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Autism: a specific cognitive disorder of 'mind-blindness'

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Summary

The last 20 years has produced a body of evidence suggesting the presence of cognitive deficits in autism. This research is briefly reviewed. The question of whether a specific cognitive deficit might underlie the social and communicative symptoms in autism is then considered. One recent proposal has been that people with autism are impaired in their ability to attribute mental states (such as beliefs, knowledge states, etc.) to themselves and other people. Experimental evidence relevant to this hypothesis is summarized, and this suggests there is indeed an autism-specific congnitive deficit in this domain. The possible origins of this deficit are discussed, and the term 'mind-blindness' is proposed to refer to this deficit.

There is considerable consensus in the scientific literature that autism is a disorder of *biological* origin (see Bolton & Rutter, this issue, for a review of the evidence for a genetic aetiology of autism, and Gillberg, this issue, for a review of the growing number of other biological factors associated with autism). The psychiatric classification of autism, on the other hand, depends on the presence of specific *behavioural* abnormalities.[1] In this paper I will argue that a promising way of bridging the biological and behavioural levels of the description of autism lies in the study of cognition in autism. In additon, I will review some studies suggesting that autism is a specific cognitive disorder of 'mind-blindness'.

Bridging biology and behaviour in autism: the role of cognitive science

Cognitive science is the study of how knowledge is organized and how information is processed in humans, animals and other intelligent systems, biological or otherwise. Cognitive science focuses centrally on the twin concepts of representation and process.[2] Crudely, representations store knowledge and information about the world, whilst processes allow representations to transform information and to drive behaviour. Representations and processes function within different kinds of cognitive mechanisms. Cognitive science provides a bridge between the study of biology and behaviour in that it comprises a framework in which to test hypotheses about the cognitive mechanisms that generate behaviour, mechanisms which are located in the brain.[3]

Precisely where in the brain such mechanisms are located is an important task for the cognitive and neurosciences to answer. In this paper I will have little to say about brain-cognition mapping in any detail except to note that such mapping is possible. Instead, I begin by briefly summarizing the evidence from studies of cognition in autism, with particular reference to abnormalities in *social cognition.* Throughout, I make the assumption that future

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research will be concerned with locating such autism-specific cognitive abnormalities in the dysfunctional brain.

A brief history of cognitive research in autism

Although autism was first described in 1943, for the first 20 years hardly any cognitive research was conducted into autism. This was partly because, in his original paper delineating the disorder, Kanner implied that autism was a purely *emotional* disorder, and this view was taken up enthusiastically by psychoanalytic writers interested in the mother–child relationship and its postulated causal role in autism. Bettelheim's (1967) book is perhaps the most well known expression of this.

Psychologists of the 1960s argued along rather different lines, focusing on autism as a developmental language disorder (see Rutter, 1978, for a review of such work at that time). Two new insights led to the shift towards seeing autism as a disorder of cognition. First, studies revealed that language disorder alone was unable to account for the social abnormalities found in autism, since such social deficits were not commonly found in other language-impaired children (see Rutter, 1983). Secondly, a series of seminal studies by Hermelin & O'Connor revealed specific cognitive deficits in autism.

These studies began in the early sixties, at the Medical Research Council's Developmental Psychology Unit in London, and developed during the subsequent decades. Their early studies are described in their monograph published in 1970, and their work continues to be of considerable importance today. Readers are encouraged to consult Hermelin and O'Connor's (1970) monograph for details of this early work. For the present purposes, their main findings can be summarized as follows: (1) Perceptual systems in people with autism are not specifically impaired in any way (although sensory handicaps can sometimes occur in conjunction with autism). (2) For any given individual with autism, the ability to make conceptual distinctions tends to be related to the degree of the person's learning difficulties. This is an important point, given the strong association between autism and 'mental handicap' (Wing & Gould, 1979). (3) However, people with autism, irrespective of their intellectual level of functioning, seem to be specifically impaired in tasks which require comprehension of *meaning*.[4] (4) People with autism seem to process information in a qualitatively different way to subjects without autism.[5]

Subsequent cognitive research has broadly supported these conclusions. To give one illustration, some recent evidence that people with autism process information in different ways to people without autism comes from an examination of their 'islets of ability', that is, the unusually intact and often superior skills in autism. Shah & Frith (1983) studied just one of these, namely the ability to perceive 'embedded figures'. This ability involves analysing complex visual patterns in order to identify smaller patterns embedded within them. They found that on such tasks children with autism were more accurate than control groups of children without autism but of a similar mental age. This suggests that the structure of the brain in autism leads to remarkably different performance in certain domains. The reader is referred to Frith's (1989) book for a fuller discussion of the implications of these results.

