THE ROYAL SOCIETY

Published online 16 January 2003

Why is joint attention a pivotal skill in autism?

Tony Charman

Behavioural and Brain Sciences Unit, Institute of Child Health, 30 Guilford Street, London WC1N 1EH, UK (*t.charman@ich.ucl.ac.uk*)

Joint attention abilities play a crucial role in the development of autism. Impairments in joint attention are among the earliest signs of the disorder and joint attention skills relate to outcome, both in the 'natural course' of autism and through being targeted in early intervention programmes. In the current study, concurrent and longitudinal associations between joint attention and other social communication abilities measured in a sample of infants with autism and related pervasive developmental disorders at age 20 months, and language and symptom severity at age 42 months, were examined. Extending the findings from previous studies, joint attention ability was positively associated with language gains and (lower) social and communication symptoms, and imitation ability was also positively associated with later language. Some specificity in the association between different aspects of joint attention behaviours and outcome was found: declarative, triadic gaze switching predicted language and symptom severity but imperative, dyadic eye contact behaviours did not. Further, although joint attention was associated with later social and language symptoms it was unrelated to repetitive and stereotyped symptoms, suggesting the latter may have a separate developmental trajectory. Possible deficits in psychological and neurological processes that might underlie the impaired development of joint attention in autism are discussed.

Keywords: autism; joint attention; play; imitation; language; symptom severity

1. INTRODUCTION

(a) *The role of psychological theory in understanding autism*

Psychological theory helps us understand autism at two levels.[1] First, it describes and delineates, in psychological terms, the behaviours that characterize individuals with autism. Second, and more powerfully, it attempts to explain, at a psychological level, the underlying processes that contribute to the abnormal development seen in individuals with autism. Abnormal psychological processing is not the primary pathogenesis that 'causes' autism. It is well established that autism is a neurodevelopmental condition whose ultimate aetiology is due to the influence of genetic and other organic disruptions to brain development and organization (Lord & Bailey 2002). It is also likely that the behavioural phenotype encompassed by the label 'autism' and the broader autism spectrum disorders includes individuals with different and complex aetiologies. However, a 'dynamic systems approach' to neurodevelopmental disorders (Bishop 1997; Karmiloff-Smith 1997) highlights ways in which abnormal psychological development, consequent on abnormal brain development, can have secondary effects on later brain and psychological development and organization. Primary neurobiological deficits may impact on optimal behavioural responses and lead to secondary neurological and psychological disturbance, via the interaction of the developing brain system with the organization of input available to children from their processing of, and interaction with, the environment ('experience expectant neural development'; Greenough *et al.* 1987).

This paper summarizes the evidence base and presents new data that highlight the pivotal role that joint attention plays in the development of autism. Two outstanding questions are discussed:

(i) In what way might impairments in the development of joint attention have secondary effects on later development in autism?
(ii) What primary pathogenic processes at the psychological and neurological level might lead to impaired development of joint attention in autism?

'Pivotal' can refer both to 'acting as a fulcrum' and to 'being of crucial importance' or 'the thing on which progress depends' (Anonymous 1994). Both meanings are relevant to discussion of the pivotal role that joint attention plays in the psychopathology of autism. Evidence comes from several sources, including parental reports of the earliest recognized signs of abnormality, early videotapes of infants who later go on to receive a diagnosis of autism, attempts to prospectively screen for autism, longitudinal studies of early predictors of language and social outcome and intervention studies.

In typical development, joint attention behaviours emerge between 6 and 12 months and involve the triadic coordination or sharing ('*joint*ness'; Leekam & Moore 2001) of *attention* between the infant, another person, and an object or event (Bakeman & Adamson 1984). The term encompasses a complex of behavioural forms including gaze and point following, showing and pointing. A distinction has been made between two different functions that

One contribution of 14 to a Theme Issue 'Autism: mind and brain'.

joint attention behaviours serve. *Imperative* triadic exchanges serve an instrumental or requesting function, whereas *declarative* triadic exchanges serve to share awareness, or the experience, of an object or event (Gómez *et al.* 1993; Mundy *et al.* 1993). Individuals with autism are impaired in the development of both imperative and declarative acts, although impairments in the latter are more severe (Baron-Cohen 1989, 1993; Mundy *et al.* 1986, 1993; Ricks & Wing 1975; Sigman *et al.* 1986). More recently, it has been shown that the critical distinction may not be the imperative versus declarative level. Rather, the degree to which a child is monitoring and regulating the attention (or attitude) of the other person in relation to objects and events determines the severity of the deficit seen in autism (Mundy *et al.* 1994; Phillips *et al.* 1995; Charman 1998).

(b) *Evidence for the pivotal role of joint attention in the early development of autism*

The first line of evidence for the central role that joint attention plays in the development of autism comes from studies that have systematically elicited retrospective parental reports of early symptoms between 12 and 18 months (Ohta *et al.* 1987; Gillberg *et al.* 1990; Stone *et al.* 1994). There is some evidence of early abnormalities in sensory, motor and RSBs, and when such behaviours are present they are highly characteristic of autism (Rogers 2001; Charman & Baird 2002). However, most studies concur that the best discriminators at this age are likely to be the social and communicative impairments, in particular, joint attention behaviours such as eye contact, gaze monitoring and response to name (Stone *et al.* 1997; Charman 2000).

The second source of evidence is the retrospective analysis of home videos taken before children are diagnosed with autism. Adrien *et al.* (1993) found that within the first year children with autism showed impairments in social interaction, lack of social smile and facial expression, hypotonia and poor attention. In the second year of life, additional impairments included ignoring people, preference for aloneness, lack of eye contact and lack of appropriate gestures. In a study examining home videos taken at first birthday parties, Osterling & Dawson (1994) found that children with autism were less likely to look at others, to show an object or point to objects, and to orient to their name, compared with typically developing controls. In an extension of this study, Werner *et al.* (2000) found that in videotapes taken between eight and 10 months of age children with autism were differentiated from typically developing children on the basis of less frequent orienting to name. Baranek (1999) found that abnormalities in orientation to visual stimuli, aversion to touch and delayed response to name, all characterized autism (but not developmental delay or typical development) as early as at nine months of life. In summary, these studies suggest that alongside a lack of effect, and in a few cases sensory abnormalities, pre-verbal social communication and social orientating behaviours, including joint attention acts, are the most reliably identified early abnormalities (retrospectively) seen towards the end of the first year of life in children with autism.

