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Targets and Cues: Gaze-following in Children with Autism

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Children with autism are known to have difficulties in sharing attention with others. Yet one joint attention behaviour, the ability to follow another person's head turn and gaze direction, may be achieved without necessarily sharing attention. Why, then, should autistic children have difficulties with it? In this study we examined the extent of this difficulty by testing school-aged autistic children across three different contexts; experiment, observation, and parent interview. We also tested whether the ability to orient to another person's head and gaze could be facilitated by increasing children's attention to environmental targets and social cues. Results for experiment and observation demonstrate that a sizeable proportion of children with autism did not have difficulties with following another's head turn. There was a difference between children with high and low verbal mental ages, however. Whereas children with higher mental ages (over 48 months) were able to orient spontaneously to another person's head turn, children with lower mental ages had difficulties with this response. When cues were added (pointing, language) or when feedback from targets was given, however, their performance improved. Parent interview data indicated that children with autism, whatever their mental age, began to follow head turn and gaze direction years later than typically developing children. Developments in attention and language are proposed as possible factors to account for this developmental delay.

Keywords: Autism, attention, nonverbal communication, gaze-following, joint attention.

Abbreviations: BPVS: British Picture Vocabulary Scale; CA: chronological age; MA: mental age; RDLS: Reynell Developmental Language Scale; VMA: verbal mental age.

Introduction

Children with autism have difficulties engaging in shared attention with others. This problem is considered to be a central part of the disorder according to current explanations of autism (Baron-Cohen, 1995; Curcio, 1978; Hobson, 1993; Mundy, 1995; Ricks & Wing, 1975). The absence of joint attention behaviours such as pointing, showing, and gaze-following is also a key feature for early detection and diagnosis (Baron-Cohen et al., 1996).

The present study investigated a behaviour that traditionally has been considered to be one of the earliest emerging joint attention responses; the ability to follow another person's head and eye direction. In typical development, this ability starts to appear in the first year of life, becoming reliably established by 10–12 months (Butterworth & Jarrett, 1991; Corkum & Moore, 1998; Scaife & Bruner, 1975), and by 18 months infants can follow gaze precisely, regardless of distance (Morissette, Ricard, & Decarie, 1995) and location (Butterworth & Jarrett, 1991). In children with autism, however, a marked *lack* of ability to follow another person's head turn and eye direction has been widely reported in the literature (Baron-Cohen, 1989; Landry & Loveland, 1988; Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997; Loveland & Landry, 1986; Mundy, Sigman, Ungerer, & Sherman, 1986).

Why should children with autism have difficulties in following another person's head turn and eye direction? The answer to this question depends on the way in which this behaviour is interpreted. One view is that gaze-following is an act of joint attention in which two people are attending to the same thing. In representational terms, this sharing of attention may be conceptualised as a representation that oneself and another are attending to the same thing. Recently, however, researchers have questioned whether a representational or even a joint attention account of early gaze-following is necessary to explain this behaviour (Gomez, 1996; Moore & Corkum, 1994; Perner, 1991). Several other levels of analysis are possible. First, gaze-following or following another's head turn may occur without sharing attention. For example, one person may turn their head to look at an interesting object without intending to direct another

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person's attention and another person might follow their direction of looking. Once one can track the movements of others' eyes and heads towards interesting places, body orientation can become an indicator of where to look in order to gain information about objects. Even chimpanzees are reported to follow gaze using this strategy (Povinelli & Eddy, 1996, 1997). At another level of analysis, "gaze-following" may involve a sharing experience with another but without representing the situation as being shared or representing the other's looking behaviour as "attentional" (Perner, 1991). Finally, gaze-following may be analysed in terms of understanding of attention in self and other.

If the specific problem for children with autism is that they cannot represent that self and other are attending to the same object, as has been suggested (Baron-Cohen, 1995), this does not necessarily predict that these children will have difficulty following another person's head or gaze. They could simply use a "nonrepresentational" strategy as described above. Yet the evidence to date suggests that following another's head and eyes *is* a problem for children with autism. What is puzzling, then, is why children with autism would not use a nonrepresentational strategy, especially since this has an adaptive value for gaining information about the world, unless their difficulties lie at the lower level of response. The purpose of the present study was therefore to examine the extent of the gaze-following deficit in autism and, second, to investigate whether this response might be acquired. For the purpose of this study, gaze-following refers to the ability to follow another person's head turn and eye movement.

The first question for the study was to determine the extent to which children with autism have a gaze-following deficit. Closer examination of the research on joint attention in fact shows that although the gaze-following deficit affects the majority of autistic children, it is not absolute. For example, there is evidence that despite difficulties in following gaze spontaneously, autistic children can follow gaze when instructed (Leekam et al., 1997). Recent evidence also shows that even spontaneous gaze-following may be found in some children. When spontaneous gaze-following ability does appear in children with autism, however, it is sensitive to the developmental level of the child (DiLavore & Lord, 1995; Mundy, Sigman, & Kasari, 1994), and to changes in environmental context (Lewy & Dawson, 1992). In our current work we examined whether or not children with autism follow gaze by studying children of different chronological and mental ages in different contexts, and we used three different methods; experiment, observation, and parent interview.

If it is the case that some autistic children with higher developmental levels are able to follow gaze, one question is, to what degree are they engaging in joint attention? Would their behaviours show a low-level response mechanism at work, allowing the child to orient to a directional cue? Is the child sharing attention and is there understanding that self and other are attending to the same thing? Unfortunately, there is no infallible behavioural sign which can indicate conclusively that the child understands that self and other are both attending to the same thing. However, researchers have observed additional spontaneous behaviours that accompany gaze-following and which seem to suggest that the child's behaviour involves more than a simple orientation response to a directional cue. For example, older typically developing infants begin to check the face of the adult spontaneously after they have followed gaze (Butterworth, 1991). Older infants also continue to look at the same target rather than switching between different target objects (Moore, 1997). Whether these additional behaviours really show that infants have an *understanding* of attention is debatable, however. For example, Tomasello (1995) considers that the appearance of spontaneous gaze-checking makes it plausible that the child understands attention, whereas Perner (1991), in contrast, argues that gaze-checking does not provide evidence for understanding of attention.