Could a cognitive deficit underlie the social and communicative symptoms in autism?

The theory of mind hypothesis

Research has also considered whether a cognitive deficit might be responsible for the specific social and communicative abnormalities in autism, abnormalities which arguably lie at the core of the disorder (Rutter, 1983). One recent hypothesis that has been tested is whether people with autism are specifically impaired in the ability to represent mental states (such as beliefs, desires, intentions, etc.). This research question has been summarized in terms of whether children and adults with autism have developed a *theory of mind* (Baron-Cohen *et al.*, 1985). The phrase 'theory of mind' comes from Premack & Woodruff (1978) who define it as follows:

> In saying that an individual has a theory of mind, we mean that the individual imputes mental states to himself and others ... A system of inferences of this kind is properly viewed as a theory, first because such states are not directly observable, and second, because the system can be used to make predictions, specifically about the behaviour of other organisms. (p. 515)

The development of a theory of mind in normal children seems to be a very early achievement, in progress from the end of the first year of life (Baron-Cohen, 1990a) and firmly established by the age of around three to four years old.[6] The hypothesis that in autism there may be a specific impairment in the development of a theory of mind is particularly attractive because of the claim that a theory of mind is essential in order to understand and predict much of human behaviour (Dennett, 1978a; Wellman, 1985). Consider, for example, how to make sense of the following scenario: A man comes out of a shop and walks off down the street. About half-way down the street he suddenly stops, turns around, runs back to the shop, and goes inside. (We instantly think to ourselves that the man must have *remembered* he has left something in the shop, that he *wants* to retrieve it, and that he *believes* it will still be in the shop). The man then re-emerges from the shop, but this time he walks along slowly, scanning the ground. (Now we make the assumption that whatever he *thought* was in the shop wasn't there, and that he now *believes* he may have dropped it on the pavement outside). If we lacked the ability to refer to the man's beliefs, desires, etc., his actions would seem most peculiar.

So, a theory of mind gives one a ready device for understanding social behaviour. We might predict that if one lacked a theory of mind, that is, if one were blind to the existence of mental states, the social world would seem chaotic, confusing and maybe therefore even frightening. At the worst this might lead one to withdraw from it completely, but at the very least it might lead to very odd attempts at interaction with people, treating them as lacking 'minds', and therefore behaving towards them in a similar manner to the way one approaches inanimate objects. Since the behaviour of people with autism is often described in these terms, it seems worthwhile considering if there are abnormalities in their theory of mind.

But this hypothesis is attractive for a second reason. It has been argued that a theory of mind is also essential for normal communication, both verbal and non-verbal. Perhaps the clearest form of this argument comes from the school of philosophy of language known as Speech Act Theory (Grice, 1957, 1975; Austin, 1962; Searle, 1965). Put simply, the argument is that all communication requires both participants to take into account the background knowledge and presuppositions of the other person in the dialogue, as well as their intentions in communicating. Such mental state attribution is necessary, it is argued, if a dialogue is to respect the conversational rules of *pragmatics*, that is, if it is to be appropriate to the social context (Sperber & Wilson, 1986).

Speech Act theory further argues that one important way in which we convey the *meaning* of our utterances or gestures, and understand the meaning behind another person's speech and gesture, is by reference to their intentions, beliefs, etc. This notion is explained more fully elsewhere (Baron-Cohen, 1988a). But again, it leads to the prediction that if one was unable to appreciate other people's mental states, communication would go seriously awry. The idea that in autism there is an impairment in the development of a theory of mind is therefore a parsimonious candidate hypothesis to explain two key symptoms, namely the social and communicative abnormalities.