Another demonstration of the importance of joint attention behaviours in the early development of autism comes from studies that have attempted to prospectively identify cases of autism using screening instruments (Baird *et al.* 2001). These have been applied both to general populations (Baron-Cohen *et al.* 1996; Baird *et al.* 2000; Dietz *et al.* 2001; Robins *et al.* 2001) and to referred and high-risk populations (Baron-Cohen *et al.* 1992; Scambler *et al.* 2001). Different aspects of giving, showing, following eye gaze, and producing and following points, form a key part of all the screens for autism developed thus far. In the CHAT screening study (Baird *et al.* 2000), two aspects of joint attention behaviour—a lack of gaze monitoring and a lack of pointing for interest—in combination with an absence of simple pretend play at 18 months of age, was highly predictive of autism. A proportion of the children prospectively identified had only failed (by parental report and health practitioner observation) the items asking about pointing for interest. An important caution is that although the CHAT screen had a high positive predictive value its sensitivity was moderate at best, identifying only 38% of cases. It may be that the majority of infants with autism did not show impairments in joint attention and play behaviours at this age (but might have shown other developmental impairments and abnormal behaviours not measured in the study). Alternatively, the threshold of impairment in these skills may have been set too high (the CHAT asked if children had *ever* produced such behaviours).

Several studies have examined the longitudinal associations between joint attention in the pre-school years and later language and social development. Mundy *et al.* (1990) found that joint attention behaviours (alternating gaze, pointing, showing and gaze following) measured at 45 months were associated with language ability 12 months later. Social interaction, requesting behaviour, and initial age, IQ and language ability were not associated with language at follow-up. Sigman & Ruskin (1999) found that responding to joint attention bids measured at the initial time-point was associated with gain in EL at age 12 years. Further, joint attention behaviours measured at 4 years of age were also associated with social and peer group behaviour 8 years later (Sigman & Ruskin 1999). Stone & Yoder (2001) reported a similar association between early joint attention ability and later EL ability from 2 to 4 years of age.

Another aspect of the pivotal role played by joint attention in the development of autism is demonstrated by evidence that intervention approaches that have placed an emphasis on the development of non-verbal social–communicative skills promote enhanced language and social development (Rogers & Lewis 1989; Koegel 2000; Lord 2000). Although few, if any, well-controlled randomized control trials exist, numerous small series case studies have suggested that promoting the NVC competence of children with autism enhances the communicative use of the language (Rollins *et al.* 1998; Kasari *et al.* 2001).

The convergence of these sources of evidence suggests that joint attention plays a critical role in the early development of autism. Impairments in joint attention behaviours are among the earliest abnormalities noticed in autism, becoming apparent around the end of the first year of life. Screening instruments that assess (among other things) joint attention behaviours can prospectively identify some cases of autism. Individual differences in joint attention ability relate to later language and social outcomes over time-periods as long as 8 years, and joint attention behaviours are emerging as a key target for psycho-educational approaches to early intervention. This does not mean that joint attention impairments 'cause' autism. However, it does suggest that joint attention is a critical 'downstream' effect of earlier brain psychopathology. Understanding why the development of joint attention skills is impaired in individuals with autism, and the mechanisms by which joint attention behaviours are related to later outcomes, are important future enterprises for psychological research.

(c) *The present study*

The present study took advantage of a small group of infants ($n = 18$) with autism and related pervasive developmental disorders prospectively identified in the CHAT screening study (Baron-Cohen *et al.* 1996, 2000; Baird *et al.* 2000). We have previously reported findings from a series of experimental tasks of joint attention, attention switching, imitation, play and empathy conducted at 20 months of age (Charman *et al.* 1997, 1998; Swettenham *et al.* 1998). In brief, the group of infants with autism and pervasive developmental disorder showed very low production of some behaviours, including empathic responding, pretend play, gaze switching and imitation, in contrast to infants with language delay. The present study reports on the longitudinal associations between performance on these experimental measures conducted in infancy, and language and behavioural outcomes (symptom severity) from a follow-up conducted when the children were aged 42 months.

Although the sample was relatively small, the study provides a unique contribution because the cohort is significantly younger than those previously studied. Previous studies with older samples of children have found positive longitudinal associations between early joint attention behaviour and later language. Consistent with the thesis that joint attention is a pivotal skill in the development of autism, we expected to replicate this finding with our younger sample but, in addition, made the prediction that joint attention ability would associate more strongly with language than imitation and play ability. Few studies have examined the association between early joint attention behaviours and later symptom severity but again consistent with our 'pivotal skill' thesis we predicted that early joint attention ability would be (negatively) associated with later symptom severity.

2. METHODS

(a) *Participants*

The participant characteristics are shown in table 1. Non-verbal ability was measured using the D and E scales of the Griffiths Scale of Infant Development (Griffiths 1986) at age 20 months, and either the Griffiths or the Leiter International Performance Scale (Leiter 1952) at age 42 months. A non-verbal IQ was calculated by dividing the age equivalent score by the child's chronological age (MA/CA). RL and EL abilities were assessed at both time-points using the Reynell Developmental Language Scales (Reynell 1985). At age 42 months, nine subjects met ICD-10 (World Health Organization 1993) criteria for autism and nine subjects met criteria for atypical autism or pervasive developmental disorder—unspecified (see Cox *et al.* (1999) for details of diagnostic assessments). Given the restricted sample size, we adopted an autism spectrum approach (Lord & Risi 1998) and results were analysed for the group as a whole.

Table 1. Age, non-verbal mental age, language scores and ADI-R scores of participants at both time points.

	time 1	time 2
	$n = 18$ mean (s.d.)	$n = 18$ mean (s.d.)
age in months	20.6 (1.3)	42.5 (3.6)
non-verbal IQ	80.6 (10.1)	83.6 (25.8)
EL[a] raw score	7.3 (3.5)	24.3 (10.5)
RL[b] raw score	4.8 (2.5)	24.9 (9.5)
RSI[c]	12.4 (6.3)	12.2 (7.0)
NVC[d]	9.4 (4.0)	8.8 (4.3)
RSB[e]	1.8 (1.4)	2.6 (1.8)

[a] Reynell EL score.
[b] Reynell RL score.
[c] Reciprocal social behaviour domain of the ADI-R.
[d] NVC domain of the ADI-R.
[e] RSB domain of the ADI-R.

(b) *Experimental measures conducted at age 20 months*

Full details of the experimental measures taken at age 20 months are given in Charman *et al.* (1997, 1998). For the present analyses, only the key variables entered into the cross-sectional and longitudinal analyses are described.

(i) *Spontaneous play task*

When the child entered the room the following sets of toys were available (all at once), spread out on the floor: a toy tea-set; a toy kitchen stove with miniature pots and pans, spoon, pieces of green sponge; and junk accessories (e.g. brick, straw, rawlplug, cotton-wool, cube, box) and conventional toy accessories (toy animals, cars, etc.). This combination of objects was based on studies by Baron-Cohen (1987) and Lewis & Boucher (1988). The child's parents and the experimenters remained seated and offered only minimal and non-specific responses to child-initiated approaches. Each child was filmed for 5 min. The presence of any functional and pretend play acts on a two-point scale (0 = no functional or pretend play; 1 = functional play; 2 = pretend play) was entered into the current analysis.

