COGNITIVE DEVELOPMENT

Cognitive Development 15 (2000) 1–16

Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development

F. Abell[a], F. Happé[b], U. Frith[a,*]

[a]Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London WC1N 3AR, UK
[b]SGDP Research Centre, Institute of Psychiatry, London University, London, UK

Abstract

Computer-presented animations were used to elicit attributions of actions, interactions and mental states. Two triangles moved around the screen according to one of three conditions. Descriptions of the animations were rated according to accuracy and type of description. Adults predominantly used action descriptions for Random animations (e.g. bouncing), interaction descriptions for Goal-directed (G-D) sequences (fighting), and mentalising descriptions for Theory of Mind (ToM) sequences (tricking). High-functioning children with autism used mentalising descriptions less often than normally developing 8-year-olds, but as often as did children with general intellectual impairment. However, the autism group frequently referred to mental states that were inappropriate to the animation. Even those children with autism who passed standard false belief tasks showed inappropriate descriptions of ToM animations, revealing continuing impairments in mentalising on-line. © 2000 Elsevier Science Inc. All rights reserved.

Keywords: Triangles; Mental states; Animated shapes

1. Introduction

In recent years there has been considerable interest in the normal and abnormal development of the everyday ability to attribute thoughts and feelings to others. This aspect of social intelligence has been referred to as 'theory of mind' (ToM) or 'mentalising.' The original, and still prevailing, litmus test for this ability is the false

* Corresponding author. Tel.: +44-(0)207-679-1166.
E-mail address: u.frith@ucl.ac.uk (U. Frith).

PII: S0885-2014(00)00014-9

belief task, in which the subject must track a character's mistaken mental state in order to predict behaviour based on that belief (in contrast to the subject's own belief or reality). Such tests have proved useful in charting the development of ToM in young children and elucidating the deficits in social insight that characterise autism.

False belief tasks, however, have a number of limitations. First, they tax other capacities including executive functions such as inhibitory control. It seems likely that normal 3-year-olds, who fail false belief tasks despite evidence of social insight in a number of real-life and experimental tasks, are limited by an inability to inhibit responses based on reality (Leslie & Thaiss, 1992). Children with autism, too, it has been suggested, may fail false belief tasks because of executive dysfunction (Russell, 1998). Second, standard false belief tasks fail to capture the real-life difficulties of some high-functioning people with autism who pass these laboratory tests despite continuing failure to recognise what others think and feel (Frith et al., 1994).

The aim of this study was to design novel stimuli that would selectively evoke mental state attribution by their motion properties. We took as our starting point Heider and Simmel's (1944) famous experiment using silent animations. These authors showed a film of two triangles and a circle moving within and around a rectangle, and found that adults were inclined to report events in terms of intentional action. Oatley and Yuill (1985) explored this tendency using their own version of the film and reported that participants increasingly used personal and mental state descriptions, as cues signalling social action appeared in the film. This was enhanced when titles, such as 'Jealous Lover,' were provided. In a study designed to investigate what evokes mental state descriptions of animated stimuli, Rimé et al. (1985) showed a number of films with different kinetic structures. They found large differences in level of emotional ratings given to different films, with a strong consensus among observers. When geometric shapes were replaced by human-like silhouettes the ratings given were less differentiated. Patterns of movement, therefore, appear to be more influential in the perception of social/emotional content than the appearance of the characters themselves. Springer et al. (1996) showed Heider and Simmel's film to 3-, 4- and 5-year-old children, and found that character attributions to the figures in the film were more differentiated and more similar to adult attributions in the 5-year-olds than in the younger children. More recently, Montgomery and Montgomery (1999) showed that even 3-year-olds can detect the intended goal of an animated shape, on the basis of a simple pattern of motion.

Impairments in mentalising ability, as evident in autism, would be expected to affect the ability to attribute mental states to animated geometric shapes. Bowler and Thommen (in press) showed the original Heider and Simmel animation to children with autism/Asperger Syndrome and controls. They found that children with autism were able to distinguish intentional action from mechanical motion at the same level as chronological and verbal mental age matched control groups. They also used comparable amounts of propositional language for actions between animate agents, such language being relatively infrequent in all groups.

Indeed, the original Heider and Simmel sequence arguably requires little more than description of goal-directed (G-D) action (chasing, blocking), and may not elicit complex mental state attribution (bluffing, deception). An intriguing group difference did emerge, however, hinting at a reduced sensitivity to interactions in the autism group; children with autism were less likely to comment on interaction between the characters when this did not involve physical contact.