Since most autistic children are expected to fail to follow gaze, the second question for this study is whether they can acquire this response. We start with the proposal that gaze-following develops with experience, as has been argued for other area of social cognitive development (Elman et al., 1996). With respect to face recognition in typical development, for example, it has been argued that some minimal predispositions may be innately specified. These predispositions channel attention to particular stimuli, but it is only with experience that the infant learns about specific facial characteristics (Johnson & Morton, 1991). In animals, evidence that brain development is dependent on experience is indicated by the presence of neurones responsive to particular characteristics of faces (Perrett, Rolls, & Caan, 1982) and responsive to gaze direction (Perrett, Hietanen, Oram, & Benson, 1992). With respect to gaze-following, recent evidence also shows that infants of 10 weeks can follow experimentally produced eye-movement displays (Hood, Willen, & Driver, 1997). It is not until 10–12 months, however, that gaze-following is reliably established within an interactional context (Corkum & Moore, 1995). This suggests that the ability to follow another person's head turn and eye gaze progressively develops with experience in the first year of typical development.

What type of experience is important for gaze-following? The child needs to be able to attend both to objects or *targets* in the environment and to the human *cues* which make these objects salient to the child. Corkum and Moore (in press) have recently argued that gaze-following in normal development may come about through the experience of repeated exposure to such cues (e.g. others' head turns), accompanied by the sight of some rewarding target event in the location indicated. Using a conditioned head turn procedure, these authors found that gaze-following could be acquired in typically developing infants who initially fail to follow gaze spontaneously. Eight- and 9-month-old infants who failed to follow an experimenter's head turn and eye gaze in the spontaneous trials of a gaze-following procedure were reinforced on subsequent trials by the activation of a toy, which appeared in the location to which the experimenter turned. A significant proportion of infants who initially failed to follow gaze did so after this training phase, suggesting that it is possible to accelerate the onset of reliable gaze-following in infants and that a gaze-following response can be acquired. Training effects such as these show that gaze-following behaviour is affected by experience.

Although experience of targets and cues affects gaze-following performance, a critical claim made by Corkum and Moore (in press), is that gaze-following is *not* acquired in purely behaviourist fashion. In subsequent experiments, Corkum and Moore found that even when the experimenter's head turn and the target activation were not paired during the training phase, infants still acquired a gaze-following response after training. This suggests that the infants were not simply learning by reinforcement. Corkum and Moore proposed that the adult's head turn cues the infant to shift attention in the direction of the turn and that both *cue* and *target* event are important for the gaze-following response in infants.

Whereas Corkum and Moore's experiments examined infants' responses to an adult's *head turn* and gaze direction, other cues such as physically touching an object, pointing, and vocalising, also make objects and their direction in space more noticeable to infants. Cues such as pointing may increase the likelihood of a response by magnifying the perceptual effect for the infant, and it may also improve the accuracy of spatial localisation within a hemifield. Research with typically developing infants has examined the differential effects of such cues. These studies show that by 18 months, typically developing children will respond to subtle cues of eye direction alone. However, for younger infants more salient cues (i.e. the more visible or audible cues) seem to be required to trigger a gaze-following response. For example, typically developing infants below 18 months are more likely to respond to another person's pointing gesture than to gaze direction alone (Butterworth & Grover, 1990; Deak, Flom, Pick, & Silberglitt, 1997) and are more likely to respond to head turn than eyes alone (Corkum & Moore, 1995). Typically developing infants as young as 3 months also follow an adult's head turn in a situation in which the adult's head turn in accompanied by talk to a puppet (D'Entremont, Hains, & Muir, in press), the change in sound direction possibly providing an added cue to the head turn.

At this stage it is not clear what the process of acquisition might be for acquiring the gaze-following response and how innate and environmental factors interact. We do not know how experience of cues alone or in combination with targets might assist in its acquisition or acceleration. Traditionally, it has been argued that joint attention acts, such as pointing and looking at objects together, provide early opportunities for joint reference and object naming (Bakeman & Adamson, 1984; Werner & Kaplan, 1963). It is therefore important to establish whether there are conditions under which gaze-following might be acquired or facilitated, particularly given recent evidence that problems in gaze-following in autism are related to problems in language, especially in mapping word meanings onto objects (Baron-Cohen, Baldwin, & Crowson, 1997).

To summarise, this study had two aims. One was to establish the degree to which children with autism are able to follow gaze spontaneously in different contexts. We used three methods to investigate this; experiment, observation, and parent interview. The second aim was to discover whether the gaze-following response in autism could be facilitated. In the experiment we used Corkum and Moore's conditioning paradigm to test whether adult's head turn (cue) followed by interesting event (target) would facilitate the gaze-following response. In the observation and parent interview we investigated whether different cues by the adult (head turn, pointing, verbalising) would facilitate a gaze-following response. On the basis of the infant findings and previous autism research, it was predicted that although some autistic children might spontaneously follow gaze in response to another's head turn, that the majority would not. However, it was expected that a significant proportion would acquire gaze-following after training (i.e. exposure to targets contingent on head turn) and would respond when additional cues are included (i.e. pointing and verbalising).

Method

Participants

Two groups participated, children with autism and children with typical development. The groups were individually matched for verbal mental age (VMA) within a 6 months range. The VMA of the two groups was not significantly different [$t(26) = -0.9$, $p < .33$]. Table 1 shows the characteristics of the participants.

Children with autism. Nineteen children were recruited from four special schools for children with autism in Essex, Surrey, and Kent. An official diagnosis of autism according to DSM-III-R, DSM-IV, or ICD-10 was confirmed by means of parents providing full diagnostic records supplied by a clinician at time of diagnosis. Three children had a diagnosis of Asperger's syndrome. Two children (CA 9;10 and 8;10) did not complete trials 1 to 4 of the experiment due to lack of co-operation. These children would not engage in interaction with the experimenter, making it impossible to gain initial eye contact. These children were happy to participate in the training and test trials, however, and the results for these children are shown separately. The remaining 17 children are shown in Table 1. All children had a wide range of verbal and nonverbal ability, with some having minimal language and others with verbal and nonverbal ability in the normal range. Verbal mental age was tested using the British Picture Vocabulary Scale (BPVS). However, three children with very low ability were not able to point to pictures in this test. These children (CA 5;5, 8;0, 7;6) were given the receptive scale of the Reynell Developmental Language (RDLS). Nonverbal mental age was tested using the Leiter International Performance Scale. One child (CA 12;0) took

Table 1
Participants

Group	CA	VMA[a]	PMA[b]
Autistic			
Mean	8;5	3;11	6;4
SD	1;11	2;5	2;1
Range	5;5–12;6	1;3–9;1	3;0–9;7
N	17	16	15
Nonautistic			
Mean	4;4	4;11	–
SD	3;1	3;1	–
Range	1;1–9;1	1;3–10;00	–
N	17	12	–

[a] Verbal Mental Age from the BPVS.
[b] Performance Mental Age from the Leiter.

part in the experiment and observation, but would not co-operate with any mental age testing, verbal or nonverbal.