(ii) *Joint attention tasks*

Activated toy task

A series of three active toy tasks based on those described by Butterworth & Adamson-Macedo (1987) was conducted. The child stood or sat between their mother and the experimenter. A series of mechanical toys, designed to provoke an ambiguous response, that is, to provoke a mixture of attraction and uncertainty in the child, were placed one at a time onto the floor of the room 1–2 m from the child. The toys were a robot, which flashed, beeped and moved around in circular sweeps; a car that followed a circular path around the room; and a pig that made 'oinking' noises and shunted backwards and forwards. The toys were controlled by the experimenter. They were active for a period of 1 min, during which time they stopped and restarted twice. The proportion of trials on which the infant produced the key joint attention behaviour—a gaze switch between the toy and adult (experimenter or parent)—was entered into the current analysis.

Goal-detection tasks

A series of tasks described by Phillips *et al.* (1992) were conducted at different times throughout the testing session: (i) *The blocking task*: when the child was manually and visually engaged with a toy, the experimenter covered the child's hands with his own, preventing the child from further activity, and held the block for 5 s. This was repeated four times during the session. (ii) *The teasing task*: the experimenter offered the child a toy. When the child looked at the toy and began to reach out for it, the experimenter withdrew the toy and held it out of reach for 5 s. The experimenter then gave the toy to the child. This was repeated four times during the session. The key behaviour recorded on each trial was whether the child looked up towards the experimenter's eyes during the 5 s period immediately after the block or the tease. The teasing and blocking scores were highly intercorrelated ($r = 0.83$, $p < 0.001$). To reduce the number of variables entered into the analysis, a composite goal-detection task score of the proportion of trials in which the infant looked up towards the experimenter on the teasing and blocking trials combined, was entered into the analysis.

(iii) *Imitation*

The materials and method for the procedural imitation task followed those employed by Meltzoff (1988). The child sat opposite the experimenter. Four actions were modelled, all on objects designed to be unfamiliar to the child. Each act was performed three times. At the end of the modelling period (*ca.* 2 min in total), the objects were placed, in turn, in front of the child. One non-specific prompt ('What can you do with this?') was given if the child failed to pick up or manipulate the object at once. The response period was 20 s for each object. The proportion of trials on which the infant imitated the modelled action on the objects was entered into the current analysis.

(c) *Symptom severity measured at 20 months and 42 months*

The ADI (ADI-R; Lord *et al.* 1994) is a semi-structured, standardized diagnostic interview that asks parents about the current (and past) functioning. The ADI-R algorithm has three domains or clusters of items that map onto the three symptom areas by which autism is defined in ICD-10 (World Health Organization 1993): *Qualitative impairments in reciprocal social interaction* (*RSI* or Dimension B), *Impairments in verbal and NVC* (*VNVC* or Dimension C), and *Repetitive behaviours and stereotyped patterns* (*RSB* or Dimension D) (see Lord *et al.* (1994) for details). ADI-R interviews were conducted with parents of all children at both the initial (age 20 months) and follow-up (age 42 months) assessments. For the purposes of the present study the summary algorithm scores (that is, the items that correspond most closely to characteristic autism symptoms) for each of the three domains of behaviour will be entered into the analysis. None of the children had sufficient language (phrase speech) for the higher-level verbal items (e.g. stereotyped and idiosyncratic language) to be scored at 20 months, and only half had sufficient language at 42 months. Therefore, the NVC algorithm score was entered into the analysis for all participants. The ADI-R algorithm domain scores are shown in table 1.

Table 2. Scores for all experimental variables.

(*a*) number of children showing		
	n	%
no function or pretend play	4	22.2
functional play	12	66.7
pretend play	2	11.1
(*b*) percentage of trials key behaviours observed		
	mean (%)	s.d. (%)
gaze switch task	45.4	44.2
goal-detection task	37.7	42.2
imitation task	43.1	35.2

3. RESULTS

The raw scores of the experimental variables are presented in table 2. The strategy for analysis was to present zero-order correlations, followed by partial correlations with IQ at 20 months which were partialled out. Given the sample size, regression analysis was not conducted.

Concurrent associations between the experimental measures and the EL and RL ability at 20 months, and longitudinal associations with EL and RL at 42 months, are shown in table 3. Concurrently, only the correlation between gaze switching and RL was significant ($r = 0.54$, $p < 0.05$) and remained so when the effects of IQ were partialled out ($r = 0.52$, $p < 0.05$). Longitudinally, the presence of functional and pretend play at the initial assessment was not associated with language ability at 42 months. The proportion of trials in which a child's gaze switched in the joint attention task was significantly correlated with both EL ($r = 0.55$, $p < 0.05$) and RL ($r = 0.74$, $p < 0.001$). In contrast, the proportion of trials in which a child made eye contact in the goal-detection tasks was not associated with later language ability. Imitation scores were significantly correlated with RL ($r = 0.63$, $p < 0.01$). When initial IQ was partialled out, the correlations between gaze switches in the joint attention task and EL ($r = 0.54$, $p < 0.05$) and RL ($r = 0.74$, $p < 0.001$) remained significant. The partial correlation between imitation and RL was also significant ($r = 0.65$, $p < 0.01$).

Concurrent associations between the experimental measures and ADI-R symptom domain scores at 20 months and longitudinal associations with ADI-R scores at 42 months are shown in table 4. Concurrent performance on the play, gaze switch and imitation tasks was significantly (negatively) associated with 20-month symptom severity measured by the ADI-R algorithm domain scores. Several of these associations remained significant for play (NVC: $r = -0.61$, $p < 0.01$; RSB: $r = -0.53$, $p < 0.05$) and for gaze switch (RSI: $r = -0.80$, $p < 0.001$; NVC: $r = -0.59$, $p < 0.05$; RSB: $r = -0.69$, $p < 0.01$) when the effect of IQ was partialled out. Fewer associations were found between performance on the experimental measures at 20 months and symptom severity at 42 months. In the full correlations, performance on the gaze switch task was associated with scores on the RSI ($r = -0.51$, $p < 0.05$) and NVC

Table 3. Full and IQ-partialled correlations between the experimental measures and language at 20 and 42 months.