The present study differed from previous ones in presenting animation sequences of three different types: random movement, G-D interactions, and ToM interactions. The protagonists were two triangles. This restricted cues for mental state attributions to pure movement and interaction without vocal or facial expression cues. The use of three conditions was intended to elicit selectively descriptions that did and did not involve mental state attribution. To enhance this distinction, character roles were provided: 'just triangles' for random animations, animals for G-D interactions, and people for ToM sequences. We presented the animations to adults in the first instance to validate the designers' judgement of their relative contents.

The focus of the present study was on children with autism, who were compared with normally developing children and those with intellectual impairment, matched for verbal mental age. Because verbal descriptions were required, the participants were selected to have relatively high verbal mental age (minimum 4 years 10 months). Previous research would lead one to expect that such able people with autism would have a good chance of passing standard false belief tasks (Happé, 1995), despite continuing deficits in real life mentalising (Frith et al., 1994). One question for the present study, then, was how the new animation stimuli would compare with standard false belief tests in discriminating people with autism from people with general learning disability and younger normally developing children. On the basis of existing work, two possible outcomes might be predicted. First, children with autism might be expected to give fewer mentalising descriptions in response to the animations. This was what Baron-Cohen et al. (1986) found in their study using a picture-sequencing task. Alternatively, children with autism might be expected to attribute inappropriate mental states. Happé (1994) reported use of inappropriate mental state explanations in response to story tests of ToM. In contrast, other theories of core impairment in autism, such as executive dysfunction (Russell, 1998) or facial emotion processing impairment (Ellis & Gunter, 1999) might not predict any specific impairment in understanding the behaviour of simple geometric shapes.

2. Method

2.1. Participants

Four groups of participants were recruited: children with autism (n = 15, 12 male), children with general intellectual impairment (n = 17, 6 male), normally developing 8-year-olds who were verbal mental age matched with the two clinical groups (n = 15, 11 male), and adults (n = 14, 14 male). The children with autism had all previously been diagnosed according to published criteria (DSM-IV, APA, 1994) by a psychologist or psychiatrist with expertise in autism, and all were attending specialist autism schools or units. The children with general intellectual impairment were pupils at special schools, placed on the basis of low measured IQ, but of mixed/unknown etiology. The term moderate learning disability (MLD) is used in the UK to refer to these children. The normally developing children were pupils at mainstream primary schools with no special educational needs. See Table 1 for group characteristics.

Participants were administered the Wechsler Intelligence Scale for Children, 3rd Edition (WISC-III, Wechsler, 1991) with the exception of two MLD children (aged 17 and 18) who were given the WAIS-R (Wechsler, 1986). No background information was gathered on the adult group (mean age 22;7, S.D. 6;10), except to verify that they had no clinical diagnoses. The autism group was matched with the MLD group on chronological age, and the verbal mental age of both clinical

Table 1
Group characteristics

	Autism	MLD	Normal development
Age (year;month)	(n = 15)	(n = 17)	(n = 15)
Mean	12;10	13;8	8;6
(S.D.)	(2;9)	(3;5)	(0;6)
Performance IQ			
Mean	78	65	94
(S.D.)	(24)	(12)	(19)
Verbal IQ			
Mean	75	63	102
(S.D.)	(16)	(14)	(17)
Full scale IQ			
Mean	74	62	97
(S.D.)	(21)	(12)	(17)
Verbal mental age[a]			
Mean	8;9	8;7	8;8
(S.D.)	(2;3)	(2;10)	(1;1)
False belief tasks[b]			
% failing	20	24	0
% passing 1st order	33	35	47
% passing both 1st and 2nd order	47	41	53

[a] As calculated from WISC data by the equation VMA = CA × VIQ/100.

[b] Criteria for passing 1st order false belief is passing both Sally-Ann Test and Smarties Test. To pass 2nd order false belief both Ice-Cream Story and Birthday Puppy Tests must be passed.

groups was matched with the normally developing 8-year-olds (VMA group). The full-scale IQ of the autism group was significantly higher than that of the MLD group (t (30) = 2.18, $p < 0.05$) but significantly lower than that of the VMA group (t (28) = 3.33, $p < 0.01$).

ToM skills were assessed by standard false belief tests at two levels of difficulty. The Sally-Ann test (Baron-Cohen et al., 1985) and Smarties test (Perner et al., 1989) assess the ability to understand a first-order false belief (‘she thinks x’). The Ice-Cream story (Perner & Wimmer, 1985) and Birthday Puppy test (Sullivan et al., 1994) examine the ability to attribute a second-order false belief (‘she thinks that he thinks x’). Subjects were judged to pass at either level if they succeeded on both tasks. Subjects who failed control questions were excluded from participating in the study. In line with the relatively high verbal ability of the autism group, a Kruskal–Wallis one-way ANOVA showed no difference across autism, MLD and young normal groups in performance on these false belief tasks (χ^2 3.11, df 2, $p = 0.21$). The high performance of the autism group may also reflect the strong emphasis on social skills training in general, and ToM in particular, in the special schools they attended.

