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Domain specificity in conceptual development: Neuropsychological evidence from autism*

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Abstract

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To understand some aspects of conceptual development it is necessary to take cognitive architecture into account. For this purpose, the study of normal development is often not sufficient. Fortunately, one can also study neurodevelopmental disorders. For example, autistic children have severe difficulties developing certain kinds of concepts but not others. We find that whereas autistic children perform very poorly on tests of the concept, believes, *they are at or near ceiling on comparable tasks that test understanding of pictorial representation. A similar pattern was found in a second study which looked at understanding of a false map or diagram: normal 4-year-olds showed a marked advantage in understanding a*

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Editor: This article should have appeared in *Cognition* volume 40, number 3, together with the article by Leekam & Perner entitled "Does the autistic child have a metarepresentational deficit?". Unfortunately, an administrative error made this impossible and delayed the appearance of the present article. We apologize for this mistake.

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false belief over a false map, while the autistic subjects performed better on the map. These findings suggest that the concept, believes, *develops as a domain-specific notion that is not equatable with "having a picture (map or diagram) in the head". This result supports the existence of a specialized cognitive mechanism, which subserves the development of folk psychological notions, and which is dissociably damaged in autism. We extend these ideas to outline a new model of the development of false belief performance.*

Introduction

We ask two related sets of questions. First, what is the origin of understanding mental states? How does the preschool child understand that, for example, mother *believes* Sally is in the garden? Does the child treat *belief* as a domain-general problem in a "theory of representation" by drawing an analogy between mental states and public representations, such as pictures and maps? Alternatively, are early mental state notions domain specific and, if so, what is their nature?

Secondly we ask: is the well-known poor performance of autistic subjects on belief tasks the result of an impairment in general problem-solving ability or the result of an impairment in a domain-specific processor? To examine these questions, we combine developmental and neuropsychological evidence in a comparative approach to cognitive architecture. We argue that children are equipped with a domain-specific processing mechanism ("ToMM") which allows the child to attend to mental states, which employs a representational system specialized for that job, and which is specifically impaired in autism.

Child's 'theory of mind' as a representational theory of mind

How do preschool children acquire a concept of *belief*? There is a deceptively simple answer to this. Children get the idea that a belief is a kind of *representation* in the head – a picture, for example. Pictures, the argument runs, are much easier than beliefs to learn about because pictures are public and observable. So, to have a belief is to have a picture in the head. When Sally puts her marble in the basket, she sees it there and forms a picture, in her head, of the marble sitting in the basket. Sally then goes away. While she is away, Anne moves the marble into a box. Sally does not see this, so she does not form a new picture. When Sally comes back, she consults her "memory" – that is, her picture in the head. In this picture, the marble is in the basket. Such internal pictures somehow direct behaviour, so Sally will look in the basket for her marble.

According to the above, the child's task in developing a concept of *belief* is to understand the nature of representations, in this case pictorial representations.

Sally's picture-in-the-head depicts a situation featuring a particular marble – the one Sally hid. In this depicted situation the marble is in a particular place – the basket (the one in which Sally put her marble). But Sally's picture-in-the-head has gone out of date; so if she acts on its basis, she will go astray. Thus, mental states like *belief* can be understood as pictures-in-the-head *iff* the child can understand the representational nature of pictures.

The above seems an important theoretical possibility. Some version or other of the representational theory of mind (RTM) figures in most current scientific thinking. The main feature of an RTM is that there are entities in the mind which represent states of affairs in the world. Representations embody structured meanings (i.e., express propositions) within a given *medium*, for example, an image, map, or sentence. Parts, identifiable within the medium (e.g., words, lines, figures), can stand for objects in the world, while relations between these parts can stand for relations between those objects. But do preschool children only understand belief by developing a common-sense RTM – like scientists, do they conceive of mental states as representations?