	20 months		42 months	
	EL	RL	EL	RL
(*a*) full correlations				
play	0.16	0.30	0.43	0.34
gaze switch	0.28	0.54*	0.55*	0.74***
goal-detection composite	−0.07	0.06	0.41	0.34
imitation	0.04	0.25	0.46	0.63**
(*b*) IQ-partialled correlations[a]				
play	0.16	0.29	0.42	0.33
gaze switch	0.28	0.52*	0.54*	0.74***
goal-detection composite	−0.09	0.00	0.40	0.32
imitation	0.02	0.18	0.47	0.65**

[a] IQ at 20 months partialled out.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Full and IQ-partialled correlations between the experimental measures and symptom severity at 20 and 42 months.

	20 months			42 months		
	RSI[b]	NVC[c]	RSB[d]	RSI[b]	NVC[c]	RSB[d]
(*a*) full correlations						
play	−0.45	−0.59*	−0.52*	−0.08	−0.27	−0.15
gaze switch	−0.81	−0.62**	−0.65**	−0.51*	−0.66**	−0.30
goal-detection composite	−0.14	−0.42	−0.38	−0.32	−0.12	−0.27
imitation	−0.23	−0.48*	−0.29	−0.37	−0.52*	−0.14
(*b*) IQ-partialled correlations[a]						
play	0.44	−0.61**	−0.53*	−0.03	−0.25	−0.14
gaze switch	−0.80***	−0.59*	−0.69**	−0.46	−0.65**	−0.27
goal-detection composite	−0.10	−0.35	−0.41	−0.22	0.02	−0.23
imitation	−0.16	−0.31	−0.38	−0.14	−0.34	−0.05

[a] IQ at 20 months partialled out.
[b] Reciprocal social behaviour domain of the ADI-R.
[c] NVC domain of the ADI-R.
[d] RSB domain of the ADI-R.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

($r = -0.66$, $p < 0.01$) domains of the ADI-R and imitation was associated with NVC ($r = -0.52$, $p < 0.05$). When the effect of IQ was partialled out, only one correlation remained significant: performance on the gaze switch task was associated with NVC score at 42 months ($r = -0.65$, $p < 0.01$), although the correlation between gaze switch and RSI fell only just short of significance ($r = -0.46$, $p = 0.06$). Performance on the goal-detection tasks was not associated with symptom severity scores cross-sectionally or longitudinally.

4. DISCUSSION

A clear pattern of findings emerged in terms of the concurrent and longitudinal associations between the experimental measures at 20 months and language ability and symptom severity at 20 and 42 months. One measure of joint attention (frequency of gaze switches in the active toy task) and the measure of imitation were associated with language ability, both concurrently and longitudinally for the former, but only longitudinally for the latter. By contrast, the other joint attention measure (proportion of trials in which a child looked to the adult in the goal-detection tasks) and the measure of functional and pretend play were not associated with language ability either concurrently or longitudinally. The play, gaze switch and imitation measures were all associated with measures of symptom severity, across all three domains of symptoms, concurrently at 20 months. However, only gaze switches on the active toy task and imitation were associated with symptom severity at 42 months. The gaze switch measure was more robustly associated with later symptom severity than imitation, in that it was associated with both the RSI and the NVC ADI-R domains, and these associations held up when the effect of initial IQ was controlled. By contrast, none of the experimental measures taken at 20 months was associated with severity of RSB measured by the ADI-R at 42 months.

These results extend downwards in age the findings of previous studies that have shown longitudinal associations between early social communication behaviours and later language ability in samples seen first in the third and fourth years of life (Mundy *et al.* 1990; Stone *et al.* 1997; Sigman & Ruskin 1999; Stone & Yoder 2001). This demonstrates that within the present sample of infants with autism individual differences in early social communication skills relate to one critical outcome measure: language ability. They also extend previous findings by examining longitudinal associations with symptom severity as well as language ability. That is, the greater the facility a child demonstrated in gaze switching during the active toy task at 20 months of age, the less severe were that child's social and communication symptoms at 42 months. This is consistent with a recent finding that an early joint attention behaviour (looking at an object held out by other), rated retrospectively from home videos of first birthday parties, was associated with symptom severity (rated on the Childhood Autism Rating Scale; Schopler *et al.* (1980)) at age 5 years (Osterling *et al.* 2002). The findings are also consistent with many studies that have demonstrated longitudinal associations between joint attention abilities, including proto-declarative pointing, following eye gaze and pointing, and language learning and later language ability in typically developing infants (Bates *et al.* 1979; Tomasello & Farrar 1986; Mundy & Gomes 1996; Carpenter *et al.* 1998).

Taken together, this pattern of findings provides further support for the thesis that joint attention is a pivotal skill in autism. Only joint attention abilities were related to both later language ability and symptom levels. Further, the present study demonstrates that the pivotal role of joint attention can be demonstrated in infants with autism, representing the youngest cohort of children with autism studied to date. However, although one measure of joint attention (gaze switches in the active toy task) was associated with later language and symptom severity, another measure of joint attention (looks to the experimenter in the blocking and teasing tasks) was not. This suggests that the underlying competencies tapped by the two tasks may differ, despite the fact that both have been described under the umbrella term 'joint attention tasks'. Previously, it has been suggested that looking to the experimenter in the blocking and teasing tasks might be a questioning ('What are you doing?'; Phillips *et al.* (1992)) or an imperative communicative act ('Give me that back!'; Charman 1998). This differs in both nature and form from the more clear declarative act involved in switching gaze between the active toy and an adult in the active toy task. One suggestion is that the triangulation and shifting of attention in this task may have a more direct social goal ('Look at that!') and this may involve sharing one's mental state of perception with others.

An analysis of the differences in both the form and the function of the two joint attention tasks is shown in figure 1. Both forms of joint attention behaviour involve eye contact (or at least looking to an adult's face) and a shift in attention, and both might have an imperative function ('Start up that toy!' in the gaze-switch task; 'Give me that back!' in the goal-detection task). The aspects of *communicative form* that characterize the gaze switch but not the goal-detection response include the distal position of the object and the triadic nature of attention focus (child–toy–adult). The aspects of *communicative function* that characterize the gaze switch, but not the goal-detection task, are that the former but not the latter involves shared attention and a directly referential goal ('Look at that!'). It has been suggested that these aspects—shared attention and communicative reference—of joint attention behaviour are early evidence for the infant's emerging understanding of others as intentional agents, and that understanding the mental state of attention in episodes of shared attention may be a precursor to understanding mental states or 'theory of mind' ability (Baron-Cohen 1993; Tomasello 1995). Some empirical evidence from typically developing children supports this claim (see Charman *et al.* 2000). The present study demonstrates that individual differences in these specific aspects of joint attention in infants with autism are related to later language ability and social and communication symptoms more than other joint attention skills and imitation and play.

	gaze switch task	goal detection task
eye contact	✓	✓
shift in attention	✓	✓
distal	✓	✗
request/demand	?	?
share attention	✓	?
triadic	✓	✗

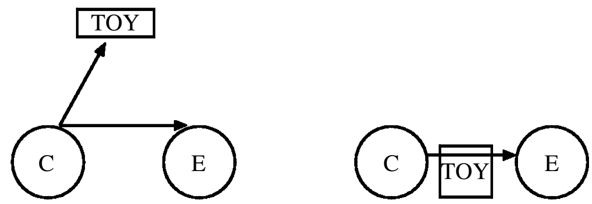

Figure 1. Differences in the form and function of joint attention behaviours in the gaze-switching and goal-detection tasks.