2.2. Experimental task design

A series of computer-presented animations was designed with the help of a graphic artist using the MacroMedia Director 4.0 programme for Power Macintosh. The animations showed one large red and one small blue triangle moving around the screen, which on most trials contained an enclosure. There were three conditions: Random, G-D, and ToM with four animations each in the G-D and ToM conditions, and two in the Random condition. These were taken from a larger set of sixteen animations. Animations that failed to convey the intended meaning to adults at initial piloting were discarded. Two of the unused animations were used as practice stimuli.

In the Random animations the triangles did not interact with each other and moved about purposelessly (floating in space; bouncing off the sides). The G-D sequences involved one character responding to the other character’s behaviour, and thus were likely to evoke direct descriptions of interaction. One sequence showed the smaller triangle following the bigger one, another showed the triangles fighting with each other, a third chasing one another, and the fourth showed the characters dancing together. In each sequence there was reciprocal interaction, but no implication that one character was reading the other’s ‘mind’. The ToM sequences, by contrast, showed one character reacting to the other character’s mental state. In one animation, one character tried to seduce and persuade the other to let it free; another sequence showed the small triangle mocking the big one behind its back; a third showed the big triangle coaxing the little one out of an enclosure; and the last involved the little one hiding behind a door and surprising the big triangle. In all three conditions — Random, G-D and ToM — the triangles moved as if self-propelled. In the

Random condition, the participants were told that they were going to see 'just triangles.' In the G-D condition the triangles were given animal roles, for example, mother duck and duckling. The triangles in the ToM animations were identified as people, for example, grandma and grandson. The three conditions were matched in length, with all animations lasting between 34 and 45 s. The G-D and ToM conditions showed enclosures equally often and each involved shape changes of the triangles (e.g. squeezing through a gap, bending round a corner) to the same extent. This was to ensure that differences in depth of interpretation were not due to differing complexity of physical information within the cartoons. An example of the ToM sequence 'Coaxing' is illustrated by means of five stills in Fig. 1.

2.3. Procedure

Participants were tested over two sessions in a quiet, distraction-free area in their school. During the first session the Wechsler Intelligence Scales were administered, and in the second session the ToM tasks were given and animations were presented on computer. To familiarise the participants with the latter task, two practice animations, one G-D and one ToM, were shown. Descriptions were elicited after each cartoon and feedback was given. If necessary, a second viewing was allowed. For the experiment proper, character assignments were given before each presentation, and after each presentation the same question was asked, "What happened in the cartoon?" The responses were noted and no feedback was given, except general encouragement. Animations were presented in a pseudo-random order, counterbalanced within each group.

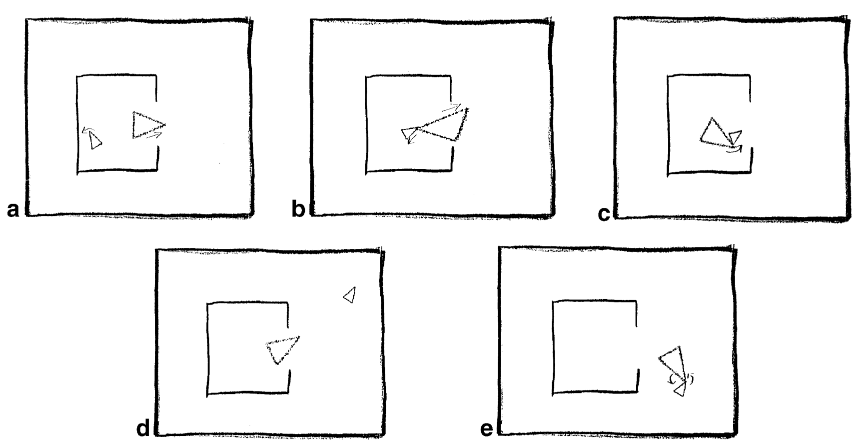

Fig. 1. Five stills taken from one of the animations scripted as Coaxing (mother and child): (a) Mother tries to interest child in going outside. (b) Child is reluctant to go out. (c) Mother gently nudges child towards door. (d) Child explores outside. (e) Mother and child play happily together.

