Insights into Theory of Mind from Deafness and Autism

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Abstract: This paper summarizes the results of 11 separate studies of deaf children's performance on standard tests of false belief understanding, the results of which combine to show that deaf children from hearing families are likely to be delayed in acquiring a theory of mind. Indeed, these children generally perform no better than autistic individuals of similar mental age. Conversational and neurological explanations for deficits in mental state understanding are considered in relation to recent evidence from studies of deaf, autistic, and normally developing children with varied levels of access to talk about mental states at home with family members during the preschool years.

Researchers in the field of developmental psychology have devoted considerable attention in recent years to the question of how children come to understand their own and others' behaviour by acquiring a theory of mind, in other words, the awareness that the human action is governed by covert mental states that do not always match objective reality (Butterworth, Harris, Leslie and Wellman, 1991; Perner, 1991; Wellman, 1990). The discovery of an atypical developmental course for autistic children who are faced with the problem of understanding other minds has extended this explosion of scientific investigation to the field of developmental psychopathology as well (Baron-Cohen, Tager-Flusberg and Cohen, 1993).

Defined in this way, a theory of mind is thought to confer the ability to impute mental states like beliefs, intentions, memories and desires to self and others 'as a way of making sense of and predicting behaviour' (Baron-Cohen, Tager-Flusberg and Cohen, 1993, p. 3). As such, its development is an important cornerstone of social, communicative, and affective life. A practical understanding of mental states enables children to appreciate that their own and others' behaviour may be shaped by cognitive abstractions that are not part of the immediately perceptible world. The awareness that beliefs may be false is crucial to sophisticated interactions with others, both negative ones like trickery and deceit, and positive ones including empathy, joking, or make-

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believe. The merging of one's own thoughts with others' in conversation, play, reminiscence, and mutual insight also becomes possible when mental states are discovered (Mitchell, 1997).

Children who, through failure to develop a theory of mind, are 'mindblind' (Baron-Cohen, 1995) are likely to be handicapped when it comes to appreciating others' emotions and viewpoints. They are likewise uniquely vulnerable to the devious manipulations of their thoughts by those who would deceive, cheat or betray them. A theory of mind is essential for effective communication (Frith and Happé, 1999). Indeed, according to Wellman (1993), once a person develops a theory of mind, 'the assumption is that this understanding guides all social action and interaction' (p. 10).

1. The False Belief Paradigm and its Historical Antecedents

Piaget (1929) proposed that children under the age of 7 years were 'mental realists' whose cognitive egocentrism blinded them to the mental life of others. Consequently, before this age, he believed children were incapable of grasping the distinction between objective reality and human cognitive representations of it. This set the stage for one line of inquiry into the growth of concepts of mind. Piagetian interviews probed children's understanding of processes like thinking, dreaming or memory. Tests of cognitive role-taking were also administered in which the mental perspectives of individuals in different situations had to be considered.

The term 'theory of mind' was introduced by Premack and Woodruff (1978) along with their proposition that chimpanzees possessed one. Their method entailed presenting videotapes about human problem-solving (e.g. food retrieval) to a language-trained chimpanzee (Sarah) and then attributing mental 'role-taking' when Sarah chose a still photo of a correct solution (e.g. a person raking bananas to the cage with a stick) in preference to an irrelevant behaviour (e.g. climbing). This procedure has generated continuing controversy (see Heyes, 1998, for a recent review) and some have argued that a theory of mind cannot be unequivocally demonstrated in humans or other organisms unless verbal tests are used (Slaughter and Mealey, 1998).

In a critique of Premack and Woodruff's (1978) conclusions, Dennett (1978) offered a hypothetical sketch of what has since become the contemporary 'litmus test' for theory of mind, namely the inferential false belief paradigm in which subjects are required to make inferences about the behaviour of actors whose beliefs about objective reality have been rendered false (e.g. they do not know that an object they saw in one place has since been moved). Because correct inferences about actors' behaviour requires acknowledgement of their mental states, the false belief paradigm offers stronger evidence for the presence of a theory of mind than Premack and Woodruff's approach (Slaughter and Mealey, 1998).