Some experimental tests of the 'theory of mind' hypothesis

One way to test if children understand about mental states is to examine if their spontaneous speech contains words that refer to mental states. This approach has been used in studying normal children (Bretherton *et al.*, 1981; Shatz *et al.*, 1983). These studies reveal that from 18 to 24 months old, normal children spontaneously produce mental state terms (such as *think, know, want, remember, pretend*, etc.). In other words, almost as soon as they start talking, normal children appear to refer to highly abstract entities, mental states. However, the problem posed by such data is that it is hard to establish the extent to which children of this age actually understand the terms they are using in their speech.

A simple but more stringent experimental test of normal children's understanding of the mental state 'belief' was developed by Wimmer & Perner, in 1983. They selected belief as the mental state to test because this is arguably the clearest case of a mental state that is *about* something in the world (Dennett, 1978b). That is, it is a mental state that possesses 'Intentionality' (Searle, 1965, 1979). Their test is based on a puppet story in which a character holds a false, and therefore different, belief to that held by the child. Children are scored as passing this test if they can demonstrate that they can take into account the story character's different belief, and that they can predict the story character's action, given her false belief.

An adaptation of Wimmer & Perner's (1983) test is shown in Fig. 1. We gave this test to children with

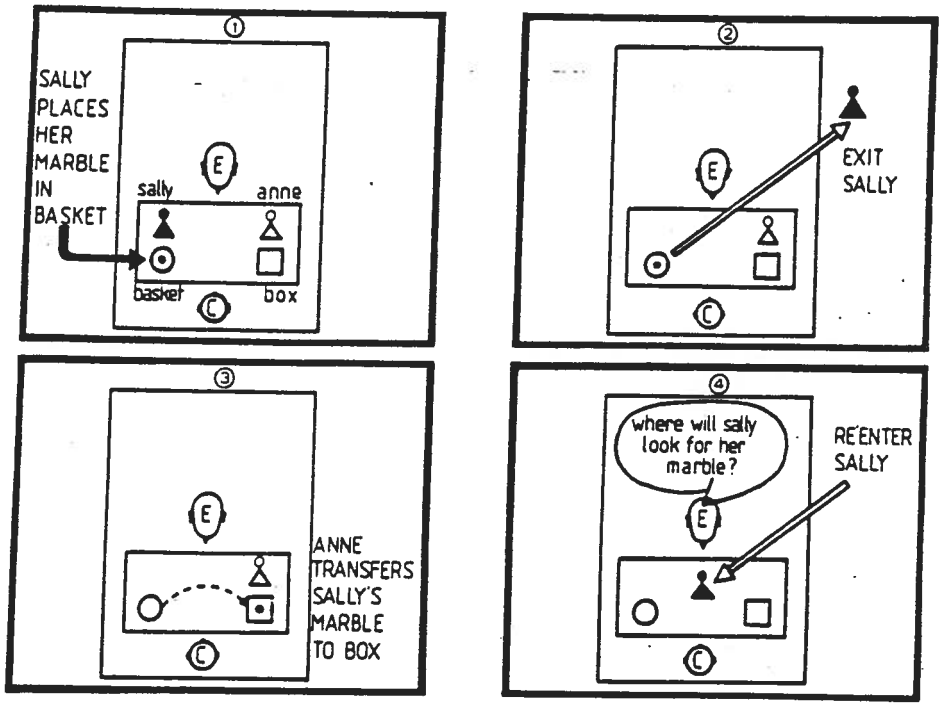

Figure 1. *Scenario of a simple test of a theory of mind.* (Reproduced from Cognition, 21, 37–46).

autism, as well as to a group of children with learning difficulties (all with the diagnosis of Down's Syndrome), and a group of normal children. The beauty of this paradigm is that although it requires a verbal mental age of about four years old to comprehend the narrative of the story, it does not require any expressive language abilities. The subject is only required to point to one location or the other, in response to key questions. Furthermore, control questions establish if the child can understand reality as distinct from belief. Indeed, this is why testing understanding of *false* belief is a good test of the child's concept of belief, in that in such cases belief clearly does not match reality.

The critical event in the story is that Sally is not present when Anne moves the object from A to B. If asked where on her return Sally will look for the object, the correct answer is location A, since this is where she originally put it, and where she therefore *believes* it still is. We found that whilst 86% of the Down's Syndrome subjects, and 85% of the normal children passed this test, only 20% of the subjects with autism did so, and this was so despite this group having a higher mental and chronological age than the two comparison groups (Baron-Cohen *et al.*, 1985). Instead, 80% of the subjects with autism indicated that Sally would look for the object at location B, where the object really was.