2.4. Scoring

Responses were given a score of 0, 1 or 2 according to their level of accuracy, with a score of 1 for partially correct descriptions. An accurate attribution was defined as one that met in part or whole the intended meaning of the animation sequence. This was previously checked by the pilot study with adults, and there was good agreement for accuracy scores between different raters (see below). Each response was also assigned to one of three categories, independent of accuracy. Any response comprising a simple action statement with no explicit mention of interaction between the triangles, or mental state/psychological language, was rated as *action* (e.g. bouncing). Any response that explicitly mentioned interaction between the triangles, without reference to mental state/psychological language, was classified as *interaction*. Descriptions that included explicit psychological or mental state terms were classified as *mentalising* (e.g. tricking). As the examples of descriptions in the Appendix A show, accuracy and response type were somewhat independent. Thus, a subject might score 2 points for accuracy even if their answer was of a type not expected for the particular animation condition. Detailed scoring criteria are shown in the Appendix A.

Four raters were shown the animations and given practice using the scoring criteria with sample descriptions from piloting data. They rated all responses blind and presented in random order. Consistency was 86% for accuracy, and 90% for description type. There were no differences in extent of agreement for the different subject populations (autism: 86%, 91%; MLD: 85%, 93%; 8-year-olds: 91%, 87%; adults: 86%, 86% for accuracy and description type, respectively). The final score agreed was that given by the majority of raters (3 or 4 out of 4). On the few occasions when there was no majority, the score that was consistent between two raters was used, or, in case of disagreement, a pre-assigned rater's response was chosen.

3. Results

3.1. Accuracy of description

In the two normal groups the descriptions were rated as equally correct for all three animation types (see Fig. 2). Analysis of variance showed that accuracy scores for normal 8-year-olds and adults were equivalent. When the younger groups (autism, MLD, 8-year-olds) were compared in a repeated measures ANOVA (group $\times$ animation condition), there was a main effect of condition (F (2,88) 7.17, $p = 0.001$) and a non-significant effect of group (F (2,44) 2.75, $p = 0.08$). Overall, descriptions of G-D animations were rated as more accurate than those for ToM animations as confirmed in a separate t-test (t (60) 3.92, $p < 0.001$), while those for Random animations did not differ from either.

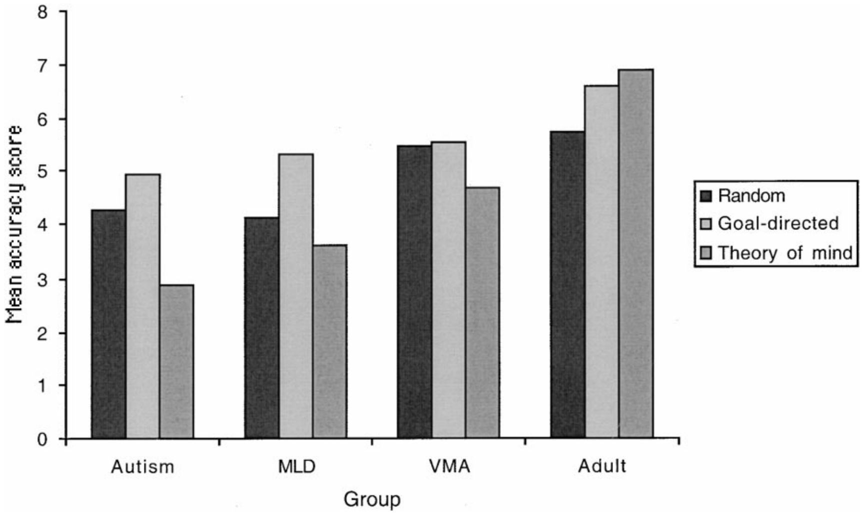

Fig. 2. Mean accuracy score (all response types) by animation type (max = 8).

The accuracy of responses (regardless of type of language used) was also examined by looking at the number of individuals who obtained a perfect score of 2 on at least two of the four animation sequences in each condition. In the ToM condition, this was the case in 7% of the autism group, 41% of the MLD group, 40% of the 8-year-olds, and 93% of the adult group. No such group differences were found for the G-D condition, where 67% of the children with autism, 76% of MLD children, 80% of the 8-year-olds and 93% of adults obtained a perfect score on at least half the trials. That is, they gave the exact description for the movement sequence that was intended by the designers. The groups also did not differ significantly in the Random condition, where the corresponding figures were: 73% for the autism group, 65% for the MLD group, 80% for the 8-year olds, and 79% for the adults. There was a tendency to over-interpret the movement sequences, and hence accuracy was rated lower.