Two versions of the false belief paradigm have together generated a large volume of recent research with normally developing and atypical children. The first of these, the inferential false belief test based on changed location (e.g. 'Sally-Ann': Baron-Cohen, Leslie and Frith, 1985), presents a sequence of events in a way that would enable an astute observer to infer a person's (or story's character's) mental state (e.g. a doll puts her ball in a basket and closes the lid, leading to the inference that she thinks the ball is in the basket despite the fact that she can no longer see it). Then the surreptitious transformation of reality is engineered so as to contradict the original belief (while the doll is away, someone moves the ball to a covered box). The subject is then asked about the original character's beliefs either directly ('Where does she think the ball is?') or by demanding a further inference about ensuing behaviour ('Where will she look for her ball?'). A stringent two-trial version of the task requires a second inference under similar circumstances to rule out chance success through guessing. When given false-belief tests in this format, most 3-year-olds fail by responding as Piagetian realists with the true location of the object (Perner, Leekam and Wimmer, 1987). But from the age of 4 or 5 years, evidence of an inferential theory of mind emerges in the vast majority of normal children, who are able to state that the character will search in the original, now false, location. Similarly, in a misleading appearance (or 'deceptive container') version of the task, a person or story character is shown an object (e.g. a rock or an apple) or a container (e.g. a Smarties or M&Ms box or teapot) that, on superficial inspection, has one obvious interpretation. The subject is then made privy to contradictory information (the rock, when touched, reveals itself as a sponge; the apple, when lighted, is really a candle; the Smarties/M&Ms box is opened and shown to contain pencils). An uninformed other is then introduced, followed by a test question about beliefs ('What will she think is in the box before I open it?') or behaviour ('When I ask him what this is before he touches it, will he say it is a rock or a sponge?'). Sometimes representational change questions are also included. In these, the subject is quizzed about his or her own beliefs before being made privy to the deceptive information ('When you first saw this, before I lit it, did you think it was a candle or an apple?'). As with changed location false belief tasks, most normally developing 4- and 5-year-olds correctly ascribe mistaken beliefs to uninformed others and to the self. However, children who are younger than 4 years generally fail to acknowledge the possibility of beliefs that are presently patently false. They therefore respond to test questions by stating the true nature, location, identities or contents of the stimuli.

2. Autism and False Belief

The success that is displayed by most normally developing 4-year-olds on false belief tests is in sharp contrast to the performance of autistic individuals, who typically continue to fail both changed location and misleading appearance tests into their teens and adulthood and at mental ages well beyond 4 years (e.g. Baron-Cohen et al., 1985; Eisenmajer and Prior, 1991; Leslie and Frith, 1988; Reed and Peterson, 1990). However, mentally retarded children without autism often succeed on false-belief tests at lower mental ages, ruling out simple cognitive deficits as an explanation for the delays that are observed in the case of autism (e.g. Baron-Cohen et al., 1985; Perner, Frith, Leslie and Leekam, 1989). Furthermore, autistic children's failure to grasp the concept of false belief appears to be specific to representations that arise in the mental domain. For example, Baron-Cohen, Leslie and Frith (1986) found that autistic young people who succeeded readily in arranging pictures to record sequences of physical events and overt behaviours were selectively incapable of performing the same task when the stimuli depicted mental states. Similarly, Reed and Peterson (1990) found that autistic children and adolescents did as well as mentally retarded and normal preschool children at making inferences about visual perception. But even though they could not only infer *invisibility* based on blocked line of sight, but also identify the varying *percepts* of viewers observing the same scene from different vantage points, they routinely failed corresponding tests that differed only in being cognitive. Thus they could neither infer *ignorance* based on blocked informational access, nor *false belief* based on the faulty mental input available to another mind.

It is conceivable that autistic children may possess an even better understanding of some forms of non-mental representation than normal preschoolers of comparable mental age. Using normally developing children aged 4 and 5 years as subjects, Zaitchik (1990) pioneered a photographic misrepresentation task that was closely parallel to inferential tests of false belief. With tight controls for comprehension, memory and attention, she discovered that normal children were no better than chance at predicting what would appear in a polaroid snapshot of a scene that had been transformed in a salient manner after the photo was taken, even though they routinely passed two corresponding narrative tests of false-belief understanding. Leekam and Perner (1991) presented a simplified version of Zaitchik's task to a group of able autistic teenagers. Subjects were shown a doll who had changed her dress either after the photo was taken, or after another doll had left the room. Only 27 per cent of the diagnosed autistic adolescents replied correctly to the question: 'What colour does (the other doll) think Judy is?' Yet 14 of these 15 autistic subjects displayed an accurate understanding of photographic misrepresentation by naming the original colour when asked: 'In the picture, what colour is Judy?' Similar results were obtained by Leslie and Thaiss (1992) on tasks assessing the understanding of two different types of mental and photographic representation (place change and identity change). Despite the fact that the vast majority of the intelligent autistic children in their sample accurately understood both types of photographic misrepresentation, only 23 per cent of them displayed a correspondingly accurate understanding of false belief. Leslie and Thaiss concluded that 'a specialized cognitive mechanism which subserves the development of folk psychological notions . . . is dissociably damaged in autism' (p. 229).

3. Deafness and False Belief

The question of whether a failure to grasp concepts of false belief at an advanced mental age is a problem unique to autism, or shared by children from other clinical populations, has considerable theoretical significance (Baron-Cohen, 1995). Autism is known to be a 'biologically-based neurodevelopmental disorder' (Bailey, Phillips and Rutter, 1996) that is diagnosed when a child displays a triad of impairments in imagination, language, and social relatedness (Frith, 1989). Evidence of a genetic link, along with general agreement on its biological basis, suggests that the root cause for these diagnostically significant behavioural manifestations of autism resides in an abnormality of the central nervous system (CNS). One theoretical possibility is that the same CNS disturbance also explains autistic children's delayed development of a theory of mind. However, if other populations are impaired in understanding a theory of mind without the clinical manifestation of autism, this would argue against attributing both abnormalities to a single CNS disruption.