This result lends preliminary support to the hypothesis that in autism there is a failure to develop a theory of mind. The data from the control groups further reveals that such a deficit must be autism-specific, rather than the result of general developmental delay. Finally, the data from control questions reveals that children with autism had no difficulty answering questions involving memory, or questions which did not involve mental state attribution.

Over the last five years, this pattern of results has been replicated in 12 subsequent studies, using a number of different paradigms. Some have used real people (Leslie & Frith, 1988; Perner *et al.*, 1989; Shaw, 1989; Russell *et al.*, 1990; Sodian & Frith, 1990), whilst others have used picture stories (Baron-Cohen *et al.*, 1986), or dolls (Baron-Cohen, 1989b, c; Leekam & Perner, 1990; Harris & Muncer, 1988), or direct questioning (Dawson & Fernald, 1987) and even computer-generated images (Swetnam, 1990). Only two studies have obtained mixed results (Prior *et al.*, 1990; Oswald & Ollendick, 1989), but the number of successful replications suggests that this deficit is fairly robust.

How specific is the deficit?

The question arises as to the specificity of this deficit. First, is it specific to autism? All childhood clinical populations that have so far been tested show no impairment on such tests, and these populations include children with the following diagnoses: Down's Syndrome, mental handicap of unknown aetiology, language-impairment and deafness. (For references to these, see the studies mentioned in the previous paragraph, and see Leslie & Sellers, 1990.) Other clinical populations remain to be tested, but the deficit does seem to be autism-specific. Secondly, is the deficit specific to understanding the mental state 'belief'? Some of the studies mentioned earlier have tested understanding of other mental states such as *know, think,* and *pretend* by children with autism, and these too appear very difficult for them. This is also borne out in studies of the spontaneous speech of children with autism, which rarely contains any mental state terms that refer to thinking, knowing, or believing (Tager-Flusberg, 1989).

Naturally, before concluding that the deficit in cognition is specific to their theory of mind, it is necessary to show that other aspects of social cognition are unimpaired in autism. Social cognition can be defined as that part of cognition which is used in everyday interaction with the social world. Studies have examined this question, and show that children with autism are unimpaired in a range of social cognitive tasks. These include visual self-recognition, peer recognition, distinguishing self from other people, person-permanence (that is, understanding that people continue to exist even when you can no longer see them), distinguishing animate and inanimate objects, and perceiving relationships. More importantly, children with autism are also unimpaired on tests of perceptual role-taking, that is, judging what another person can see. This array of findings is reviewed in more detail elsewhere (Baron-Cohen, 1988a, 1989d, 1990).

The deficit in their theory of mind thus contrasts with this growing list of unimpaired social cognitive skills, and in particular contrasts strongly with their good performance on tests of perceptual role-taking, suggesting that the impairment is in conceptual (rather than perceptual) role-taking.[7] This is not to say that all other social cognitive abilities are unimpaired: some studies have also found impairments in imitation skills in people with autism (Ohta, 1987), and in their ability to recognize emotional stimuli relative to non-emotional stimuli (Hobson, 1986; Hobson *et al.*, 1989). How these deficits relate to their difficulties in understanding mental states is a key question for autism research.

Linking a theory of mind with the brain

In building the bridge between a theory of mind and the brain, an assumption needs to be made. This is that in normal children the development of a theory of mind reflects a specific biological change in the brain. From this assumption we can infer that in autism this biological development does not occur in the normal way. This assumption receives some indirect support from the fact that in normal development the emergence of a theory of mind is both universal (that is, it appears to be present in all cultures,[8] much like language), and follows a highly specific and dramatic timetable. These issues are discussed further in Astington *et al.* (1988). Direct evidence for a brain basis of a theory of mind must await future research. We return to this point in the conclusion of this paper.

Linking a theory of mind with behaviour

In building the bridge between a theory of mind and behaviour, another assumption needs to be made. This is that in normal people social and communicative behaviour is largely appropriate to the immediate social context because our theory of mind allows us to imagine the thoughts, expectations, etc., others may hold, and to modify our behaviour in the light of these. From this assumption we can infer that deficits in the theory of mind of a child with autism might underlie some important symptoms in their social and communicative behaviour. Let us briefly summarize this behaviour.