Item analysis showed that responses for all sequences within each condition obtained equal accuracy scores without ceiling effects. The exception was one G-D sequence ('fighting'), where all adults gained a maximum score. The G-D sequence 'dancing' less often solicited the intended description in the three young groups. In the case of the Random and ToM animations only the autism group showed some indication of more specific difficulties ('Bouncing' and 'Coaxing' animations). However, none of the item differences was significant.

3.2. Type of description

Table 2 shows the type of descriptions used by each group in each animation condition. The different types of responses given reflected the

Table 2
Number of explanations of each type (max = 4)[a] for three animation conditions
Mean (standard deviation).

	Autism	MLD	8-year-olds	Adults
Random animation				
Action	1.73 (1.03)	1.53 (1.50)	2.13 (1.41)	2.57 (1.65)
Interaction	2.27 (1.03)	2.12 (1.50)	1.20 (1.01)	1.15 (1.51)
Mentalising	0 (0)	0.12 (0.49)	0.13 (0.52)	0 (0)
G-D animation				
Action	0.33 (0.49)	0.18 (0.39)	0.07 (0.26)	0.07 (0.27)
Interaction	3.53 (0.52)	3.59 (0.51)	3.60 (0.63)	3.71 (0.61)
Mentalising	0.07 (0.26)	0.18 (0.39)	0.13 (0.35)	0.21 (0.58)
ToM animation				
Action	0.07 (0.26)	0.12 (0.33)	0 (0)	0 (0)
Interaction	2.73 (0.80)	2.53 (1.18)	1.93 (0.96)	0.43 (0.65)
Mentalising	1.13 (0.92)	1.29 (1.26)	1.73 (1.03)	3.57 (0.65)
of which appropriate	0.73 (0.96)	1.24 (1.3)	1.6 (1.06)	3.5 (0.65)

[a] Note that number of answers of each type do not sum to 4 in every case because of occasional unclassifiable responses.

intended content of the three animation types. For all four groups, action descriptions were used primarily for Random animations and interaction descriptions for the G-D animations. For the three groups of children, ToM animations evoked mainly interaction and mentalising descriptions. In the adult group the vast majority of responses were categorised as mentalising descriptions. Comparison of the three groups of children showed that the autism group used more interaction descriptions (inappropriately) in response to Random animations than did the VMA-matched 8-year-olds (F (2,46) 3.43, $p < 0.04$; post-hoc Tukey test $p < 0.05$). There were no group differences in use of interaction explanations for G-D or ToM animations.

The frequency of use of mentalising descriptions (regardless of accuracy) in response to ToM animations was similar in the two clinical groups and did not differ significantly from normal 8-year-olds (Fig. 3). Use of mentalising language in response to the Random or G-D animations was minimal, and there were no significant differences between groups in these two conditions.

A difference appeared, however, when descriptions were split into appropriate and inappropriate mental state attributions (i.e. those with accuracy score 0). The autism group used significantly fewer appropriate mentalising descriptions than the VMA-matched normal group (Mann Whitney z-2.38, $p < 0.05$). In addition, the autism group gave significantly more mentalising descriptions that were inappropriate to the animation than did the MLD group (z-2.29, $p < 0.05$). The percentage of appropriate and inappropriate mentalising descriptions is shown in Table 2 as a percentage of all types of description (action, interaction and mentalising), but it is perhaps more informative to consider these numbers as a

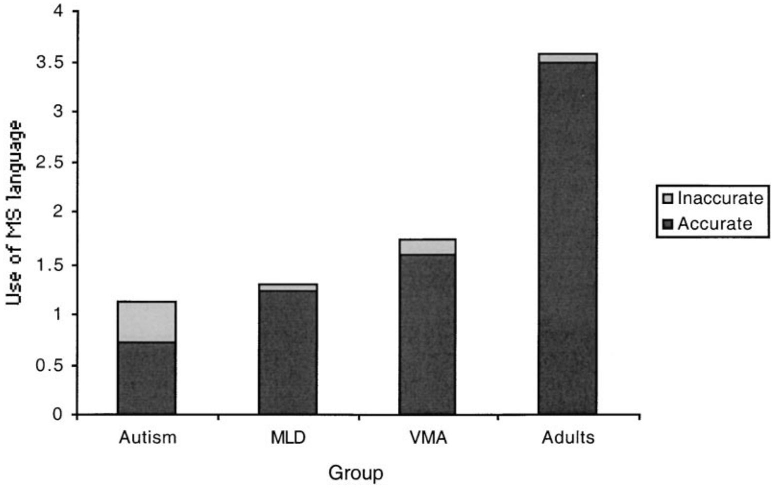

Fig. 3. Accurate and inaccurate use of mentalising language in the ToM animations (max = 4).

proportion of the mentalising descriptions. In the autism group, 36% of mentalising descriptions of ToM animations were inappropriate, compared with 3% in the MLD group, 7% in the 8-year-olds, and 2% in the adult group. Six of the 15 children with autism (40%) gave at least one inappropriate mentalising description in the ToM condition, compared with 1 of the 17 MLD children (6%), 2 of the 15 8-year-olds (13%), and 1 of the 14 adults (7%), see Fig. 4.