Initial empirical evidence supported the notion of autism specificity. In addition to mentally retarded children, subjects with emotional disturbance (Siddons, Happé, Whyte and Frith, 1990), like those with specific language disorders (Leslie and Frith, 1988; Perner et al., 1989) and with the cognitive deficits of Williams Syndrome (Tager-Flusberg, 1995) have been shown to succeed more readily on false-belief tests than children with autism. More recently, however, another diagnostic group has been discovered that appears to share autistic children's extreme delays on tests of an inferential theory of mind.

In particular, the results of a number of recent studies show that profoundly deaf children who grow up in hearing families often lag several years behind hearing children in their development of an understanding of false belief, even when care is taken to include only children of normal intelligence and social responsiveness in the deaf samples (Deleau, 1996; Peterson and Siegal, 1995, 1997, 1998; Russell, Hosie, Gray, Scott and Hunter, 1998; also see Table 1). For example, Peterson and Siegal (1995) and Russell et al. (1998) each observed that only a minority of deaf children aged 5 to 12 years passed a standard two-trial (Sally-Ann) false-belief test based on changed location (see above for a detailed description), and it was not until aged 13 to 16 that deaf children's success rates were seen to approximate those of normally developing 4-year-olds (Russell et al., 1998).

Furthermore, the delays observed among deaf children also resemble those displayed by autistic children in being specific to concepts of mind, rather than pertaining to false representation more generally. In two experiments, Peterson and Siegal (1998) presented matched groups of children from three populations: (1) autistic children, (2) normal preschoolers, and (3) signing deaf primary school children from hearing families, with standard tests of false mental and photographic representation, using a within-subjects design. The results of the first study, which borrowed Leekam and Perner's (1991) and Leslie and Thaiss's (1992) procedures, replicated these authors' findings (see above) of significantly better performance by autistic children on Zaitchik's (1990) false-photo task than on a comparable two-trial false-belief test (Baron-Cohen et al., 1985). Exactly the same pattern of differential success and failure was observed among the normally intelligent severely and profoundly deaf children in the sample who came from hearing families and had acquired signed communication belatedly upon school entry. Furthermore, the levels of success by deaf and autistic children were almost identical to one another.

The second study, which used a nonverbal response mode, essentially replicated these results. Deaf and autistic children performed similarly, each showing better understanding of false photographic than false mental representation. Incidental linguistic or conversational differences between mental and photographic tasks were ruled out in this study, since all aspects of the two types of task, apart from the locus of the obsolete representation in a camera or a human mind, were carefully equated.

Nevertheless, deaf and autistic children displayed chance accuracy on the belief task, while exceeding chance on the comparable photographic version. No such domain-specific dissociation emerged in normally developing preschoolers in the second experiment, where all linguistic and conversational demands of the tasks had been minimized and carefully equated. Four-year-olds were near ceiling on both tasks, while 3-year-olds were no better than chance with either false mental, or false photographic, representation. (In line with these findings for normal children, it is worth noting that other recent studies have similarly contradicted Zaitchik's (1990) original suggestion that normal developers find false photographs harder to understand than false beliefs (e.g. Slaughter, 1998).

Peterson and Siegal's (1995, 1997, 1998, 1999) findings regarding Australian deaf children's poor performance on theory of mind tests have been widely replicated. Table 1 displays a summary of the results of 11 separate investigations that have examined the performance of independent samples of severely and profoundly deaf children from several different cultures and educational systems on standard test of false-belief understanding. (See Happé, 1995, for a similar tabulation of studies of false-belief understanding in subjects with autism).

Taken collectively, the populations of deaf children that have been assessed in these studies are impressively varied, and can be seen to represent a wide range of family circumstances, preferred communication modalities, and approaches to deaf education. A broad span of ages has also been encompassed, and a range of techniques for measuring false-belief understanding has been

Table 1 Summary of 11 studies of deaf children's understanding of false belief

Investigations	*Subjects*	*Mean Age*	*False-Belief Tasks*	*Results*
Courtin & Melot (1998)	N = 79 French deaf children, including 13 native signers, 22 signers from hearing homes and 44 oral deaf	Signers and oral from hearing homes: 7.5 years; native signers: 5.4 years	Three (unspecified) first-order tasks	Native signers aged 5 outperform older oral and signing deaf from hearing homes; less than half in the latter two groups pass at least two of three tasks after age 7 years
Deleau (1996)	N = 48 French signing deaf children	Unspecified: range passing control questions: 5–8 years	One-trial changed location task	Only 60% pass at ages 6 to 8 years; hearing controls outperform
de Villiers et al. (1997)	N = 22 USA orally trained deaf from hearing homes	7.6 years	Two-trial narrative changed location task	Only 54% pass
Peterson & Siegal (1995)	N = 26 Australian severely and profoundly deaf signers aged 8 to 13 years from hearing homes	10.6 years	Two-trial changed location (Sally-Ann) task	Only 35% pass
Peterson & Siegal (1997)	N = 35 deaf Australian total communication pupils: 25% native signers; 74% from hearing homes	8.9 years	Two-trial changed location (Sally-Ann) task	Native signers: 89% pass Signers from hearing homes: 46% pass
Peterson & Siegal (1998); Experiment 1	N = 30 Australian deaf signers from hearing homes	8.4 years	Two-trial changed location (Sally-Ann) task	Only 40% pass