One other notable finding emerged. Although early joint attention and imitation abilities were related to both later language and symptom severity (above and beyond initial IQ), this only held for social and communication symptoms and not for repetitive behaviours and stereotyped patterns. This suggests that the developmental trajectories, and perhaps at a psychological level the underlying psychopathology, of these symptom domains may be separable. There is other evidence to suggest that this might be the case (see Charman & Swettenham 2001, for a review). Tanguay *et al.* (1998), for example, found that three factors derived from factor analysis of the social and communication items on the ADI-R ('affective reciprocity', 'joint attention' and 'theory of mind') did not correlate with scores on the repetitive behaviours and stereotyped interests ADI-R domain score. At least two studies have found that RSBs were identified less consistently in the second and third years of life compared with older samples of 4- and 5-year-old children with autism (see Cox *et al.* 1999; Stone *et al.* 1999). Consistent with this, two recent studies have found social communication impairments (including in joint attention) but not executive function deficits in 3-year-olds with autism relative to controls, in contrast to studies with school-age children with autism (see Griffith *et al.* 1999; Dawson *et al.* 2002). It is possible that in at least a subgroup of children with autism, repetitive, restricted and stereotyped abnormalities only begin to emerge in children with autism after infancy, later than the social and communication deficits are apparent.

Thus, although joint attention may be a pivotal skill in the development of individuals with autism, it may not be related to RSBs and restricted interests, which may be due to different underlying pathology at both the psychological and neurological level. It is not well understood how the social and communication symptoms in autism 'hang together' with the repetitive and stereotyped symptoms. This has implications both for our understanding of autism and for interventions. Whereas there is evidence that intervention approaches that place an emphasis on the development of non-verbal social–communicative skills promote enhanced language and social development (Rogers & Lewis 1989; Koegel 2000; Lord 2000; Kasari *et al.* 2001), we do not know if such approaches have a direct effect on RSBs. Although some of the latter may be secondary to communication difficulties they might also be expected to ameliorate as communication improves. However, direct interventions that target RSBs may be required (National Research Council 2001).

(a) *What are the origins of the joint attention deficit in autism?*

Much theoretical interest has focused on the role of joint attention behaviours as 'precursors' to later language (Tomasello 1995) and theory of mind development (Charman *et al.* 2000) in both typically developing children and children with autism. Acting as a 'precursor' involves either joint attention growing or transforming into language or theory of mind ability (i.e. it is an earlier form of these behaviours) or via experiences gained through the precursor behaviour (e.g. jointly attending to events in the world) the child acquires the later abilities. However, recognition that joint attention is not a starting point but merely a staging post in early social communicative development, and hence a 'postcursor' of earlier psychological and developmental processes (Tomasello 1995), focuses attention on what earlier impairments underlie the impaired development of joint attention skills in autism. Several candidate precursors have been suggested.

Using a paradigm measuring spontaneous attention switching during free play, Swettenham *et al.* (1998) found that, compared with controls, infants with autism looked less and for shorter duration at people, and more and for longer duration at objects. They also switched attention less frequently between social and non-social stimuli. This mirrors recent findings using a sophisticated eye-tracking methodology to examine where adults with autism look when watching film of social interactions (Klin *et al.* 2002*b*). Thus, individuals with autism (from a very early age) may have less exposure to people and the facial, gestural and eye gaze information that, in the typical case, draw them into social interaction and an understanding of the social world. In one sense, this reduced exposure to social information means that they are less 'expert' in social interactions than typically developing children. What might underlie this preference for directing attention to objects rather than to people?

Mundy and colleagues have proposed a 'social orienting' model of autistic pathology, whereby disturbances to frontally mediated neuroaffective motivation systems, that serve to prioritize social information processing, are apparent in development in advance of cognition as the primary regulator of behaviour (Mundy 1995; Mundy & Neal 2001). Dawson and colleagues have developed a similar account and provided experimental evidence of a deficit in social orienting in pre-school children with autism (Dawson & Lewy 1989; Dawson *et al.* 1998; see also Hobson 1993). Consistent with this account, Leekam *et al.* (2000) found that children with autism were unimpaired in low-level exogenous orienting to objects but they were impaired in exogenous orienting to a social cue (a head turn), and the latter was strongly related to joint attention behaviour (gaze following). This suggests that impairments in dyadic social engagement may be present in autism and may relate to the triadic social engagement impairments, most notably in joint attention behaviours (Leekam & Moore 2001). Under such accounts, primary neurobiological deficits that underlie impaired social orienting impact on optimal behavioural responses from as early as the first few months of life. This may lead to secondary neurological (and later psychological) disturbance via the interaction of the developing brain system with the organization of social input available to the children from their processing of, and interaction with, the environment ('experience expectant neural development'; Greenough *et al.* 1987) (see Mundy & Crowson 1997; Mundy & Neal 2001).

Another clue as to what impairments might underlie disturbances in joint attention behaviours in autism is provided by a secondary finding from the study of Dawson *et al.* (1998). Although the impairment in orienting found in children with autism was greatest for social stimuli (e.g. name called), they also showed impairments in orienting to non-social stimuli (e.g. jack-in-the-box). Results from studies examining attention orienting to non-social stimuli are mixed, with some studies finding slow spatial orienting to cues implicating cerebella dysfunction (Townsend *et al.* 1996) and others finding no deficit in automatic shifts of attention, but impairments in suppression of context-inappropriate responses implicating executive brain systems in the prefrontal and parietal cortex (Minshew *et al.* 1999). Other, more recent, lines of research suggest that the fundamental cognitive impairments that underlie these abnormalities might be at a more basic, low-level perceptual processing level (Happé 1999; Plaisted *et al.* 1999; Milne *et al.* 2002) or at the level of processing and understanding emotions (Baron-Cohen *et al.* 2000; Klin *et al.* 2002*a*).

The association between executive deficits and joint attention impairments has been directly explored in several recent studies of 3- and 4-year-old children with autism. As noted above, two recent studies have found no executive function deficits in 3 year olds with autism relative to controls, in contrast to studies with school-age children (see Griffith *et al.* 1999; Dawson *et al.* 2002). Both studies also examined the longitudinal associations between executive measures and joint attention. Griffith *et al.* (1999) found that performance on a spatial reversal task at age 3 years was associated with joint attention ability at age 4 years (but not vice versa) for children with autism but not for controls. Dawson *et al.* (2002) found that tasks tapping ventromedial but not dorsolateral prefrontal function were correlated with joint attention ability. They suggested that impairments in rule learning regarding the relations between stimuli and reward that is mediated by the ventromedial system may underlie the deficits in the development of joint attention (and later theory of mind) abilities in autism.