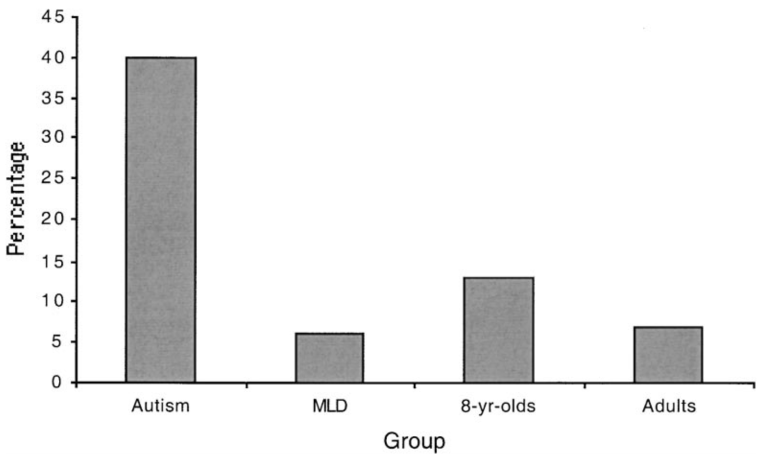

Fig. 4. Percentage of participants giving at least one inappropriate mentalising explanation for ToM animations.

4. Discussion

The three types of animations evoked differential responses that matched in content the intended categories of Random, G-D and ToM scenarios. In this sense the animations appear to have face validity and the scoring system used proved adequate to distinguish different description types. Despite these differences, the animations were moderately well matched for difficulty as assessed by accuracy of descriptions. The lack of ceiling effects suggests that this task is suitable for measuring subtle differences: there is still some ambiguity in these simple silent animations.

The children with autism differed from young normal and MLD children in the appropriateness of the mental state language used. Children in the autism group often (around one in three responses) referred to a mental state that did not fit with the respective ToM animations. For instance, for the sequence which depicted, purely by the triangles' movements, a gently encouraging 'mother,' coaxing a timid 'child' to come out of the house, one inappropriate mentalising response was, 'the boy is being cheeky to his mother'; another: 'they are trying to push each other and want to kiss one another.' While on the face of it, one might say that almost any explanation for the movement of geometric shapes may be considered valid, in actuality the present animations elicited remarkably consistent interpretations in the normal and learning disabled individuals. It was notable too that participants with autism used interaction explanations inappropriately to describe the Random animations.

Our relatively able autism group performed as well on standard false belief tasks as did younger normal and less bright MLD groups, matched on VMA. The animations, however, revealed abnormalities in mental state attribution even in these high-functioning individuals with autism. For instance, four of the seven children with autism who passed both first- and second-order false belief tasks nonetheless performed poorly on the ToM sequences. All these children had poor accuracy scores, and either did not use mentalising language to describe the sequences, or referred to inappropriate mental states. This contrasted with just one of seven MLD children who performed poorly on the ToM animations despite passing all false belief tasks. The fact that group differences still emerged on the ToM animations suggests that, for individuals with autism, passing false belief tasks does not necessarily signal the intuitive ability to attribute mental states appropriately in real time. It is interesting to speculate that the essentially non-verbal nature of the animations may have deprived the children with autism of one route by which they may attempt to understand other minds: explicit verbal information. The more novel, non-verbal and on-line stimuli revealed continuing deficits in ToM. This is particularly interesting in the light of current theories of autism. For example, Baron-Cohen (1995) has emphasized the importance of reading the eyes in mental state attribution, but a deficit in this ability cannot account for the difficulties in the present task.

Another candidate explanation of standard ToM task failure is an inability to inhibit prepotent responses (Russell, 1998). As far as we can see the animation task does not make large demands on executive control. Despite this, it proved challenging for the group with autism.