Abnormalities in social behaviour in autism have as their common feature a lack of 'reciprocity' (Rutter, 1983). In its most severe form, the child may be totally withdrawn, but in its mildest forms the child may attempt to interact with other people, but does so in an 'odd', one-sided, stilted and repetitive way (Wing & Gould, 1979). Abnormalities in the communication of people with autism have as their common feature a failure to respect the 'pragmatics' of conversation, that is, an apparent lack of awareness of how to use language appropriately to a given social context (Baron-Cohen, 1988a). Such problems can be accompanied (and sometimes even masked) by difficulties in comprehension or expression of speech. In its mildest form however, a child may be able to produce normal sentences but in a way that violates the norms of

dialogue. Could a lack of reciprocity and a pragmatics deficit be the behavioural signs of an impaired theory of mind? Consider the following story.

An anecdote

Martin,[9] a 13-year-old boy with autism, approached me in the playground in his school. He asked me my name, and when I told him it was Simon he replied "I know seven Simons, and three of them have gold glasses". Slightly taken aback, I said 'Oh, really?', but he paid no notice to my response. He was already continuing with a set of questions which (as I later learned from one of his teachers) he asked all visitors to his school: 'Where do you live? Which bus goes to your house? Have you got round windows or square windows in your house? How many sides does a hexagon have? Is Princess Anne's birthday on August the 15th?'. Between each question he left suitable pauses for my answers, but if I tried to steer the conversation on to other topics and away from his, he ignored these and carried on with his own questions.

When I next saw Martin on a later visit, he launched into the same set of questions, but this time I persisted and succeeded in asking one of my own questions: I asked him what he had done today. He replied 'He pushed me'. When I asked him who had pushed him, Martin replied 'Did he throw a book at me?' I said 'Martin, was I there when it happened?'. He correctly said that I hadn't been there. 'Then would I know if he threw a book at you?'. At this point Martin abruptly walked away, without explanation.

This story illustrates a number of things. First, it is clear that some children with autism are highly motivated to interact with other people, but do so in very repetitive and restricted ways. Secondly, it reveals the way in which abnormalities in reciprocity and pragmatics are intimately intertwined. But more importantly for the present purposes, this example conforms closely to what one might predict social behaviour and language might be like if one was 'blind' to the beliefs, intentions, knowledge, or other mental states of other people. Martin appeared unaware of my desires and intentions in the conversation, and of what I might think of his behaviour, and failed to take to take into account the background knowledge that I would need in order to follow his conversation.

Of course, just because such observed social and communicative behaviour in autism resembles what we imagine this would look like if one lacked a theory of mind, this is insufficient to conclude that it is *due* to this deficit. A stronger case could be made if it was shown that measures of communication and social functioning correlated with performance on tests of a theory of mind. This has been demonstrated in the case of communication (Perner *et al.*, 1989), and a study is currently underway to investigate this for social behaviour (Frith & Siddons, personal communication).

The theory of mind hypothesis of autism is not intended as an account of all behavioural abnormalities in autism. There are, for example, syptoms in autism which are likely to be independent of the social and pragmatic impairments discussed earlier. These may include abnormal reactions to sound, light, heat and even touch, shown by some people with autism (Wing, 1976). Arguments have been put forward that the theory of mind hypothesis might nevertheless relate to the symptom of impoverished imagination in autism (see Leslie, 1987, or Baron-Cohen, 1987 for further discussion of this idea), and perhaps to the repetitive behaviours seen in autism (Baron-Cohen, 1989e), but the hypothesis has been proposed primarily to account for the social and communicative abnormalities.

A theory of mind: does it develop at all in people with autism?

On all tests of autistic children's theory of mind, an identifiable sub-group consistently pass. They comprise about 30% of children with autism with a mental age (verbal or non-verbal) above 4 years old. From this it becomes clear that a theory of mind cannot be impaired in a blanket sense in all children with autism. One hypothesis that has been advanced is that there may be a *delay* in the development of a theory of mind in autism, such that all children with autism are very late in developing this ability, but that after a severe delay it may emerge.