In the literature on the child's "theory of mind", there is near consensus that the preschooler develops a representational theory of mental states (e.g., Flavell, 1988; Forguson & Gopnik, 1988; Gopnik & Slaughter, 1991; Perner, 1988, 1991; Wellman, 1990; Wimmer & Hartl, 1991; Zaitchik, 1990). This idea is carried furthest by Perner (1991) who argues that 4-year-olds can succeed on false belief tasks only to the extent that they adopt an explicit RTM.

One version of RTM a child could have is a "pictures-in-the-head" theory. With this in mind, Zaitchik (1990) investigated children's understanding of the representational nature of photographs. The results of her elegant experiments were a little surprising on the above analysis (but only a little). Four-year-olds did not understand out-of-date photographs any better than out-of-date beliefs. If anything, they understood false beliefs slightly earlier than false photographs. That is, some 4-year-olds passed standard false belief tasks while failing false photographs tasks, even when tested in comparable ways. The reason that this was only a *little* surprising, however, was because, as Zaitchik argued, there might be particular reasons why photographs were less well understood. For example, young children may find the mechanisms of cameras and photograph taking somewhat baffling.

Neuropsychological perspectives

Still Zaitchik's results should give us pause in pursuing a "picture-picture" of belief understanding. The results are, after all, compatible with an alternative view: that understanding mental states is not the same as understanding other kinds of representations. Understanding mental states may follow its own proprietary developmental course and not depend on a general theory of representation.

The above might result if, for example, brain mechanisms responsible for developing an understanding of mental states were separate and dissociable from mechanisms responsible for developing notions of other, non-mental representations. There would then be (at least) two neuropsychologically different concepts of "representation" (mental vs. the rest) with different developmental courses.

We shall argue that the preschooler employs a set of notions substantially weaker than those entailed by RTM. These weaker notions, called "informational relations" by Leslie (1987), correspond to concepts of *propositional attitudes*. Though weaker, these notions are specific to the "theory of mind" domain.

Under some circumstances, it would be impossible to tell if the alternative assumption of dissociable domains was correct simply by looking at normal development. For example, two parallel but independent streams of development, which result in two parallel but independent sets of concepts, but which happen to follow a similar time course in the normal case, will create the appearance of a single process of development. Such an analysis will erroneously favour attributing a unitary concept to the child. Zaitchik's data suggest that such circumstances obtain for pictures and beliefs.

Fortunately, we are not limited to study of the normal case. We can use the occurrence of neurodevelopmental disorders to factor apart cognitive components which otherwise appear seamless and monolithic. Morton (1986) calls this "developmental contingency modelling" (see also, for example, Farah, 1984, and Shallice, 1988, on factorizing cognition through the study of acquired disorders; and also Marr's remarks, 1982, pp. 35–36). Such an approach is particularly relevant if development requires a rich innate cognitive organization rather than the homogeneous potential assumed, for example, in the Piagetian view. When we apply this neuropsychological method to the present problem, we obtain, as we shall see, striking evidence of a dissociation in *autism* between understanding false photographs and maps and understanding false beliefs. This reinforces the idea that conceptual development in understanding mental states ("theory of mind") is, at least partly, domain specific.

Figure 1 shows four possible patterns of developmental relationship between concepts of *mental states* and the concept *pictures-as-representations*. The first option is that a single mechanism is responsible for producing both sets of concepts. The second is that there are two distinct mechanisms, one of which is a necessary precursor of the other. In this case, the mechanism which is responsible for producing mental state concepts is the necessary precursor. The third option is a similar arrangement to the second, but this time the precursor is the mechanism responsible for understanding pictures as representations. Finally, there are two distinct mechanisms which develop independently and in parallel. So far, Zaitchik's data leads us to consider only that option three might possibly be wrong.