Typically developing children. Seventeen children were recruited from advertisements in local nurseries and local radio and from advertisements placed on the university campus. At the time of recruitment it was checked that children had no language or learning delay and no history of autism or any other disorder. Each child was individually matched with a child with autism by ensuring that each typically developing child's chronological age (CA) matched a preselected autistic child's VMA within a range of 6 months. An assumption was made in this matching procedure that the mental age (MA) and CA of typically developing children would be the same but in the event the mean MA for the typically developing group was higher than their CA (but this difference was nonsignificant). Two children (CA 18 mths and 20 mths) were too young for the BPVS and the RDLS was substituted. Due to time constraints in the testing session, some MA testing was omitted. VMA data was omitted for five children (CA 3;0, 13 m, 2;4, 2;7, 4;1) and nonverbal testing was not included for any member of the group.

Design and Procedure

Testing took place at the university. To ensure familiarity with the testers and with the environment, children with autism stayed on campus with their families for 2 days. Both the experiment and observation session took place in the same testing room and the order of the tasks was counterbalanced. The parent interview took place in another room whilst the child was in the observation session.

Experiment. We aimed to replicate the Corkum and Moore design as closely as possible with some changes in the targets as appropriate to the subject population. Following a parent survey of autistic children's favourite toys, we chose Thomas the Tank Engine, a favourite children's book character, for the target object. As in the Corkum and Moore set-up, testing took place inside a screened cubicle. The only targets present were two 44 cm × 44 cm black boxes, each 76 cm in height and positioned to the left and right of the cubicle, 1 m away from the centre of the chair on which the child sat. Each box contained an identical Thomas the Tank Engine toy train and a motor. The train was suspended on the inside of the box lid, invisible to the child until the box was activated by a second experimenter in another room, using a remote control. The remote control activated a motor in the box which caused the box-lid to flip over, bringing the train upright. Each train was illuminated with moving flashing lights.

During the experiment the experimenter interacted with the child who sat on a chair 50 cm directly opposite her. If the child was very young, he or she sat on the parent's lap and the parent kept their eyes closed. Pilot testing showed that autistic children's initial distractibility could be reduced by setting up a narrow table (200 cm × 53 cm) between the child and the experimenter with a story-book to facilitate the interaction. The experimenter used a combination of techniques to engage the child in eye contact (e.g. conversation, calling child's name, touching). At the point of eye-contact, the experimenter immediately reoriented her head and eyes approximately 90 degrees to fixate the box located to the left or right. This head turn marked the beginning of a trial. Each trial lasted 6 seconds and ended when the experimenter turned back to the child. The session was recorded with two separate video-cameras. Two full-face images of child's and experimenter's head and shoulders were combined on a split screen. The session consisted of a maximum of 28 trials and lasted approximately 10 minutes.

As in Corkum and Moore's procedure, there were three phases in each experimental session. Phase 1 (Baseline) allowed assessment of the child's spontaneous gaze-following. This phase comprised four trials in which the experimenter turned her head 90 degrees to the side (two trials each side) towards one of the boxes. The targets inside the boxes remained inactive and invisible to the child during these trials. Phase II (Shaping), also consisted of four trials (two to each side). On each trial, regardless of whether the child followed gaze or not, the observer in the other room activated the target to which the experimenter turned, approximately 2 seconds after the start of her head turn. This phase assisted in shaping the gaze-following response. Phase III (Test) consisted of a maximum of 20 trials (10 to each side) in which the activation of the train was purely contingent on the child matching the direction to which the experimenter turned. Although a maximum of 20 Test trials was possible, the exact length of this Test Phase varied due to individual attention and performance.

Observation and interview. As far as was possible, all the children who participated in the experiment also took part in the observation and parent interview. However, due to difficulties in co-ordinating the tasks, some children and parents could not participate, resulting in smaller samples. For the observation the samples comprised 13 children with autism and 14 typically developing children. For the interview, samples comprised 17 autistic and 13 typically developing children.

The *observation* was based on work by Loveland and Landry (1986), Mundy et al. (1986), and Rheingold, Hay, and West (1976). It comprised a series of unstructured and semi-structured play tasks designed to measure initiating and response behaviours. Only one section of the observation session is reported here. This section took place immediately after the first 5 minutes of spontaneous play at the beginning of the observation session. At the end of this 5-minute period, the researcher (a different adult from the one involved in the conditioning experiment), rose from her position behind the child and sat on the other side of the table, opposite the child. After clearing the toys from the table, she then carried out a series of actions to direct the child's attention to different objects (puppets, dolls, toys, and colourful posters) that were either hanging on the walls of the room or on the floor, out of the child's reach. All objects were positioned to the left or right of the child. Four types of attention-directing actions were used; (1) head turn without any other cues, (2) head turn plus pointing gesture only, (3) head turn plus pointing gesture plus verbalisation "Look", (4) head turn plus pointing gesture plus verbalisation—name of object. Each action was separated by intervals of play with toys, to keep the situation as naturalistic as possible. The experimenter ensured that she had the child's eye contact before starting each trial. Two trials were carried out for each action, resulting in eight possible trials, two without cues (head turn only) and six with head turn and cues (pointing, "Look", name of object). All the gestures to the left of the child were completed first, followed by the gestures to the right. The observation session was recorded by two separate concealed video-cameras. One camera recorded the entire scene with images of the faces and upper bodies of child and adult; the second gave a close-up image of the child's face. The two images were combined on a horizontal split screen.

Whilst the observation was taking place, the parent was asked questions about their child's gaze-following behaviour in the *parent interview*. These questions were part of a larger interview designed by Reddy (unpublished), with modifications made to include details of gaze-following. The exact wording of these questions was as follows.