The use of mentalising language in the ToM animations was probably facilitated by the human roles given to the triangles in only that condition (e.g. grandma and grandson). This may have cued all groups, including the autism group, to look for social interaction between the characters, encouraging reference to mental states and access to pre-learned social scripts or schemas. For this reason, group differences may have been reduced. It remains to be seen whether different results would be obtained without allocation of differential roles. Bowler and Thommen (2000) found no gross difference between children with autism and controls when describing interactions between agents in the Heider and Simmel cartoon. They did not, however, code the descriptions for correctness, and it is uncertain whether any mentalising language used was appropriate for the given sequence. Happé (1994) found that high-functioning individuals with autism, who passed standard first- and second-order false belief tests, used mentalising explanations of story characters' actions as frequently as did control participants. However, as in the present study, the autism group was marked out by use of inappropriate mentalising explanations (e.g. explaining a joke as a lie) — tell-tale errors of a type seldom if ever made by young normal or MLD children.

Accuracy in explaining ToM animations did not improve from 8 years to adulthood in our sample, although there was an increase in use of mentalising language. The question is whether this reflects increasing ToM skills or simply increasing linguistic competence. Although this task goes some way towards addressing the limitations of standard ToM tasks, it still relies on verbal output. In future studies it would be desirable to devise non-verbal response modes. This might help locate the difficulty on standard false belief tasks in groups with language related problems, such as deafness or specific language impairment. In addition, such tasks might allow assessment of on-line ToM processing in individuals without language, and elucidate the role of expressive language skills in the false belief task success of high-functioning individuals with autism.

Acknowledgments

We are grateful to the staff and pupils of the following schools who made this research possible: Hargrave Park School, Kisharon School, Latymer School, Linden Bridge School, Northway School, Oak Lodge School, St. John's Upper Holloway School, Springhallow School, and Tufnell Park Primary School. This research was supported by the MRC, UK.

Appendix A. Scoring criteria

A.1. Accuracy of description: general rules

Each description is scored 2, 1, or 0 according to how accurately it reflects the sequence.

2 spot-on description of the story or the actions represented; can be concise just capturing gist, or can be discursive
1 partial description of the sequence; description is related to the sequence, but imprecise or incomplete
0 bizarre descriptions, plainly wrong descriptions, and responses that focus solely on a minor unimportant aspect of the sequence

Random movement sequences
Floating/Bouncing: Character roles: just triangles (both sequences without enclosure)
2 anything implying random or purposeless movement including moving, bouncing, just dancing
1 purposeful movement without interaction, including turning round and getting dizzy, dancing in a circle
0 purposeful movement implying interaction between the triangles including copying each other; avoiding each other

G-D movement sequences
Fighting: Character roles: two deer. No enclosure.
2 action implying physical fight, e.g. bashing each other
1 action that conveys the idea of a conflict, but is either too specific or too vague, e.g. biting; pushing
0 action that does not relate to conflict, e.g. following each other
Following: Character roles: mother duck and duckling. Enclosure.
2 description which conveys following each other
1 description that is related to but somewhat remote from following, e.g. copying; chasing
0 action that does not relate to following each other, e.g. jumping
Chasing: Character roles: two cats. Enclosure.
2 description that conveys the idea of a chase
1 description that is related to but somewhat remote from chasing
0 action that does not relate to chasing, e.g. going up and down
Dancing: Character roles: two ponies. No enclosure.
2 description that conveys the idea of moving in formation, e.g. dancing; making a pattern
1 description that is partially correct or related to dancing, e.g. doing different things — one went one way — the other went the other way
0 action that is not related to moving in formation, e.g. galloping along

ToM movement sequences
Surprising: Character roles: grandma and grandson. Enclosure.
2 any mention of boy tricking, surprising his grandma; hiding, hide and seek
1 description which gives part of the story but misses the critical point (see above)
0 description which gives only minor part of action e.g. knocking on the door, or does not relate to any of the events in the sequence.
Coaxing: Character roles: mother and child. Enclosure.
2 description that conveys child's reluctance to go out and mother's attempts to get child out, e.g. persuading
1 partially correct description focussing on one aspect of the story or one character only, e.g. child does not want to go out; or, mother is pushing child to go out

0 actions that do not relate to the events or relate to a minor aspect of the sequence only, e.g. dancing together, or unrelated description.

Mocking: Character roles: teacher and boy. No enclosure.

2 description that conveys that boy is copying teacher without the teacher noticing, including pretending, hiding, being naughty

1 partially correct, e.g. following, copying

0 focus on a single unimportant event, e.g. boy ran away, or unrelated description

Seducing: Character roles: girl prisoner and guard. Enclosure.

2 description that conveys the girl prisoner luring, persuading or tricking the guard

1 partial story with minimal action for each character, e.g. girl trying to escape; guard blocking

0 description which focusses on unimportant event or is extremely minimal, e.g. she got out, or unrelated description

A.2. Type of description: general rules

Each description (regardless of accuracy score given) is rated as showing *random action*, *interaction action* or *mental state attribution*.