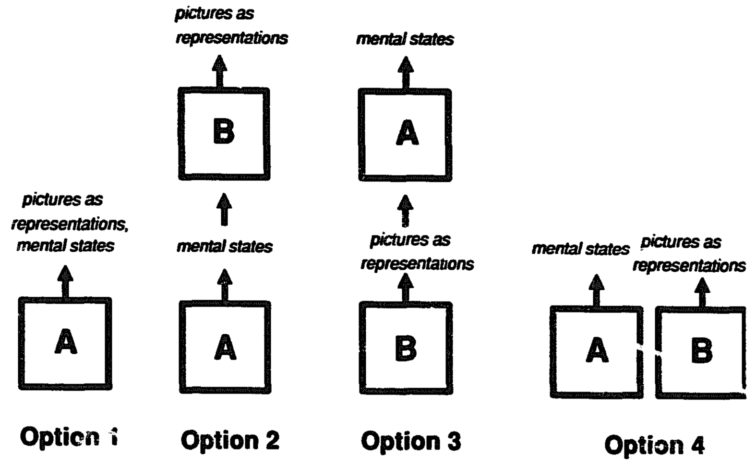

Figure 1. *Four theoretical possibilities for the cognitive architecture underlying the development of concepts of mental states and concepts of pictures as representations. Option 1: a single mechanism is responsible for both. Option 2: there are two distinct mechanisms; one (labelled A) develops mental state concepts, the other (B) concepts of non-mental representations. Mechanism A is a necessary precursor for mechanism B. Option 3: Same as 2 but B is a necessary precursor for A. Option 4: Mechanisms A and B develop independently and in parallel.*

We now briefly outline some recent theory and evidence on a cognitive developmental abnormality in autism that makes this disorder particularly relevant to studying the spontaneous development of "theory of mind".

Autism and theory of mind deficit: evidence and theory

There is a growing body of evidence showing that autistic children are specifically impaired in their capacity to develop a theory of mind. For example, autistic adolescents have a poorly developed concept of *belief* (in both its true-belief and false-belief varieties). These children perform well out of line with their general intellectual level on tasks which test these concepts, while other clinical groups, such as Down's syndrome or specific language-impaired children, perform roughly in line with mental age (Baron-Cohen, 1989b; Baron-Cohen, Leslie, & Frith, 1985; Leslie & Frith, 1988; Perner, Frith, Leslie, & Leekam, 1989; Russell, Mauthner, Sharpe & Tidswell, 1991). At the same time, autistic children appear to be relatively unimpaired in their understanding of social events that do not require an understanding of mental states but simply of behavioural dispositions (Baron-Cohen, Leslie, & Frith, 1986). Autistic children also show characteristic abnormalities in communication, having, for example, difficulties understanding non-instrumental communicative gestures (Attwood, Frith, & Hermelin, 1988; Baron-Cohen, 1989a; Sigman, Mundy, Sherman, & Ungerer, 1986) and in pragmatic aspects of language use (see Frith, 1989b, for review). Finally, autistic children show abnormalities in their development of pretence, and do not exhibit spontaneous pretend play (e.g., Baron-Cohen, 1987; Ungerer & Sigman, 1981; Wulff, 1985).

Leslie and Frith (1990) have argued that the traditional, affective theory of autism (Hobson, 1990; Kanner, 1943) is unable to explain the above pattern which recent work has uncovered. What is required is a biologically based cognitive deficit having specific but profound consequences for the child's social cognition (Frith, 1989a). Leslie (1987, 1991; Leslie & Happé, 1989; Leslie & Frith, 1990; Leslie & Roth, in press) has outlined a theoretical model of the cognitive impairment underlying this pattern. The model assumes that autism is a neurodevelopmental disorder with a biological aetiology resulting in a core *triad of impairments* (Wing & Gould, 1979) which are defined at the behavioural level. This triad comprises impairments in social competence, in communication skills, and in pretending. Leslie's model ties the explanation of the triad of impairments, together with the above pattern of abilities and disabilities, to impairment of a single cognitive mechanism.

Outline of the theory of ***ToMM***

In the normal child, according to Leslie (1987; Frith, Morton, & Leslie, 1991; Leslie & Frith, 1990), brain development leads to the functional emergence of a cognitive mechanism whose task is to understand agents' behaviour in terms of agents' mental states. To carry out this task, the mechanism infers from a representation of behaviour to a representation of the *propositional attitude* which accounts for the behaviour.[1] This emerging mechanism embodies the initial state of the child's "theory of mind" providing the specific basis for the normal capacity to acquire and elaborate folk psychological ideas. We call this mechanism, the theory of mind mechanism or **ToMM**.

