement.

Finally, account is taken of the *explicit mention* of a figure as object. To

Table 7

Predicate and type of agent[a]	*Presence and type of complement*		
	Without complement	*Complement is one of the three 'animate figures' (T, t or c)*[b]	*Complement is the rectangle*
Action A–A	Act	ActA	∅
Action A–M	Act	ActA	ActR
Action A–I	Act	∅	ActR
Movement or state A–	Int	Int	Int
Movement or state M–	Neu	ActA	RelR

∅ Impossible proposition.
[a] A animate agent, I inanimate agent, M mixed agent.
[b] T large triangle, t small triangle, c circle.

simplify, we have grouped predicates with understood agents to obtain the five possibilities listed in Table 7.

Appendix 2: complete protocols for a child who gave an 'implicated' and a 'distanced' account of the film in experiment 2

Implicated propositions are shown in bold.

Implicated style
look at the dot, it's trying to get into the square
but it can't
and those two triangles are trying to get in as well
but they can't.
Now the dot can get in,
dunno if the triangles can.
Oh the triangle can get in,
the biggest one can,
dunno if the little one can get in.
Ooh, it's going to open it,
but do you think it'll get in?
It's trying to . . .
Ooh the dot's come out . . .
now the dot and the little triangle are trapped . . .
and they're going round . . .
there's the big triangle . . . and . . . oh two of the shapes have gone,
and that one's turning round . . .
it's pointing . . .

oh, oh, it's cracked it and it's er all gone.

Distanced style
ok, the big triangle closed the rectangle
or else the big triangle opened the rectangle
so after the little triangle hit the big triangle
and the big triangle began to hit the circle
and the circle went to close . . . went to close the rectangle
and the big triangle was chase . . . was hitting the little triangle
and after, the big triangle opened up the door
and and then went in the rectangle
and like he closed it
and the circle's trapped
and after, the little triangle opened up the rectangle
and the big triangle ran out
and the big triangle started chasing the circle
and the little triangle, the big triangle closed the rectangle
and after, he broke it into five.

Acknowledgements

Earlier versions of this article were presented at the Vth European Conference on Developmental Psychology, Krakow, 1995, the XXth Conference 'Autisme Europe', Barcelona, 1995, 'The Growing Mind' Piaget Centenary Conference, Geneva, September 1996 and the VIth European Conference on Developmental Psychology, Rennes, 1997. The authors would like to acknowledge the support of the British Council, Fonds National Suisse pour la Recherche Scientifique and the Wellcome Trust for financial support. Thanks are also due to Paul Harris for helpful comments on an earlier version, Gillian Baird, Auriol Drew and Martin Smedley of the Newcomen Centre, Guy's Hospital, London for help with pilot studies and to the children and staff of Springhallow, London Fields, William Tyndale and Alexandra schools for their participation.

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