Some evidence for this notion comes from a study of those children with autism who can pass so-called *first-order* belief attribution tests (that is, who are able to make correct attributions of the form *Sally thinks the marble is in the basket*). In this study (Baron-Cohen, 1989b) the subjects with autism were nevertheless shown to be impaired in more complex tests of a theory of mind, namely at the level of *second-order* belief attribution. (An attribution at this level takes the form *Mary thinks that John thinks the ice cream van is in the park.*) First-order belief attribution is easily within normal 4 year olds' understanding, whilst second-order belief

attributions can be made by normal children over 7 years old (Perner & Wimmer, 1985). Such studies therefore suggest that a minority of children with autism do reach the stage of a normal 4 year old in the development of a theory of mind, but are nevertheless delayed in reaching the stage of a normal 7 year old.

What distinguishes those children with autism who can make first-order belief attributions from those who cannot? One critical variable seems to be chronological age. To date, we have found no subject with autism aged less than 11 years old who can pass even this simple test. However, chronological age by itself cannot explain how this sub-group is different, in that there are children with autism older than 11 years old who continue to fail such tests. An additional variable also seems to be mental age, in that most (but not all) of the subjects with autism who pass at this level have a mental age of at least 6 years old. But even this is not sufficient, in that there are children with autism with a higher mental age who nevertheless fail these tests. Which additional factors contribute to an individual belonging to this sub-group is currently being investigated in a longitudinal study (Baron-Cohen & Humphreys, 1990).

Strong but indirect evidence that there is indeed one single deficit underlying the failure on many tests of different aspects of a theory of mind comes from the fact that the *same* individual subjects who pass one test of a theory of mind also tend to pass any other test of a theory of mind. Thus, the few children with autism who pass false belief tests (such as that shown in Fig. 1) also tend to pass tests of the mental–physical distinction, the appearance–reality distinction, and can conceive of the brain as having mental functions (Baron-Cohen, 1989c). Such evidence is also consistent with the notion of a severe delay in the development of this ability, in that it appears that once it has developed in a particular child with autism, he or she is then likely to pass a range of different 'theory of mind' tests. Finally, it appears that as a theory of mind develops in autism, albeit at a delayed rate, it may proceed in the same sequence as it does in normal development. For example, the mental state 'desire' is understood earlier than 'belief' by normal children (Wellman & Bartsch, 1988), and this is true in autism too (Baron-Cohen, 1990b).

Possible origins of an impaired theory of mind

It cannot be the case that development is entirely normal in children with autism until the age at which children usually pass tests of a theory of mind, namely at 3 or 4 years old. We can be sure of this for two reasons. First, social and communicative abnormalities in autism are known to begin before 36 months (DSM–IIIR, 1987). Secondly, normally developing 1 and 2 year olds also fail tests of a theory of mind, yet nevertheless show a range of social and communicative abilities not seen in autism. It is therefore likely that in infancy there are precursors to the development of a theory of mind.

One likely precursor to a theory of mind is the ability to understand another person's *attentional states*, that is, the ability to appreciate what another person is attending to, or what they find of interest (Baron-Cohen, 1989f, 1990a). This develops very early and is certainly present from around 10–14 months of age, as manifested in young children's production and comprehension of 'joint-attention' behaviours (Bruner, 1983). These include giving and showing objects, and pointing to objects.

The first two of these behaviours are, I think, self-explanatory, but the latter needs a little elaboration. Pointing occurs when a person extends their index finger towards an object, and it seems to occur for at least two different functions. The first is in order to obtain an object (so-called 'protoimperative pointing'), whilst the second is in order to comment or show interest in an object (so-called 'protodeclarative pointing'). Interestingly, children with autism are impoverished in the amount of giving and showing behaviours they produce (Sigman *et al.*, 1986), and whilst they do use and understand protoimperative pointing they almost never use or understand protodeclarative pointing (Baron-Cohen, 1989d). This may hold important clues about the developmental origins not only of a theory of mind in normal development, but also about its impairment in autism. It also suggests that early diagnosis of autism might be possible on the basis of the absence of joint-attention behaviours. We are currently testing this possibility.