(1) If you see an object of interest and (a) turn to look at it, (b) point at it, (c) say "look", (d) name it, how does your child respond?
(2) When did this response first begin (age)?

One week before the interview, the parent was sent a copy of the interview schedule to give them an opportunity to think about the questions and observe the child. The interview was then conducted by the researcher with the written questions in front of the parent. The interview was recorded by tape-recorder.

Scoring

Experiment. The videotapes from the experiment were coded by an independent coder who was blind to the child's diagnosis and to the hypothesis of the study. The coder had no previous experience of the children in the study and no knowledge of autism. For each trial, the direction of the child's first head turn was scored. The head turn was designated a "match" if the child turned towards the correct target, and a "mismatch" if he or she turned towards the incorrect target. Any head turns in other than the horizontal plane were ignored in accordance with coding procedures of Butterworth and Cochran (1980) and Corkum and Moore (1995). Additional head turns within each trial (i.e. number of head turns made by child in addition to the first head turn during any trial) were also scored in accordance with the procedure described by Moore (1997).

As in the Corkum and Moore procedure, the 28 trials in the experiment were divided into 4 trial blocks: a Baseline block, a Training block, and 5 Test blocks. Children were assigned difference scores (match minus mismatch scores) for each block. Because the number of test blocks completed varied across participants, Corkum and Moore's procedure was applied. This involved analysing three critical blocks; Baseline, First Test, and Last Test block. The First Test block was the first four trials after the Training Phase. The Last Test block was designated as the end of the four trial blocks in which the child demonstrated reliable gaze-following (a run of five consecutive trials with matched responses—see Corkum & Moore). If reliable gaze-following according to this criterion did not occur, scoring continued to the point when the child or experimenter stopped the experiment and the Last Test block was the last four trials completed by the child. Reliability coding was carried out by a second independent coder on the data for 12 subjects (33%) randomly selected from the autism group, as these data were predicted to be more unreliable. This resulted in a significant Cohen's kappa coefficient (.73; $p < .001$).

In addition to this scoring, a third independent coder scored children's checking behaviour during the spontaneous trials of the Baseline block. A subject was scored as checking if he or she looked back at the experimenter's face (after following experimenter's head movement) at least once, during any of the four 6-sec trials on any of the four trials in the Baseline block.

Observation and interview. Videotapes and audiotapes were coded by two different coders (neither involved in the coding of experiment) who were also blind to the hypothesis of the study and the diagnosis of the children. Instructions for coding both methods involved coders making a judgement about whether the child followed an adult's direction of gaze and head turn in four different situations; (1) when the adult turned their head only, (2) when they turned their head and pointed, (3) when they turned their head and pointed with the verbalisation "Look", (4) when they turned their head and pointed, verbalising the name of the object. For the observation, instructions to the coder included recording child's head turn responses as match, mismatch, and no response. Each of the four attention direction actions (head turn, point, point with "Look", point with name of object) was designed to be carried out twice, once to the left and once to the right, resulting in a maximum score of 2 for each two-trial action. For the interview, each child was scored from parent report according to whether they usually followed gaze in response to either head turn, point, point with "Look", or point with name of object. Reliability coding of 100% of the videotapes and audiotapes for both observation and interview was conducted by a second coder. Reliability for both methods was high (Observation: Cohen's kappa coefficient = .88; Interview; Cohen's kappa coefficient = .92, both $p < .001$).

Results

Experiment

As in Corkum and Moore's (1995) experiment, not all children completed 20 trials of the Test session due to individual attention and performance factors. Six of the 34 children had a reduced Test Phase for this reason (3 had 16 trials, 1 had 12 trials, 2 had 8 trials). All the children who completed less than 20 test trials were children with autism. This difference in Test Phase length was dealt with according to Corkum and Moore's method of categorising the session for analysis using three critical blocks; Baseline, First, and Last).

Initial inspection of the data for spontaneous gaze-following (Baseline), showed that VMA was related to children's performance in following other's head and gaze. However, the relationship between VMA and gaze-following was quite different for the autism group and for the typical development group. There was a positive correlation between the Baseline difference score and VMA for the autism group (Spearman's *rho* .72; $p < .001$) compared with a negative correlation between Baseline score and VMA for the typical development group (Spearman's *rho* $-.50$, $p < .099$). It was therefore decided to carry out the analysis in two stages.

In the first stage, all scores were analysed independent of CA and MA (see Table 2). A 2 (Group) × 3 (Block) repeated measures ANOVA for all subjects showed a significant difference between autistic and controls [$F(1,32) = 8.66$, $p < .006$]. The Block effect did not reach significance [$F(2,64) = 2.79$, $p < .069$]. There was no interaction between Group and Block. Post hoc tests showed that the mean autism score was significantly lower for Last Test block only [$t(32) = -2.60$, $p < .01$] but not for Baseline and First Test block [$t(32) = -1.47$, 1.70 respectively). Both autism and control groups had difference scores above 2 for every block (see Table 2). For both groups this was significantly different from 0 for all three blocks (one-sample *t*-tests, $p < .0001$ for each block for both groups).

In order to look at the pattern of performance, the scores for each child were categorised according to Corkum and Moore's scheme. According to this category analysis, children who reach a difference score of two or more during the Baseline Phase and go on to reach a criterion of five consecutive target responses during the

Table 2
Mean Difference Scores (SD) for Each Group During Each Block of Testing in Experiment

Group	Block		
	Baseline	First Test	Last Test
Autistic	2.29	2.82	2.53
	(1.10)	(1.42)	(1.74)
Nonautistic	2.88	3.53	3.71
	(1.22)	(0.94)	(0.69)

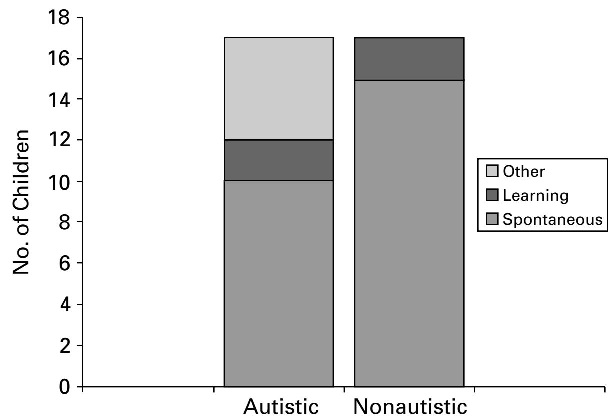

Figure 1. Category analysis of response patterns in autistic and nonautistic groups.