Table 1 Continued

Peterson & Siegal (1998); Experiment 2	N = 24 Australian signing deaf children from hearing homes	9.3 years	One-trial changed appearance task with nonverbal response option	Only 54% pass
Peterson & Siegal (1999)	N = 59 Australian deaf children (58% signers from hearing homes; 19% native signers; 23% oral)	9.4 years	Three tasks (1) Two-trial Sally-Ann (2) Smarties (3) Changed appearance	Most oral deaf and native signers pass all tasks and outperform signers from hearing homes, less than half of whom pass
Remmel, Bettger & Weinberg (1998)	N = 12 USA signing prelinguistic deaf children; 5 with signing deaf parents and 7 with hearing parents	8.7 years	Three-question misleading appearance task	Native signers: M = 2.5/3 correct; deaf from hearing: M = 1.1/3 correct
Russell et al. (1998)	N = 32 Scottish severely and profoundly deaf children: 2 native signers and 30 signers from hearing families	10.7 years	Two-trial changed location task	Age 6: 17% pass Age 10: 10% pass Age 15: 60% pass Total: 28% pass
Steeds, Rowe & Dowker (1997)	N = 22 English profoundly deaf children	9.7 years	One-trial changed location task	33% fail control questions; 70% (including control-question failers) pass false-belief

used. Overall, the results of these studies provide consistent support for the proposition that signing deaf children from hearing families are seriously delayed in acquiring a theory of mind.

The results of the studies that are summarized in Table 1 reinforce the similarities noted earlier between deaf and autistic children, indicating that even in the presence of normal intelligence, these groups are likely to continue through adolescence to fail the simple tests of false-belief understanding that are passed by most normally developing preschoolers at age 4. Furthermore, the one published study that followed a substantial group of deaf children into late adolescence (Russell et al., 1998) suggested that it was not until after the age of 15 years that a slight majority (60 per cent) of normally intelligent deaf students from hearing households displayed a consistently accurate understanding of false belief. However, deaf adults are found to organize cognitive verbs in a similar manner to hearing adults (Clark et al., 1996), consistent with presence of a functional theory of mind in maturity.

4. Differences among Deaf Groups in Rates of Theory of Mind Development

Interestingly, the results of the studies summarized in Table 1 also combine to suggest that the ease with which deaf children develop a theory of mind may be related to the nature and extent of their exposure to conversation at home while growing up as preschoolers. Three separate groups of preschool deaf children can be identified on the basis of their access to signed or spoken conversation with family members who are able to communicate in these modalities with varying degrees of fluency. Profoundly deaf children of signing deaf parents, along with those who have another native speaker of sign language in their immediate household (e.g. a signing deaf grandparent or an older deaf sibling who has become a fluent signer at school), can be dubbed 'native signers' owing to their access, throughout their growing up, to a natively fluent conversational partner with whom they are able to share a common first language, such as Australian Sign Language (Auslan), American Sign Language (ASL) or signed English. Another group consists of orally trained deaf children who, with the help of amplifying hearing aids, have been taught to speak and to comprehend spoken language. (Though not always successful in children with serious hearing losses, oral training does enable some deaf children to participate in family conversation through the spoken modality). The third group consists of severely and profoundly deaf children who eventually acquire their preferred medium of communication, sign language, in school after varying periods of conversational deprivation while growing up in families without any fluently signing members.

When tested during their early years of primary school, severely and profoundly deaf children who are native signers are found to differ markedly in their performance on false-belief tests from their signing severely and profoundly deaf classmates who have grown up in exclusively hearing homes. Deaf native signers appear to develop concepts of false belief at the same age as do children of normal hearing. But belatedly signing deaf children from hearing families are consistently found to do worse than native signers on false-belief tasks (Courtin and Melot, 1998; Peterson and Siegal, 1999; Remmel et al., 1998). Furthermore, these differences are not transitory, but can be observed throughout the age period from 5 through to 16 years (Peterson and Siegal, 1997, 1999; Russell et al., 1998).

When a child is born deaf into a hearing family (which is the case for the vast majority of deaf schoolchildren today), there are likely to be many departures from the normal course of development of language, social experience and conversation (Marschark, 1993; Vaccari and Marschark, 1997). Even when hearing parents make extensive efforts to learn to communicate in sign with their profoundly deaf children, the result is apt to be disappointing. According to Vaccari and Marschark: 'over 90 percent of deaf children have hearing parents, the majority of whom either do not know sign language or have relatively little skill in that domain' (1997, p. 793).