Even when these developmental processes are better understood, the need to study and understand joint attention and other early social communication impairments in autism will not disappear. The pivotal role that joint attention appears to play in the course and outcome of development for individuals with autism, and its potential as a target for intervention, will remain, whatever its neurological and psychological antecedents. One example is a recent study by Siller & Sigman (2002) who found that individual differences in the degree to which mothers synchronized their focus of attention with that of their child were associated with child language gains up to 16 years later. The authors suggest several mechanisms that may underlie this association. These include providing attentional, social and language experiences that partly compensate for the child's attentional impairments, providing a more consistent model of being an agent directing attention (and having intentions) in relation to objects and events in the world, or simply being a more fun and motivational partner in social exchanges (Siller & Sigman 2002). Understanding how early psychopathological processes affect joint attention ability, and what the mechanism of transmission is of the associations identified between joint attention and later social and language development, remain important goals for psychological research into autism.

The author is grateful to his research collaborators on the CHAT project for many discussions over the years that have helped develop and inform his views on this topic: Simon Baron-Cohen, Gillian Baird, Antony Cox, John Swettenham, Auriol Drew and Sally Wheelwright.

ENDNOTE

[1]For reasons of parsimony the term 'autism' will be used throughout to describe individuals with autism and the related 'pervasive developmental disorders' described in DSM-IV (American Psychiatric Association 1994) and ICD-10 (World Health Organization 1993), commonly referred to as 'autism spectrum disorders'.

REFERENCES

Adrien, J. L., Lenoir, P., Martineau, J., Perrot, A., Hameury, L., Larmande, C. & Sauvage, D. 1993 Blind ratings of early symptoms of autism based upon family home movies. *J. Am. Acad. Child Adol. Psychiat.* **32**, 617–626.

American Psychiatric Association 1994 *Diagnostic and statistical manual of mental disorders, (DSM-IV)*, 4th edn. Washington, DC: American Psychiatric Association.

Anonymous 1994 *Collins English dictionary*, 3rd edn. Glasgow: Harper Collins.

Baird, G., Charman, T., Baron-Cohen, S., Cox, A., Swettenham, J., Wheelwright, S. & Drew, A. 2000 A screening instrument for autism at 18 month of age: a six-year follow-up study. *J. Am. Acad. Child Adol. Psychiat.* **39**, 694–702.

Baird, G., Charman, T., Cox, A., Baron-Cohen, S., Swettenham, J., Wheelwright, S. & Drew, A. 2001 Screening and surveillance for autism and pervasive developmental disorders. *Arch. Dis. Child* **84**, 468–475.

Bakeman, R. & Adamson, L. B. 1984 Coordinating attention to people and objects in mother–infant and peer–infant interaction. *Child Dev.* **55**, 1278–1289.

Baranek, G. T. 1999 Autism during infancy: a retrospective video analysis of sensory-motor and social behaviours at 9–12 months of age. *J. Autism Devl Disord.* **29**, 213–224.

Baron-Cohen, S. 1987 Autism and symbolic play. *Br. J. Devl Psychol.* **5**, 139–148.

Baron-Cohen, S. 1989 Perceptual role-taking and protodeclarative pointing in autism. *Br. J. Devl Psychol.* **7**, 113–127.

Baron-Cohen, S. 1993 From attention–goal psychology to belief–desire psychology: the development of a theory of mind and its dysfunction. In *Understanding other minds: perspectives from autism* (ed. S. Baron-Cohen, H. Tager-Flusberg & D. Cohen), pp. 59–82. Oxford University Press.

Baron-Cohen, S., Allen, J. & Gillberg, C. 1992 Can autism be detected at 18 months? The needle, the haystack, and the CHAT. *Br. J. Psychiat.* **161**, 839–843.

Baron-Cohen, S., Cox, A., Baird, G., Swettenham, J., Nightingale, N., Morgan, K., Drew, A. & Charman, T. 1996 Psychological markers of autism at 18 months of age in a large population. *Br. J. Psychiat.* **168**, 158–163.

Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C. & Williams, S. C. 2000 The amygdala theory of autism. *Neurosci. Biobehav. Rev.* **24**, 355–364.

Bates, E., Benigni, L., Bretherton, I., Camaioni, L. & Volterra, V. 1979 *The emergence of symbols: cognition and communication in infancy*. New York: Academic Press.

Bishop, D. V. M. 1997 Cognitive neuropsychology and developmental disorders: uncomfortable bedfellow. *Q. J. Exp. Psychol.* A **50**, 899–923.

Butterworth, G. E. & Adamson-Macedo, E. 1987 The origins of pointing: a pilot study. In *Annual Conference of the Developmental Psychology Section of the British Psychological Society York, September, UK*. [Abstract.]

Carpenter, M., Nagell, K. & Tomasello, M. 1998 Social cognition, joint attention and communicative competence from 9 to 15 months of age. *Monog. Soc. Res. Child Dev.* **63**, 1–143.

Charman, T. 1998 Specifying the nature and course of the joint attention impairment in autism in the preschool years: implications for diagnosis and intervention. *Autism* **2**, 61–79.

Charman, T. 2000 Theory of mind and the early diagnosis of autism. In *Understanding other minds: perspectives from autism and developmental cognitive neuroscience*, 2nd edn (ed. S. Baron-Cohen, H. Tager-Flusberg & D. Cohen), pp. 422–441. Oxford University Press.

Charman, T. & Baird, G. 2002 Practitioner review: diagnosis of autism spectrum disorder in 2- and 3-year-old children. *J. Child Psychol. Psychiat.* **43**, 289–305.

Charman, T. & Swettenham, J. 2001 Repetitive behaviors and social-communicative impairments in autism: implications for developmental theory and diagnosis. In *The development of autism: perspectives from theory and research* (ed. J. A. Burack, T. Charman, N. Yirmiya & P. R. Zelazo), pp. 325–345. Hillsdale, NJ: Lawrence Erlbaum Associates.

Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G. & Drew, A. 1997 Infants with autism: an investigation of empathy, pretend play, joint attention and imitation. *Devl Psychol.* **33**, 781–789.

Charman, T., Baron-Cohen, S., Swettenham, J., Cox, A., Baird, G. & Drew, A. 1998 An experimental investigation of social-cognitive abilities in infants with autism: clinical implications. *Infant Mental Hlth J.* **19**, 260–275.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A. & Drew, A. 2000 Testing joint attention, imitation and play as infancy precursors to language and theory of mind. *Cogn. Dev.* **15**, 481–498.