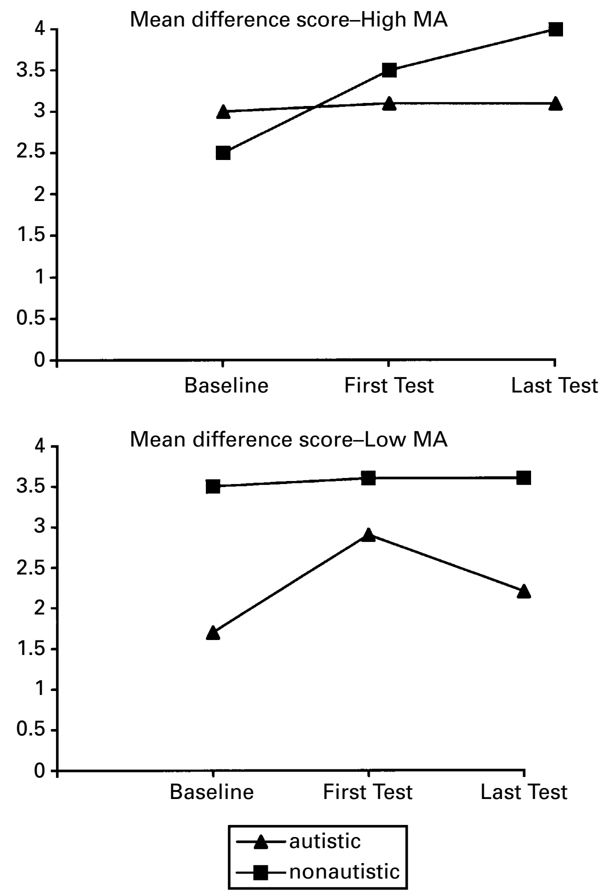

Figure 2. Mean difference scores for children with verbal mental age above and below 48 months.

Test Phase are classified as Spontaneous Gaze-followers. Children who fail to reach the Baseline criterion but go on to meet the Test Phase criterion of five consecutive target responses are classified as Learners. All other patterns are classified as Other. This included the Perseverating pattern, in which the child fails the Baseline and Test Phase criteria but makes a majority (70%) of head turns in the same direction or three or more sequences of three or more consecutive turns in the same direction. Figure 1 showed that 10 autistic children (59%) were spontaneous gaze-followers compared with 15 (88%) typically developing children. This difference did not quite reach significance, however [$\chi^2(1) = 3.77, p = .059$]. There were very few children in either group with a response pattern in the Learning category (two Autism, two Typical development) and, of the five autistic children in the "Other" category, none had a perseverating pattern. Instead, three of these five met the Baseline criterion but failed to meet criterion in the Test Phase. If these 3 are added to the group of 10 Spontaneous Gaze-followers who sustained their responses in the Test Phase, this makes a total of 76% autistic children who followed gaze in the Baseline Phase.

In the second stage of the analysis, the effects of verbal mental age, chronological age, and performance mental age were examined. Subsequent analyses used VMA as a blocking factor. To keep sample sizes similar (note that sample sizes were affected by missing MA scores for one child with autism and five controls), data were split above and below VMA of 48 months, the mental age nearest to the median for each group. Analysis for performance mental age (PMA) was conducted separately. As Fig. 2 shows, both typically developing and children with autism in the high VMA group had high scores on every block. Category analysis of these children showed that every child with autism in the high VMA group (7/7) and all but one typically developing child (5/6) had a Spontaneous Gaze-following pattern. The same pattern was also found for typically developing children in the low VMA group. All had a Spontaneous pattern. In contrast, children with autism in the low VMA group had lower Baseline scores (mean = 1.66). They significantly improved after training [First Test block, mean 2.88, $t(8) = -2.48$, $p < .04$] but did not sustain performance, reducing to mean of 2.22 for Last Test [$t(8) = 1.26$, $p =$ .84]. Category analysis showed that only three of nine children with autism had Spontaneous Gaze-following patterns. The remaining six had either a Learning pattern (two children) or Other pattern (four children). Two of the four who showed Other patterns had reached Baseline criterion but not Test Phase criterion. None showed a Perseverating pattern.

To assess the relative effect of VMA, PMA, and CA on spontaneous gaze-following (difference score in Baseline Phase), multiple regression analyses were run separately for each group. For each analysis, standard regression was followed by backward stepwise regression. For the first analysis involving CA and VMA, the overall regression equation accounted for .68 of the variance for the autism group and .59 of the variance of the nonautism group. VMA explained more of the variance than CA. For the autism group, VMA significantly predicted Baseline score [$F(15) = 12.24$, $p < .004$; *Beta* .68] and for the typical development group, decreased VMA significantly predicted the score [$F(11) = 5.52$, $p < .04$; *Beta* $-.59$]. The second analysis involved VMA, PMA, and CA. PMA scores were available only for the autistic group. VMA and PMA were highly correlated ($r = .73$, $p < .002$). The overall regression equation accounted for .65 of the variance. PMA explained more of the variance than VMA or CA [$F(14) =$ 16.70, $p < .001$; *Beta*, .195 for CA, .284 for VMA, and .552 for PMA].

All the analyses reported thus far have used Corkum and Moore's criterion of five consecutive responses, originally selected as a measure that gives an estimate of probability at $p < .05$. As some children with autism had difficulty sustaining attention across five test trials, however, we also tested whether children with low VMA might show some ability to follow gaze if a less stringent criterion was used. Children were rescored as Spontaneous Gaze-followers if they achieved a difference score of 2 or more in the Baseline Phase and a difference score of 2 or more in the First Test block. A Learning pattern using this more lenient criterion was scored where a difference score of less than 2 was achieved for the Baseline Phase but more than 2 for the First Test block. All other patterns were coded Other. This recategorisation made the original results clearer. Amongst children with high VMA, 6 of 7 (86%) with autism and 5 of 6 (83%) typically developing, every child but one showed a Spontaneous Gaze-following pattern. There were no "Learners". Amongst children with low VMA, every typically developing child had a spontaneous pattern (100%) but most children with autism did not. Using the new criterion, 4 (44%) children with autism were categorised as Learners and 4 (instead of 3 using the previous criterion) as Spontaneous Gaze-followers, with only 1 (11%) child showing an Other pattern. Results of this revised category analysis were supported by an analysis which used scores of Baseline, First and Second Test blocks for the low VMA group only. Results of a 2 (Group) by 3 (Block) ANOVA for the low VMA group only showed that (low VMA) typically developing children have significantly higher difference scores than children with autism [$F(1,13) = 10.02$, $p < .007$]. There were no other significant effects.