In contrast to parents who are deaf native signers, hearing parents typically report difficulties in communicating with their deaf children even about familiar everyday routines and have extreme difficulty sharing their thoughts, memories, intentions, and beliefs (Meadow, 1975). In many hearing families with a deaf child, any signs or communicative gestures that are produced by parent or child are restricted to topics in the immediately perceptible visual field, leaving parents and offspring alike unclear about one another's needs, desires, beliefs and capabilities (Vaccari and Marschark, 1997). Hearing mothers are found to share their emotions and intentions rarely, if at all, with their deaf offspring and may adopt a didactic role which discourages playful or inquisitive conversational exchange (Courtin and Melot, 1998).

Consequently, most deaf adults who eventually become fluent users of sign language acquire this language belatedly after varying periods of restricted conversation in their hearing families of origin. For example, when Power and Carty (1990) surveyed deaf native speakers of Auslan, they discovered an unusual linguistic background in that 'in 90 percent of cases Auslan is learnt not from parents within a family setting, but from other deaf students, usually in school' (p. 223). This means that until they enter a signing (or Total Communication) primary school, many profoundly deaf children have no readily available means of conversing with any of their hearing family members, especially about topics like mental states which may have no obvious visual referent. This is consistent with research showing that 'a deaf child of hearing parents may have no language in the sense of a code shared by many users' (Charrow and Fletcher, 1974, p. 436) until school entry at the age of 5 or 6 years.

Vaccari and Marschark (1997) noted that even mothers who make considerable effort to learn sign language frequently report difficulties in gaining the child's attention and conversing about unobservable thoughts and feelings. Morford and Goldin-Meadow (1997) studied four profoundly deaf children who were not exposed to a usable conversational language, but managed to express themselves at home by means of idiosyncratic systems of gestures known as 'homesign' (p. 420). Only one of them made spontaneous references to fantasy, hypothetical ideas or future events in conversation. Initiations of communication about the non-present by their caregivers were even less frequent. According to Marschark (1993): 'Deaf children are less likely than hearing children to receive explanations from their parents concerning emotions, reasons for actions, expected roles and the consequences of various behaviours' (p. 60). Similarly, Meadow (1975) concluded from one observational study of hearing families with a deaf child that: '95 percent of deaf children and their parents limited communication to topics with a visual referent' (p. 489), while the results of another study (Collins, 1969, cited in Meadow, 1975, p. 489) showed that 81 per cent of hearing mothers complained that 'they could communicate with their preschool deaf child only about things or events that were present in the time and/or space' (p. 489). If the spoken language skills of children with serious hearing impairments are poor, these unique features of conversation in hearing families might well limit deaf children's opportunities to gain insight into other people's thought processes. In the absence of a shared representational language, it is only in obvious cases when both conversational partners are looking at the objects they are thinking and talking about that a meeting of minds can take place.

In the case of oral deaf children with some residual hearing who are taught in spoken language classrooms with the aid of amplification, there is a possibility (not always actualized) of achieving fluent communication with hearing family members using speaking and listening. Consequently, for oral deaf children, any departure from the normal course of theory of mind development is likely to depend on the level of language proficiency. As shown in Table 1, Peterson and Siegal (1999) found that a group of orally trained Australian deaf pupils in a Total Communication primary school (who had enough spoken language fluency to cope readily with theory of mind tasks presented in an exclusively oral modality) performed near ceiling, and on a par with normally developing children and deaf native signers. But de Villiers et al. (1997) found that approximately half of their sample of 7-year-old orally taught North American deaf children failed standard false-belief tasks, and those who passed had significantly better language skills (such as vocabulary and verb complementation) than those who failed. Thus spoken language ability, a factor influencing access to family conversation at home, may also be central to oral deaf children's mastery of concepts of the mind. This is understandable, since spoken language may not only provide insight into the thought processes of peers and family members, but may also help to determine an oral deaf child's ability to display mental-state understanding when presented with standard tests of false belief.

5. Nature and Nurture in Theory of Mind Development

The difference in performance on false-belief tasks between native signers and deaf children from hearing families implicates family conversation in the growth of a theory of mind. Deaf children of hearing parents who lack an early conversational partner with whom to discuss imaginary, false, or abstract ideas and beliefs may miss out on a necessary source of cognitive input. The situation can be different for oral deaf with sufficient spoken language to discuss their beliefs with their family members in speech. Natively signing deaf children of deaf parents are similarly likely to gain conversational insight, via sign, into family members' mental states. Meadow, Greenberg, Erting and Carmichael (1981) discovered that deaf native signers converse as fluently in sign about non-present ideas, objects and events with their signing deaf relatives as hearing children with their hearing parents in spoken language.