These rules apply to all descriptions for any sequence. In each case the *highest* level of descriptive language is scored (i.e. mentalising trumps interaction trumps action).

Random action: Simple action, no mention of goal, no reference to interaction of the characters, e.g. floating.

Interaction: Specific reference to purposeful movement, without reference to mental states, e.g. following; fighting; copying; having a race. More than one action may be described, e.g. leading and following. May involve use of direct speech without mental state verb; may include qualification of verb by ‘trying to’, e.g. boy trying to ask her something, but teacher kept walking away.

NOT: purposeless action. NOT: implied mental state attribution.

Mentalising attribution: Use of mental state verbs to describe reciprocal interactions, e.g. wanting; hiding; tricking; pretending; being naughty. NOT: complex interaction, e.g. chasing each other round the house; x pushing y out of the way. NOT: solely direct speech. NOT: solely ‘trying to.’

Examples of descriptions with scores given (accuracy, type).

Bouncing (random animation)

Bouncing on a bouncy castle.	**2, action**
Full of energy, bouncing around.	**2, action**
Having rugby — red won 12–9.	**0, interaction**
Making patterns.	**1, interaction**
Pretending they are rockets.	**0, mentalising**

Following (G-D animation)

Having a jog.	**0, action**
Trying to catch big one, little is behind.	**1, interaction**
Duckling is following mother.	**2, interaction**
Boy is copying mother.	**1, interaction**
Boy is fooling mother.	**0, mentalising**

Coaxing (ToM animation)	
Dancing around.	**0, action**
Fighting each other.	**0, interaction**
Boy is being cheeky to his mother.	**0, mentalising**
Playing around, mother goes out, child is stuck in there, mother is pushing her.	**1, interaction**
Playing a game, child would not go out, mother pushed, cuddled.	**2, interaction**
Dancing around, mother is trying to take the little one out, little one does not want to go out.	**2, mentalising**

References

American Psychiatric Association (APA). (1994). *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)* (4th edn.). Washington, DC: American Psychiatric Association.

Baron-Cohen, S. (1995). *Mindblindness: An Essay on Autism and Theory of Mind*. Cambridge, MA: MIT Press.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition 21*, 37–46.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1986). Mechanical, behavioural and intentional understanding of picture stories in autistic children. *Br J Dev Psychol 4*, 113–125.

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

Ellis, H. D., & Gunter, H. L. (1999). Asperger syndrome: a simple matter of white matter? *Trends Cognit Sci 3*, 192–200.

Frith, U., Happé, F., & Siddons, F. (1994). Autism and theory of mind in everyday life. *Soc Dev 3*, 108–124.

Happé, F. (1994). An advanced test of theory of mind: understanding of story characters' thoughts and feelings by able autistic, mentally handicapped and normal children and adults. *J Autism Dev Disord 24*, 129–154.

Happé, F. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Dev 66*, 843–855.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *Am J Psychol 57*, 243–259.

Leslie, A. M., & Thaiss, L. (1992). Domain specificity in conceptual development: evidence from autism. *Cognition 43*, 225–251.

Montgomery, D. E., & Montgomery, D. A. (1999). The influence of movement and outcome on young children's attribution of intention. *Br J Dev Psychol 17*, 245–261.

Oatley, K., & Yuill, N. (1985). Perception of personal and interpersonal action in a cartoon film. *Br J Soc Psychol 24*, 115–124.

Perner, J., Frith, U., Leslie, A. M., & Leekham, S. R. (1989). Exploration of the autistic child's theory of mind: knowledge, belief and communication. *Child Dev 60*, 689–700.

Perner, J., & Wimmer, H. (1985). John thinks that Mary thinks that . . . : attribution of second-order beliefs by 5- to 10-year-old children. *J Exp Child Psychol 39*, 437–471.

Rimé, B., Boulanger, B., Laubin, P., Richir, M., & Stroobants, K. (1985). The perception of interpersonal emotions originated by patterns of movement. *Motiv Emotion 9*, 241–260.

Russell, J. (1998). *Autism as an Executive Disorder*. Oxford: Oxford University Press.

Springer, K., Meier, J. A., & Berry, D. (1996). Nonverbal bases of social perception: developmental change in sensitivity to patterns of motion that reveal interpersonal events. *J Nonverbal Behav 20*, 199–211.

Sullivan, K., Zaitchik, D., & Tager-Flusberg, H. (1994). Preschoolers can attribute second-order beliefs. *Dev Psychol 30*, 395–402.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children* (3rd edn. (UK)). London: The Psychological Corporation.

Wechsler, D. (1986). *Wechsler Adult Intelligence Scale* (revised (UK)). London: The Psychological Corporation.