Checking behaviour. Analysis of checking behaviour (any trial in Baseline block), by Spontaneous Gaze-followers (original analysis), showed that 5 children with autism (50%) and 11 typically developing children (73%) looked back to the experimenter to check their face. This difference was not significant [$\chi^2(1) = 1.148$, $p = .42$]. Separate analysis of high and low VMA groups showed that although more typically developing children than children with autism checked gaze in both groups, the difference was not significant for either group (Low VMA: Fisher's Exact Probability Test, $p = .277$; High VMA: Fisher's Exact, $p = .559$).

Within-trial head turns. After the child's initial head turn, few subsequent within-trial head turns were made by either group. In any block (Baseline, First, and Last), the maximum mean for typically developing children was 0.94 (*SD* 1.6) and for children with autism 1.52 (*SD* 1.9). There was no difference between autistic and typically developing gaze-followers in the total number of these head turns [$t(23) = 1.35$, $p = .19$]. No other significant differences were found when high and low MA groups were analysed separately.

Noncooperating children. Two children with autism (both low VMA) did not cooperate with the Baseline trials but did complete the subsequent trials (both completed 20 Test trials). Both had difference scores of 4 for every Test block they completed. Had they cooperated with the Baseline Block they would have been categorised as either Learning or Spontaneous.

Observation

Coding of videotapes revealed that it had not been possible during the session to give children all four types of action. Ten children had data missing for Action 4, (pointing and naming the object) and eight children had data missing for Action 2 (pointing). However, every child except for one child with autism was tested on both trials of Action 1 (head turn without cues) and all children were tested on both trials of Action 3 (head turn, point and "Look"). Analysis is based on only these data, which provide a comparison between two trials of following head turn without cues and two trials with cues. Children were scored as gaze-following when they followed gaze correctly on both trials of each action (chance level is 25%). No child showed any mismatch responses.

As Table 3 shows, half the children with autism responded to head movement alone whereas the remainder responded only when additional cues were given. Within-subject analysis comparing no cue and cue conditions showed that this difference was significant for both groups together (11 vs. 0), McNemar's Test, $p < .001$. It was also significant for the autistic group, (6 vs. 0) McNemar's Test, $p < .03$ independently, and almost reached significance for the nonautistic group, (5 vs. 0) McNemar's Test, $p < .06$

Further analysis was carried out to obtain more detail of gaze-following ability when verbal and nonverbal cues were not involved (i.e. responses to head turn *without cues*). First, analysis of mental age showed a significant correlation between VMA and number of trials correct for the autism group (Spearman's *rho* = .612, $p < .045$) but not the typical development group (Spearman's *rho* = .231, $p < .47$). The correlation between PMA and number of trials correct (autism group only), however, did not reach significance (Spearman's *rho* = .56, $p < .07$). Second, analysis was made of the consistency in performance between experiment and observation. Initial analysis of gaze-followers in the Baseline Phase of the experiment (score of 2 or more for Baseline followed by five consecutive matches in the Test Phase) and gaze-followers in the observation (score of 2 for trials involving experimenter's head turn without cues) showed that in the typical development group, there was a consistency

Table 3
Percentage of Children Who Consistently Followed Gaze When Adult Turned Head (with and without Cues) During Observation

Group	Response category: Follows head	Follows head with cues	Total
Autistic			
%	50	50	100
N	6	6	12[a]
Nonautistic			
%	64	36	100
N	9	5	14[a]

[a] Four autistic children and three nonautistic children did not have an observation; one autistic child did not complete both trials of head turn condition.

between gaze-following in the experiment and the observation [10 children followed in both, 3 in the experiment only, and 1 in neither, $\chi^2(2) = 9.57, p > .008$]. In contrast, in the autism group, there was no consistency. Four children passed both, three failed both, three followed in experiment only, and two in the observation only [$\chi^2(3) = 0.66, p = .88$, n.s.]. This pattern of performance changed, however, when each group was analysed in terms of high and low VMA above/below 48 mths. In the autism group all but one child in the high VMA group (5/6) followed gaze in both methods but none (0/6) of the low VMA children did so. A similar pattern for the autism group was found when PMA was analysed above and below the median of 65 months. In contrast, in the typical development group, most children in both high VMA (5/6) and low VMA (4/6) groups followed gaze in both experiment and observation.

Parent Interview

All parents in both groups reported that their child would respond when the parent turned to look at something. However, the majority of parents of the autistic children reported that their child would only follow gaze when the parent accompanied their head turn with a *cue*. In fact, only one parent in this group (6%) reported that their child would follow gaze in response to head turn alone. In contrast, the majority of parents of typically developing children (62%) reported that their child would follow *without* any cue [$\chi^2(1) = 10.87, p < .002$, columns 2, 3, & 4 collapsed to avoid small expected frequencies]. As Table 4 shows, for most children with autism, parents stated that a verbal cue was needed to elicit a gaze-following response. This was not the case for the typical development group [group difference $\chi^2(1) = 13.27, p < .001$, columns 3 & 4 and 1 & 2 collapsed].

Over 75% of parents in each group remembered when their child started to follow gaze. As the preceding analysis and Table 4 shows, since parents of children with autism assume that their child would follow another's head turn alone, all but one parent (14) referred to the age when child started following pointing gestures and/or language cues. For the parents of typically developing children, eight referred to the start age for head turn and five to head turn accompanied by pointing gesture and/or language. Most recalled the age to the nearest few months but if the child was older, a wider age range was given. Data were divided into four time-bands. Table 5 shows that the majority of children with autism were reported to begin to follow gaze (with pointing/language) after the age of 4 years. In contrast, 12 of the 13 (92%) typically developing children were reported to begin before the age of 4 (one parent did not remember) (Fisher's Test $p < .002$). Further analysis showed no systematic associations between the age that gaze-following started and other variables such as VMA, PMA, or gaze-following performance in the experiment. The difference in months between each child's current CA and the age at which he or she was reported to have started gaze-following was not significantly different for the two groups (49.23 for autistic and 40.08 for typical development group, $p = .37$).