Children with autism are as likely as signing deaf children from hearing families to miss out on these formative early conversational experiences, though for different etiological reasons. As noted above, a diagnosis of autism entails a triad of impairments in (1) imagination, (2) spoken language ability and (3) social relatedness (Frith, 1989). Consequently, a child with autism is likely to remain socially aloof from family members, to have too few linguistic skills to be fully able to engage in sophisticated family conversations about abstract ideas, and to have too little imagination to appreciate another person's imaginary, or false, beliefs. A deficit of pragmatic communication skill has been reliably identified with autism, beginning in infancy with absences of joint attention and directive pointing, and evolving, as vocabulary develops, into deficits in narrative fluency and such pragmatic conversational tactics as maintaining relevance and responding to questions (Bruner and Feldman, 1993). The relatively few autistic subjects who manage to pass false-belief tests display better language skills than those who fail (Happé, 1995). But a direction of causality for these results is difficult to determine. Conceivably, a basic theory of mind deficit may delay the development of language and pragmatic communication skills which are acquired through social interaction. Alternatively, a more basic language processing deficit may block the autistic child's access to the verbal, syntactic, and conversational information that is necessary in order to develop a theory of mind. Still a third possibility is that some core deficit in a different area of 'interpersonal–affective relatedness' (Hobson, 1993, p. 216) may underpin both the linguistic and the mentalistic deficits observed in individuals with autism. The empirical evidence to date does not enable a conclusive choice among these alternatives.

Nevertheless, there is convincing empirical support for the propositions both (1) that autistic children suffer conversational deprivation at home during the age period from 2 to 5 years when their peers without autism are developing an awareness of false belief, and (2) that conversation in families where a child has autism is selectively restricted when it comes to talking about mental states like intentions, beliefs, false ideas, or imaginary thoughts. Tager-Flusberg (1993) compared the conversations that arose spontaneously over a two-year period between mothers and preschoolers in households where the child either had autism or mental retardation owing to Down's syndrome. The children were matched for levels of productive language skill and were simply observed as they engaged in everyday interaction with their mothers over cooking, play, snacks and so on. A number of striking differences arose when the dialogues were analysed. None of the retarded children made pronoun reversal errors (e.g. saying 'you' to describe self while speaking) but all of the autistic did so at least some of the time, suggesting their confusion over the pragmatic roles of speaker and listener in a conversational exchange. In addition, autistic children asked fewer questions than retarded children and were less likely to expand, continue or oppose a topic their mother had introduced. Their dialogues were especially striking for their virtual absence of references to mental states like knowledge and belief. Indeed, while retarded and autistic children were no different in their talk about perception, desire, and facially visible emotions (e.g. happy, scared, angry), references to cognitive mental states (e.g. believe, dream, forget, guess, trick, wonder, pretend, etc.) almost never arose in the autistic children's conversations.

Tager-Flusberg concluded that: 'One of the primary functions of language, to serve as a major source of knowledge, is impaired in autistic children even in the prelinguistic period. It is this impairment which links deficits in joint attention, later problems with communication, and the understanding of belief' (p. 153). Bruner and Feldman (1993) also noted that one of the consistent differences between autistic children and both retarded and normally developing children of similar mental age is lack of pragmatic skill in conversation. Autistic children have difficulty sustaining a conversational exchange with another person. As Bruner and Feldman (1993) explained: 'In dialogue, autistic speakers seem unable to extend the interlocutor's previous comment' (p. 274). In addition, they appear to suffer a narrative deficit which leaves them unable to construct a coherent story line and deprives them of the ability to 'make new comments on a topic in discourse' (p. 275). A narrative deficit may combine with the diagnostic indicator of impaired imagination to interfere with the autistic child's capacity to engage in pretend play, while both pragmatic conversational problems are likely to limit autistic children's access to the kinds of social input through dialogue that might yield insight into the workings of other people's minds.

A conversational account of theory of mind development that ascribes deaf, and possibly autistic, children's difficulties with concepts of false belief to selective deprivation of conversational access to other people's intangible mental states is consistent with studies of individual differences in the rate at which young normal children develop an understanding of the mind. Though most normally developing preschoolers have a firm grasp of false belief by the age of 4 to 5 years, a more precocious understanding by 3-year-olds has been linked with these children's exceptionally rich and varied exposure to dialogue and conversation in early family life. For example, using a longitudinal methodology, Dunn, Brown, Slomkowski, Tesla and Youngblade (1991) found that the breadth and depth of the conversational exchanges involving mental-state information that took place spontaneously between 33-month-olds and their mothers and siblings predicted these children's aptitude for standard theory of mind tasks some seven months later. Those subjects who, as 40-month-olds, displayed a sufficiently advanced grasp of mental-state concepts to be able to explain story characters' behaviour in terms of false belief had talked more with their mothers and siblings about emotions and desires at age 2 than their peers who failed. In addition, those with a precocious understanding of false belief had more frequent discussions with their mothers about psychological causality (e.g. 'Why don't you like to eat ice-cream before dinner?') than failers, even when matched for age and overall verbal fluency. Brown, Donelan-McCall and Dunn (1996) likewise found that 4-year-olds' successful performance on theory of mind tests was correlated with frequent use of mental-state terms when playing and talking with their siblings and peers, suggesting that spontaneous mention of mental contents may trigger the growth of the level of understanding that is assessed in structured tests. Indeed, these authors argued that children become motivated to think about their own and other people's abstract ideas, and mistaken or pretend beliefs, 'not as solitary cognitive exercises, but while negotiating the social interactions in which these cognitive states are shared' (p. 848).