Cox, A., Klein, K., Charman, T., Baird, G., Baron-Cohen, S., Swettenham, J., Wheelwright, S. & Drew, A. 1999 Autism spectrum disorders at 20 and 42 months of age: stability of clinical and ADI-R diagnosis. *J. Child Psychol. Psychiat.* **40**, 719–732.

Dawson, G. & Lewy, A. 1989 Arousal, attention and the social impairments of individuals with autism. In *Autism: nature, diagnosis and treatment* (ed. G. Dawson), pp. 49–74. New York: Guilford Press.

Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J. & Brown, E. 1998 Children with autism fail to orient to naturally occurring social stimuli. *J. Autism Devl Disord.* **28**, 479–485.

Dawson, G., Munson, J., Estes, A., Osterling, J., McPartland, J., Toth, K., Carver, L. & Abbott, R. 2002 Neurocognitive function and joint attention ability in young children with autism spectrum disorder versus developmental delay. *Child Dev.* **73**, 345–358.

Dietz, C., Willemsen-Swinkels, S. H. N., Buitelaar, J. K., van Daalen, E. & van Engeland, H. 2001 Early detection of autism: population screening. Presentation at the *Bienn. Meeting Soc. Res. Child Development, Minneapolis, April*.

Gillberg, C., Ehlers, S., Schaumann, H., Jakobsson, G., Dahlgren, S. O., Lindblom, R., Bagenholm, A., Tjuus, T. & Blinder, E. 1990 Autism under age 3 years: a clinical study of 28 cases referred for autistic symptoms in infancy. *J. Child Psychol. Psychiat.* **31**, 921–934.

Gómez, J. C., Sarria, E. & Tamarit, J. 1993 The comparative study of early communication and theories of mind: ontogeny, phylogeny and pathology. In *Understanding other minds: perspectives from autism* (ed. S. Baron-Cohen, H. Tager-Flusberg & D. Cohen), pp. 397–426. Oxford University Press.

Greenough, W. T., Black, J. E. & Wallace, C. S. 1987 Experience and brain development. *Child Dev.* **58**, 539–559.

Griffith, E. M., Pennington, B. F., Wehner, E. A. & Rogers, S. J. 1999 Executive functions in young children with autism. *Child Dev.* **70**, 817–832.

Griffiths, R. 1986 *The abilities of babies*. University of London Press.

Happé, F. 1999 Autism: cognitive deficit or cognitive style? *Trends Cogn. Sci.* **3**, 216–222.

Hobson, R. P. 1993 *Autism and the development of mind*. London: Lawrence Erlbaum.

Karmiloff-Smith, A. 1997 Crucial differences between developmental cognitive neuroscience and adult neuropsychology. *Devl Neuropsychol.* **13**, 513–524.

Kasari, C., Freeman, S. F. N. & Paparella, T. 2001 Early intervention in autism: joint attention and symbolic play. *Int. Rev. Res. Mental Retard.* **23**, 207–237.

Klin, A., Jones, W., Schultz, R., Volkmar, F. & Cohen, D. 2002*a* Defining and quantifying the social phenotype in autism. *Am. J. Psychiat.* **159**, 895–908.

Klin, A., Jones, W., Schultz, R., Volkmar, F. & Cohen, D. 2002*b* Visual fixation patterns during viewing of naturalistic social situations as predictive of social competence in individuals with autism. *Arch. Gen. Psychiat*. **59**, 809–816.

Koegel, L. K. 2000 Interventions to facilitate communication in autism. *J. Autism Devl Disord.* **30**, 383–391.

Leekam, S. & Moore, C. 2001 The development of attention and joint attention in children with autism. In *The development of autism: perspectives from theory and research* (ed. J. A. Burack, T. Charman, N. Yirmiya & P. R. Zelazo), pp. 105–129. Hillsdale, NJ: Lawrence Erlbaum Associates.

Leekam, S. R., López, B. & Moore, C. 2000 Attention and joint attention in preschool children with autism. *Devl Psychol.* **36**, 261–273.

Leiter, R. G. 1952 *Leiter international performance scale*. Wood Dale, IL: Stoetling.

Lewis, V. & Boucher, J. 1988 Spontaneous, instructed and elicited play in relatively able autistic children. *Br. J. Devl Psychol.* **6**, 325–339.

Lord, C. 2000 Commentary: achievements and future directions for intervention in communication and autism spectrum disorders. *J. Autism Devl Disord.* **30**, 393–398.

Lord, C. & Bailey, A. 2002 Autism spectrum disorders. In *Child and adolescent psychiatry: modern approaches*, 4th edn (ed. M. Rutter & E. Taylor), pp. 636–663. Oxford: Blackwell Scientific.

Lord, C. & Risi, S. 1998 Frameworks and methods in diagnosing autism spectrum disorders. *Mental Retard. Devl Disab. Res. Rev.* **4**, 90–96.

Lord, C., Rutter, M. & Le Couteur, A. 1994 Autism diagnostic interview-revised. *J Autism Devl Disord.* **24**, 659–686.

Meltzoff, A. N. 1988 Infant imitation and memory: nine-month-olds in immediate and deferred tests. *Child Dev.* **59**, 217–225.

Milne, E., Swettenham, J., Hansen, P., Campbell, R., Jeffries, H. & Plaisted, K. 2002 High motion coherence thresholds in children with autism. *J. Child Psychol. Psychiat.* **43**, 255–263.

Minshew, N. J., Luna, B. & Sweeney, J. A. 1999 Oculomotor evidence for neocortical systems but not cerebellar dysfunction in autism. *Neurology* **52**, 917–922.

Mundy, P. 1995 Joint attention and social-emotional approach behavior in children with autism. *Dev. Psychopathol.* **7**, 63–82.

Mundy, P. & Crowson, M. 1997 Joint attention and early social communication: implications for research on intervention with autism. *J. Autism Devl Disord.* **27**, 653–676.

Mundy, P. & Gomes, A. 1996 Individual differences in joint attention skill development in the second year. *Infant Behav. Dev.* **21**, 469–482.

Mundy, P. & Neal, R. 2001 Neural plasticity; joint attention and autistic developmental pathology. *Int. Rev. Res. Mental Retard.* **23**, 139–168.

Mundy, P., Sigman, M., Ungerer, J. & Sherman, T. 1986 Defining the social deficits of autism: the contribution of non-verbal communication measures. *J. Child Psychol. Psychiat.* **27**, 657–669.

Mundy, P., Sigman, M. & Kasari, C. 1990 A longitudinal study of joint attention and language development in autistic children. *J. Autism Devl Disord.* **20**, 115–128.