Table 4
Percentage of Children Who Follow Gaze When Adult Turns Head as Reported in Interview

Group	Response category				
	Follows head	Follows point	Follows point and "Look"	Follows point and obj. name	Total
Autistic					
%	6	12	70	12	100
N	1	2	12	2	17
Nonautistic					
%	61	23	8	8	100
N	8	3	1	1	13[a]

[a] Four parents in the nonautistic group were not interviewed.

Table 5
Percentage of Children with Autism Who Started to Follow Gaze (with or without Cues) at Different Ages According to Parent Interview

	Age at which child started to follow gaze			
	Before 48 mths	48 mths to 71 mths	After 72 mths	Can't remember
%	29	35	12	24
N	5	6	2	4

Discussion

This study arose out of two questions. The first asked to what extent children with autism have a gaze-following deficit. The second question asked whether the gaze-following ability in children can be improved by the use of targets and cues.

In addressing the first question, we aimed to examine more closely the assumption that children with autism fail to follow gaze. As other researchers have pointed out, it is possible to follow another person's gaze without taking into account their attention, or without even "sharing" attention or experience with that person (Perner, 1991; Povinelli & Eddy, 1996, 1997; Tomasello, 1995). Since an inability to represent or share another's attention is commonly regarded as the core of the joint attention impairment, it is not clear why one would predict difficulties of gaze-following in children with autism.

We investigated the extent to which autistic children have a gaze-following deficit using three different methods. As expected from previous research, group differences were found across all three methods. In general, children with autism followed another's head turn less than typically developing children. Yet surprisingly, a sizeable proportion of children with autism did follow gaze spontaneously; 59% in the experiment and 50% in the observation.

When the results were compared for high and low mental age children, however, it became clear that the ability to follow another's head turn and gaze was an ability largely confined to the high MA group only. Results for the experiment showed that all autistic children with VMAs over 48 months were spontaneous gaze-followers compared with one third of children in the low VMA group. Even when a more lenient category analysis was used, the majority of low VMA children still did not demonstrate spontaneous gaze-following. When the results for the experiment and observation were combined, most children with autism in the high VMA group, but none in the low VMA group, followed gaze in both methods.

These results suggest that all high VMA children with autism and a few low VMA children spontaneously orient to directional cues of head turn and eye movement. Are these children also sharing attention and representing their own and other's attention? We found that "gaze-followers" with autism in the experiment not only followed head turn and eye gaze, but half of them also checked back to the experimenter's face. Gaze-followers also made few additional head turns within trials, focusing instead on the target that the experimenter was looking at. Although gaze-checking and focus on target are not conclusive evidence for representing another's attentional state, it indicates that gaze-following behaviour, for some children with autism at least, involves something more than a simple orientation response to a directional cue. In contrast, the majority of low VMA children with autism seem unable to respond even at the lower level of response orientation.

How do these results relate to previous experimental and observational findings in autism research? Given the widely reported difficulties with joint attention, the results seem surprising. A closer look at the literature, however, shows two studies with evidence in support of our finding. DiLavore and Lord (1995), in a longitudinal study with preschool children, found that responses to an adult's pointing and/or gaze direction improve between the ages of 3 and 5 years. Mundy et al. (1994), in a cross-sectional study of preschool children, also showed clear developmental effects in children's responses to an experimenter's *pointing* gesture. Children with MA below 19 months were impaired relative to controls, whereas children with MA above 20 months were not. There are very few joint attention studies of school-aged children with autism. Leekam et al.'s (1997) results showed poor spontaneous gaze-following by older, higher MA children. In contrast, a re-examination of the data for two studies by Loveland and Landry (1986) and Landry and Loveland (1988) showed that children with MA above 38 months and expressive language ages above 20 months performed very well on gaze-following tasks but poorly on other measures, although data for all measures were reported together. A critical factor for demonstrating gaze-following ability might be the level of mental age reached. In our current study, for example, were a number of children with very high VMAs. Four of the seven children with autism in the High VMA group had VMAs above 72 months.

The results for our parent interview data showed a different pattern from the results for experiment and observation. Only the parent of one child with autism reported that their child would follow head turn only. There are several possible reasons for this discrepancy. One possibility is that children with autism, whatever their mental age, continue to have problems with gaze-following in various contexts but the laboratory settings provided here gave more optimal conditions for eliciting gaze-following. This suggests that gaze-following performance may be affected by experience in certain situations only. Another possibility is that these children are able to follow another person's gaze in different contexts but were very unresponsive when they were younger and parents still continue to use additional cues. The tendency for parents of autistic children to use strategies in which they act on objects to make them more perceptually salient has been previously reported in the literature (Bakeman & Adamson, 1984; McArthur & Adamson, 1996).

In the current study, parents of children with autism reported that the ability to follow gaze did not appear until years later than in typical development, even when salient cues (pointing or verbalising) were added. Even high MA children were not exempt from this late start. High MA children who were now likely to be gaze-followers, as shown by their performance in the experiment and observation, were reported not to have begun to follow gaze until after age 4. Although it might be argued that it is difficult to be accurate about such details given the age range and time lapse since these abilities have been observed, in fact there were no differences between the children with autism and typical development in this respect.

In addressing the second question, our purpose was to discover the extent to which the gaze-following response would be facilitated. It was predicted that, like normal infants, non-gaze-following children with autism would acquire a gaze-following response after training (i.e. exposure to targets) and would respond when cues are added (i.e. pointing and language). Since the higher MA children in this group are already following gaze, it is not possible to say anything about the effects of training or cues to facilitate performance. For the lower MA group, however, some speculative conclusions can be drawn, which await confirmation from larger samples. First, with respect to targets, the experimental results showed that low MA children who did not spontaneously follow gaze did initially benefit from the activation of rewarding targets contingent on the experimenter's head turn. The less stringent category analysis using the First Test and block revealed that 44% fell into this category. This result resembles the performance of some typically developing 8–11-month-old infants who follow gaze only when there are targets to look at (Corkum & Moore, 1995).