The importance for theory of mind development of engaging in conversations and playful interactions with varied partners may also underpin discoveries both that children with larger numbers of siblings develop concepts of false belief at a significantly earlier age than singletons (Jenkins and Astington, 1996; Perner, Ruffman and Leekam, 1994) and that children in broad extended family networks who are regularly exposed to talk with adults and older children inside and outside home are more adept at understanding false belief than those whose familiar range of conversational partners is narrow (Lewis et al., 1996).

For profoundly deaf children in exclusively hearing families, as for socially aloof autistic children, these important sources of insight into the minds of friends and kin may be relatively inaccessible. According to Nelson (1996) this may preclude both the basis and the necessity for developing a theory of mind. As she explained:

> Individual organisms without communicative capacities for exchanging information about what they think, feel, and desire must remain in a solipsistic state, implicitly assuming that other individuals seek, know, act and desire the same things they themselves do . . . Engaging in the exchange of thoughts and feelings through language with other humans

> enables the move to a new level of understanding others as different from oneself (p. 134).

Conversational accounts like these belong to a broad category of 'cultural' explanations for theory of mind (Lillard, 1997) that ascribe the mastery of mental-state understanding to the forces of social interaction. According to Smith (1996), 'Young incipient mind-readers need to be supported in their ontogenetic development of mind-reading skills. We need to consider as prerequisites *both* individuals who can develop mind-reading, *and* enculturation within a community which mind-reads' (p. 353). Children may entertain a wide variety of explanations for human behaviour initially on the basis of their direct observations of the world, only narrowing these down to a mentalistic source subsequently if they happen to grow up in a social environment where people converse freely about psychological states and in a culture that ascribes human action to such mentalistic causes as false beliefs.

This emphasis on culture and conversation in the development of a theory of mind contrasts with an alternative explanation for autistic children's false-belief difficulties in terms of genetic or prenatal damage to a modular, neurological mechanism for processing information about the mind (Baron-Cohen, 1995; Fodor, 1987; Frith, Morton and Leslie, 1991; Leslie and Thaiss, 1992). While differing in detail, these nativist neurobiological approaches share the view that a specialized cognitive mechanism with a distinctive architecture and circumscribed function becomes dissociably damaged in autism, accounting not only for the difficulties that autistic individuals have on tests of false belief, but also for their triad of diagnostically significant impairments in everyday language, imagination and sociability (Frith, 1989).

To the extent that impaired social relatedness is deemed a necessary offshoot for autism as a disorder and for the neurobiological damage that is held by the nativist approach to be jointly responsible for children's problems with concepts of mental state, it is hard to reconcile the poor false-belief understanding that is consistently observed in deaf children with this account, as summarized in Table 1. When attending schools and units where sign language is used, these deaf children are commonly observed to enjoy normal levels of social interaction with their deaf classmates (Marschark, 1993; Power and Carty, 1990). Very few of them could be described as socially aloof or deviant, or as aligning themselves in other ways with the diagnostic criteria for autism.

In addition, it is well known that no single identifiable neurological or traumatic process accounts for all cases of childhood deafness (Marschark, 1993). For example, although some children in the Peterson and Siegal (1998) sample had lost their hearing as fetuses through rubella infection, others had become deaf postnatally (though prelinguistically) through illnesses and accidental injuries specific to the peripheral auditory system. Yet these latter children performed similarly on false-belief tests to those who were known or suspected to have suffered prenatal brain damage. In addition, the fact that the replication studies reported in Table 1 predominantly involved deaf children with no known or suspected serious clinical diagnoses apart from hearing impairment rules out the pervasive congenital neurological impairments that have been implicated in the case of autism. Thus it would be seen that a nativist account, while potentially applicable to autistic children's problems with concepts of false belief, cannot effectively be generalized to deafness for the following reasons:

(1) Deaf children from hearing families consistently fail theory of mind tasks at advanced chronological and mental ages, performing on a par with autistic children of similar mental age.
(2) Deaf children are unlikely to be neurologically damaged with respect to the theory of mind modules that are postulated by a nativist account as the explanation for the delays connected with autism.
(3) Deaf children's failure of false-belief tests could conceivably reflect their deficient early conversational interaction in hearing families where absence of a shared language restricts discussion of beliefs and other mental states.
(4) Natively signing deaf children with signing deaf family members develop concepts of false belief at a normal age, a pattern that is more consistent with a conversational than a neurobiological account of other deaf children's difficulties.

If a conversational explanation for deaf children's delayed development of a theory of mind is entertained, the question of whether this account might also be applicable to autism naturally arises. Of course, it is conceivable that older deaf and autistic children could display similar problems with false-belief understanding for quite different reasons. On the other hand, as Tager-Flusberg's (1993) research has shown, autistic children do resemble deaf children in their selective deprivation of talk about mental states at home while growing up. Consequently, the conversational account may provide a parsimonious explanation for the similarities displayed by deaf and autistic children on false-belief tests, but also for their equally inferior performance to normal developers and retarded children of lower verbal mental age, who enjoy fluent dialogue about mental states with family members at home (Tager-Flusberg, 1989, 1993). In other words, deaf children and autistic children may both be delayed in developing a theory of mind owing to their restricted early conversational exposure at age 2 to 3 years due to hearing impairment and lack of a shared language in the one case and to social aloofness and language difficulties in the other.