Summary and implications for future research

In this paper I have explored a way of linking the biology and behaviour of autism. This link focuses on cognitive deficits in autism, deficits which are assumed to be based in the brain and which cause behaviour. One such autism-specific deficit is in the child's theory of mind, that is, in the ability to

attribute mental states to others. This deficit, which shows up reliably across a series of studies, would by itself wreak havoc with the child's social and communicative development, given its critical importance in normal development (Wellman, 1985; Astington *et al.*, 1988). In the title of this paper I have coined the term *'mind-blindness'* to describe the circumscribed nature of the cognitive deficit in autism, and to emphasize the gulf that I imagine must exist between these children and the access people without autism naturally have to other people's minds.[10]

Some questions for future research include the following. First, is such a deficit amenable to any form of psychological treatment? Currently there is no data with which to answer this question. It is clear that a broad-based social skills training package has little effect on deficits in the child's theory of mind (Howlin & Rutter, 1987), but whether a specifically tailored social-cognitive training programme which focuses precisely on this cognitive deficit will have any benefits is an open question, and one which we are currently studying.[11]

Secondly, where in the brain might a dysfunction exist, to disrupt the development of a theory of mind in autism? The new scanning techniques that allow imaging of the brain *during* cognitive tasks may provide answers to this question. One possibility is that the brain system responsible for the dramatic onset of protodeclarative pointing in normal children, at around 10–14 months, may be dysfunctional in autism.

Thirdly, does a delayed development of a theory of mind lead to additional psychiatric complications? There are two clues that this may be the case. One clue is the occasional case studies (Baron-Cohen, 1988b) describing anti-social acts by people with autism, acts which are associated with a lack of awareness of the victim's thoughts and feelings. The second clue also comes from occasional case studies (Newson *et al.*, 1984) which describe depression occurring in older and more able people with autism. These studies again suggest this may be associated with the person becoming aware that other people *think* they are different.

Finally, are there *degrees* of mind-blindness? If so, do these correspond to the different positions at which an individual may lie on the 'autistic continuum' (Wing, 1988; Bishop, 1989)? To answer all of these questions, we need research in which neurobiological and cognitive, or cognitive and behavioural measures, are *simultaneously* considered.

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Notes

1. Thus, within most classificatory systems, a diagnosis of autism is made if abnormalities are present in social and communicative development, and if repetitive, stereotyped behaviours are also present. An age of onset for these features is also stipulated in most classificatory systems, of before 36 months of age.
2. Mandler (1985) discusses the scope and objectives of cognitive science. Although cognitive science is relatively new, its roots go back at least to Plato and Aristotle (see Posner, 1973, for a historical discussion).
3. In cognitive science the assumption is made that although cognitive mechanisms are in the brain in the case of humans and other animals, these could in principle be instantiated in any other formally equivalent non-biological system.
4. Thus one of Hermelin and O'Connor's tasks, carried out in conjunction with Frith, involved recall of meaningful or meaningless lists of items. They found that whilst all children had a rather low limit on the number of meaningless items they could recall, normal (and non-autistic mentally handicapped) children's recall dramatically improved when they were tested using lists of meaningful items. In contrast, children with autism did not show this pattern. These tasks are reported in Hermelin & O'Connor (1967) and Aurnhammer-Frith (1969).
5. So, for example, whereas normal children tend to convert visual information into a verbal/auditory code when storing it in memory, children with autism tend to store it directly as visually coded information (Hermelin, 1978).
6. For a recent book which brings together this fascinating area of normal development, see Astington *et al.* (1988). I have reviewed the significance of this book for child psychiatry elsewhere (Baron-Cohen, 1989a).
7. In this paper I use the term 'conceptual role-taking' synonymously with 'theory of mind'.
8. More cross-cultural studies are needed in this area. The prediction is that whilst the content of a theory of mind is likely to vary from culture to culture, all cultures have some concept of beliefs, desires, etc. (Fodor, 1987).
9. This name is fictitious. The content of the conversation was noted down immediately after the conversation, as accurately as I could recall it.
10. Since writing this paper, I have subsequently read Frith & Frith's (1990) chapter in which they use the term 'mind-reading blindness' to refer to the same deficit in autism. The similarity in our independent choices of metaphor suggests to me that the comparison with blindness may indeed turn out to be a useful one.
11. This research is being carried out in collaboration with Patricia Howlin.

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