The fact that most low VMA children did not continue to improve beyond the First Test block, however, raises a question about the degree to which they could sustain this ability. An obvious explanation for this is that these children had a motivational deficit. If so, it is important to know what they may lack the motivation *for*. It is possible that low VMA children were unmotivated by the targets. Although the mean score for the training trials for low VMA children was high (3.42), and no different from any other group, perhaps children with low VMA lost interest in the targets. However, the most unmotivated children would presumably be the two uncooperative children who did not complete the spontaneous trials. Yet these two followed gaze on every trial once the targets appeared. Also, following participation in this experiment, all children were given a second task in which the same targets were activated without the experimenter's head turn. All children turned to the target on at least eight trials (unpublished data). This suggests that lack of motivation may lie more with engaging with the experimenter than with watching the target display.

Second, with respect to the facilitating effect of cues, evidence from the observation and parent interview showed that all children, including those who did not spontaneously follow head turn, followed gaze when cues were presented such as a pointing gesture and verbalisation "Look". This is a robust finding across both methods and across mental age and shows that children with autism are not incapable of spontaneously looking where someone else is looking, even if they do not follow head movement alone.

Some support for this finding appears in the literature. Loveland and Landry's studies showed that performance was *less* good when language ("Look at the…") was added. Yet DiLavore and Lord (1995) found a difference between complete (follows gaze) and partial (follows point) response behaviours in line with our own findings for the effect of cues. This result also closely resembles our previous finding (Leekam et al., 1997), showing that children with autism follow gaze when a linguistic instruction is given ("What am I looking at?") even if they do not follow gaze spontaneously. The result is also in agreement with infancy research showing that pointing (Butterworth & Grover, 1990) and language (Deak et al., 1997) are more effective cues for eliciting gaze-following responses in 10–20-month-olds than head turn alone. The pointing cue makes more explicit the spatial location the person is referring to and in infants this may be an important factor for improved performance. It is not clear whether autistic children are responding to cues in the same way, since the results of the parent interview suggest that it is the vocal cue that is most effective for autistic children. It is difficult to tell the extent to which vocal cues specify reference. Locke (1997) suggests that acoustic cues that accompany head turns do serve to specify reference for the blind child but empirical evidence separating visual from nonvisual cues is still needed to determine this.

To summarise, this study showed that a sizeable proportion of children with autism are able to follow another person's head turn. This ability, even if it is analysed at its lowest level of orienting to another's body movement, seems to be delayed. Despite this delay, the majority of children do acquire this response and the performance of the children with higher mental ages in this study was no different from typically developing children. In contrast, children with low mental age do not spontaneously orient to another's head movement but their performance does improve when cues and feedback from targets is provided.

What is the reason for this developmental delay in following head turn and eye direction? We suggest two possibilities. One is that the *initial* basic problem is *what to attend to*. Moore (in press) argues that the pattern of development in gaze-following found in normal infants may be explained by the emergence of endogenous attention control in the first year of life. This explains why infants up to 9 months do not follow head turn cues unless there are targets to be seen and why they do not follow eye as well as head direction until much later. Up until this time attentional responses rely on sensory stimulation external to the child (exogenous attention). If an analogy can be made for the development of gaze-following in autism this may explain why the use of targets and sensory salient cues (pointing and vocalising with head turn) are effective in eliciting more gaze-following responses from low-ability children.

In opposition to this view, it might be argued that children with autism know what to attend to as demonstrated by their obsessional interests. As yet, there are no longitudinal studies of the obsessional interests of children with autism. However, diagnostic reports show that when special interests are found in infants with autism, these often take the form of preoccupations with sensory stimuli such as lights and sounds (Wing, 1996). This might support the idea of an overdependence on sensory stimuli. Other evidence shows that when special interests occur (e.g. collecting or unusual fascination with particular objects) these are significantly more likely to appear in higher mental age children (Prior et al., in press), a pattern similar to the results shown here.

Another reason for the delay in gaze-following might be that children with autism fail to detect *what it is important to attend to*. In the case of gaze-following, one has to treat certain body parts (eyes, heads, arms) selectively, as having a signal function. To do this (as pointed out by an anonymous reviewer), the child needs to perform a kind of part-whole analysis, selecting a specific part of the body (e.g. the pointing arm) from the whole orienting system and treating it as significant. This cognitive ability, outlined by Piaget, is a development acquired at the end of the sensorimotor period at the onset of symbolic understanding. Evidence suggests that children with autism are good at selecting parts from within wholes (Shah & Frith, 1983) and are often preoccupied with parts of objects (DSM-IV; American Psychiatric Association, 1994). However, they may have a problem integrating parts with context, as shown by their performance with visual illusions (Happé, 1996). If a difficulty in relating parts to wholes may also explain their problems with responding to parts of the body, this would give further support for the claim of "central coherence" theory (Frith, 1989; Frith & Happé, 1994), that children with autism have weak coherence.

The results of this study also have implications for our understanding of the relation between joint attention and the emergence of language. Researchers have argued that gaze-following specifically has important implications for facilitating language development (Baron-Cohen et al., 1997). But as Landry and Loveland (1988, p. 632) point out, the nature and direction of the relationship between language and joint attention in autism is not clear. Landry and Loveland reported that many children in their study had advanced language but also had poor joint attention, and concluded that the language development of children with autism may not be built on preverbal joint attention skills, as it is for typically developing children. In our experiment, nonverbal mental age as well as verbal mental age correlated with test score for children with autism. It is possible that language is also developing independently of nonverbal joint attention and, in the case of autism, may even assist in helping joint attention to develop.

A similar explanation might apply to blind children, who do not have access to the same information as do other children. This may mean that there are alternative routes to language learning, which children with autism may also use. Landau (1997) suggests that both blind and sighted children have available a range of *non*visual information. The reliance on vocal cues, as reported by the parents of children with autism in this study, suggests a possible similarity between the way that children with visual impairment and children with autism might use such nonvisual information. Children may use nonvisual information to support joint attention and hence aid language development (e.g. mutual tactile exploration of objects with another while naming). Alternatively they may use information directly, without engaging in shared attention (e.g. auditory localisation directing attention to an object being named by someone). Further research is needed to help us to understand the way in which children take advantage of different kinds of information, in situations in which shared experiences both do and do not occur.

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