6. Deafness and Neurobiological Development

On the other hand, there may be a neurobiological basis for the performance of deaf children as a result of differential patterns of brain development following hearing loss. Indeed, congenitally deaf children with limited conversational exposure in purely oral families have been observed, in adulthood, to display patterns of language-related brain activity that differ in salient ways both from those of hearing adults from oral households and from those of deaf native signers from signing families (Marschark, 1993; Neville, Coffrey, Lawson, Fischer, Emmorey and Bellugi, 1997).

In this respect, in keeping with recent findings that have shown that the brain seems to have evolved systems dedicated to different features of the social world, areas of the right hemisphere may be implicated in understanding that involves a theory of mind. Between 3 and 4 years, children undergo a developmental change leading to accurate responses to theory of mind tests that require the ability to follow pragmatic implications of conversation, questions and other features of social interactions (Siegal and Beattie, 1991; Surian and Leslie, in press). This development occurs at the same time as the spurt of right-hemisphere growth at around 4 years of age that has been reported by Thatcher (1992).

There are grounds to believe that these findings cannot be dismissed as simply reflecting an anatomical coincidence. First, adult stroke patients who have suffered right-hemisphere (RH) damage share similar difficulties with young children in interpreting the conversational implications of questioning in theory of mind tasks (Siegal, Carrington and Radel, 1996). These patients often succeed on conversationally explicit versions of the false-belief questions (e.g. when asked 'Where will Sally look first', rather than 'look for' the hidden object, so as to distinguish clearly between searching and successful retrieval). Such results are consistent with reports that RH damage is associated with substantial impairment in pragmatic understanding (Molloy, Brownell and Gardner, 1990).

To complicate matters, however, pragmatic modifications of the wording of false-belief questions (e.g. 'look first'), though shown to assist RH stroke patients, fail to benefit either deaf children (Peterson and Siegal, 1995) or autistic children (Surian and Leslie, in press). Furthermore, deaf and autistic children are found to differentially fail false-belief tasks but not false-photographic tasks even when identically worded test questions are used with each task (Peterson and Siegal, 1998). These findings suggest that the pragmatic deficit implicated in the case of children with autism and deafness is not restricted to simple misunderstanding of specific questions during the standard false-belief testing situation. Furthermore, to the extent that a theory of mind is a necessary component of a skilled conversationalist's pragmatic understanding of an interlocutor's mind and intentions, impairments in pragmatic skill and mental state understanding are likely to be reciprocal and inextricably interconnected.

Nevertheless, the possibility that delayed exposure to conversation may influence patterns of right-hemisphere brain development in deaf children warrants further investigation, as does the question of how similar these children are to RH stroke patients in terms of awareness of conversational pragmatics and theory of mind. The latter have suffered impairments through a cerebrovascular accident to areas of the right hemisphere whose activation is associated with conversational awareness, whereas the former have had a restricted access to conversation in the first place owing to the language patterns of their families. This restricted conversational access may even limit theory of mind understanding in response to situations in which the need to follow inferences in conversation is eliminated, perhaps owing to a failure of the mutual representation of contexts between speakers and listeners that is essential for effective comprehension (Clark et al., 1996).

Furthermore, there is evidence that right-hemisphere activation is more central to the general interpretation of language in deaf native signers than in hearing persons who use speech. Neville et al. (1997) have shown that reading messages in sign language involves the activation of parietal and temporal cortices in the right-hemisphere as well as the traditional left-hemisphere language areas. The greater theory of mind proficiency that we have found in deaf native signers than in delayed signers from hearing homes is consistent with the increased right-hemisphere activation among children in the former group that may also assist them in their skilled interpretation of conversationally sophisticated questioning when being tested on theory of mind tasks. Whether native signers perform better than hearing preschoolers on false-belief tests at age 3 to 4 years is an interesting question that awaits further research.

Indeed, very little work has so far directly compared social and neurobiological influences on mental-state understanding in groups of children as diverse as autistic, deaf and normally developing children. Further study of these influences and their interconnections is urgently needed, as is continued investigation of the conversational and pragmatic distinctions between signed and spoken languages. Though, for example, it has been noted that sign language involves a special awareness of nonverbal communication cues and social cognition (Emmorey, 1993), its role in cognitive development has rarely been studied.

Finally, of course, it is conceivable that a critical level of conversational input about mental states is necessary to trigger neurobiological development and hemispheric specialization, so that biological and social-experiential accounts of theory of mind development need not be mutually exclusive. Whatever their interpretation, the results we report from our own and others' investigations of deaf children's performance on tests of false belief underscore the likely role of early family conversation in developing an awareness of the mind, while also highlighting the need for further research to clarify the degree to which cognitive representations of mental states are influenced by biological and cultural factors.

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