Mundy, P., Sigman, M. & Kasari, C. 1993 The theory of mind and joint attention in autism. In *Understanding other minds: perspectives from autism* (ed. S. Baron-Cohen, H. Tager-Flusberg & D. Cohen), pp. 181–203. Oxford University Press.

Mundy, P., Sigman, M. & Kasari, C. 1994 Joint attention, developmental level, and symptom presentation in young children with autism. *Devl Psychopathol.* **6**, 389–401.

National Research Council 2001 *Educating children with autism. Committee on educational interventions for children with autism*. Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.

Ohta, M., Nagai, Y., Hara, H. & Sasaki, M. 1987 Parental perception of behavioral symptoms in Japanese autistic children. *J. Autism Devl Disord.* **17**, 549–563.

Osterling, J. & Dawson, G. 1994 Early recognition of children with autism: a study of first birthday home videotapes. *J. Autism Devl Disord.* **24**, 247–257.

Osterling, J. A., Dawson, G. & Munson, J. A. 2002 Early recognition of 1-year-old infants with autism spectrum disorder versus mental retardation. *Devl Psychopathol.* **14**, 239–251.

Phillips, W., Baron-Cohen, S. & Rutter, M. 1992 The role of eye-contact in goal-detection: evidence from normal toddlers and children with autism or mental handicap. *Devl Psychopathol.* **4**, 375–384.

Phillips, W., Gómez, J. C., Baron-Cohen, S., Laá, V. & Rivière, A. 1995 Treating people as objects, agents, or 'subjects': how children with autism make requests. *J. Child Psychol. Psychiat.* **36**, 1383–1398.

Plaisted, K. C., Swettenham, J. & Rees, L. 1999 Children with autism show local precedence in a divided attention task and global preference in a selective attention task. *J. Child Psychol. Psychiat.* **40**, 733–742.

Reynell, J. K. 1985 *Reynell developmental language scales*, 2nd edn. Windsor, UK: NFER Nelson.

Ricks, D. N. & Wing, L. 1975 Language, communication, and symbols in normal and autistic children. *J. Autism Child Schizophrenia* **5**, 191–222.

Robins, D. L., Fein, D., Barton, M. L. & Green, J. A. 2001 The modified checklist for autism in toddlers: an initial study investigating the early detection of autism and pervasive developmental disorders. *J. Autism Devl Disord.* **31**, 131–144.

Rogers, S. 2001 Diagnosis of autism before the age of 3. *Int. Rev. Mental Retard.* **23**, 1–31.

Rogers, S. & Lewis, H. 1989 An effective day treatment model for young children with pervasive developmental disorders. *J. Am. Acad. Child Adol. Psychiat.* **28**, 207–214.

Rollins, P. R., Wambacq, I., Dowell, D., Mathews, L. & Reese, P. B. 1998 An intervention technique for children with autistic spectrum disorders: joint attentional routines. *J. Commun. Disord.* **31**, 181–193.

Scambler, D., Rogers, S. J. & Wehner, E. A. 2001 Can the checklist for autism in toddlers differentiate young children with autism from those with developmental delays? *J. Am. Acad. Child Adol. Psychiat.* **40**, 1457–1463.

Schopler, E., Reichler, R. J., DeVellis, R. & Daly, K. 1980 Towards objective classification of childhood autism: childhood autism rating scale (CARS). *J. Autism Devl Disord.* **10**, 91–103.

Sigman, M., Mundy, P., Sherman, T. & Ungerer, J. 1986 Social interactions of autistic, mentally retarded and normal children and their caregivers. *J. Child Psychol. Psychiat.* **27**, 647–656.

Sigman, M. & Ruskin, E. 1999 Continuity and change in the social competence of children with autism, Down syndrome and developmental delays. *Monogr. Soc. Res. Child Dev.* **64**, 1–114.

Siller, M. & Sigman, M. 2002 The behaviors of parents of children with autism predict the subsequent development of their children's communication. *J. Autism Devl Disord.* **32**, 77–89.

Stone, W. L. & Yoder, P. J. 2001 Predicting spoken language in children with autistic spectrum disorders. *Autism* **5**, 341–361.

Stone, W. L., Hoffman, E. L., Lewis, S. E. & Ousley, O. Y. 1994 Early recognition of autism: parental reports vs. clinical observation. *Arch. Ped. Adol. Med.* **148**, 174–179.

Stone, W. L., Ousley, O. Y. & Littleford, C. D. 1997 Motor imitation in young children with autism: what's the object? *J. Abn. Child Psychol.* **25**, 475–485.

Stone, W. L., Lee, E. B., Ashford, L., Brissie, J., Hepburn, S. L., Coonrod, E. E. & Weiss, B. 1999 Can autism be diagnosed accurately in children under three years? *J. Child Psychol. Psychiat.* **40**, 219–226.

Swettenham, J., Baron-Cohen, S., Charman, T., Cox, A., Baird, G., Drew, A., Rees, L. & Wheelwright, S. 1998 The frequency and distribution of spontaneous attention shifts between social and non-social stimuli in autistic, typically-developing and non-autistic developmentally delayed infants. *J. Child Psychol. Psychiat.* **39**, 747–754.

Tanguay, P. E., Robertson, J. & Derrick, A. 1998 A dimensional classification of autism spectrum disorder by social communication domains. *J. Am. Acad. Child Adol. Psychiat.* **37**, 271–277.

Tomasello, M. 1995 Joint attention as social cognition. In *Joint attention: its origins and role in development* (ed. C. Moore & P. Dunham), pp. 85–101. Hillsdale, NJ: Lawrence Erlbaum Associates.

Tomasello, M. & Farrar, M. J. 1986 Joint attention and early language. *Child Dev.* **57**, 1454–1463.

Townsend, J., Harris, N. S. & Courchesne, E. 1996 Visual attention abnormalities in autism: delayed orienting to location. *J. Int. Neuropsychol. Soc.* **2**, 541–550.

Werner, E., Dawson, G., Osterling, J. & Dinno, N. 2000 Brief report: recognition of autism spectrum disorder before one year of age: a retrospective study based on home videotapes. *J. Autism Devl Disord.* **30**, 157–162.

World Health Organization 1993 *Mental disorders: a glossary and guide to their classification in accordance with the 10th revision of the international classification of diseases: research diagnostic criteria (ICD-10)*. Geneva: World Health Organization.

GLOSSARY

ADI: autism diagnostic interview
ADI-R: autism diagnostic interview—revised
CHAT: CHecklist for Autism in Toddlers
EL: expressive language
IQ: intelligence quotient
NVC: non-verbal communication
RL: receptive language
RSB: repetitive and stereotyped behaviour
RSI: reciprocal social interaction