To represent propositional attitudes, **ToMM** employs a special representation system, which Leslie (1987) called the "metarepresentational schema". The metarepresentation makes explicit four kinds of information. These categories of information are:

(1) an informational relation (specifying an attitude – e.g., PRETEND) followed by three arguments which specify, respectively:
(2) an agent (e.g., mother or self);
(3) an anchor (e.g., some aspect of the current real situation);
(4) an imaginary or pretend situation.

[1]A propositional attitude is a relation between an agent and a proposition such that the agent takes an attitude to the truth of the proposition (Fodor, 1981). For example, John *believes*, but Mary *hopes*, that it is raining.

Thus, the metarepresentation describes a given agent as holding a particular attitude to (the truth of) a specified imaginary situation in respect of a specified aspect of reality.

The metarepresentation can be illustrated with respect to the understanding of *pretence*. The propositional attitude concept, *pretends*, appears to be first employed between 18 and 24 months. This allows the child to make sense of mother's behaviour – for example, talking to a banana – by reference to mother's mental state, captured by the metarepresentation, **Mother** PRETEND (of) **this banana** (that) **"it is a telephone"**.

Employing the concept *pretend* requires the child to cognize opaque contexts and to reason counterfactually. The metarepresentational schema makes this possible by way of a "decoupled" component (the expression in quotes above) which describes the imaginary situation. The effect of decoupling is to introduce extra structure into the metarepresentation. This extra structure influences how inferences are carried out (Leslie, 1987, 1988b).

A metarepresentation, as defined by this theory, is a particular relational data structure computed by an information processing device.[2] This device, **ToMM**, begins to develop in infancy. The metarepresentational model successfully predicts the yoking in development between the ability for solitary pretence and the ability to understand pretence-in-others, by way of substitutability of "**I**" in place of, for example "**mother**" above. Thus, pretence provides an early example of the workings of **ToMM**. Leslie (1991, in press) suggests that **ToMM** provides a small initial set of basic attitude concepts forming a core theory of mind.

The theory of **ToMM** becomes relevant to autism with the suggestion that biological factors intervene in autism to damage or impair the growth of the neural systems underlying **ToMM**. The result, according to the "metarepresentational conjecture", is a specific impairment in the autistic child's capacity to develop a theory of mind. Leslie and Frith (1990) list three sets of domain-specific cognitive impairments that might result from a dysfunctional **ToMM**: (1) an impairment in the normal capacity to develop propositional attitude concepts; (2) difficulties with representing imaginary situations in relation to agents' attitudes ("decoupling" hypothesis); and (3) difficulties with processing metarepresentations. Any or all of these possibilities may be relevant to understanding the neuropsychology of autism.

[2]The term "metarepresentation" was subsequently adopted by Perner (1988, 1991) but used in a quite different sense. Perner insists that the term should be reserved for denoting the child's conscious *theory of representation*. Perner then goes on to criticize Leslie (1987) for not establishing that infants have "metarepresentation" in Perner's intended sense, as if this had been Leslie's intended sense too. But the shift from the perspective of an information processing device (Leslie) to the perspective of what the child consciously knows (Perner) is crucial. After all, no one thinks that because infants represent 3-dimensional space, they must have a conscious theory of geometry. The terminological issue at least is easily resolved – we can call the data structure computed by **ToMM** an *M-representation*.

Comparing RTM and ToMM

The theory of ToMM provides an important reason for suspecting that the idea of an early picture-notion of belief may be wrong. The system of metarepresentation employed by ToMM makes explicit the informational relation (or attitude) that an agent bears to a proposition. The theory therefore highlights the importance of (a) attitude concepts and (b) the role of agents. Attitude concepts, like PRETENDS and BELIEVES, appear to be *sui generis*, and are critical in marking off "theory of mind" as a domain. Furthermore, only agents can hold attitudes. A photograph may depict a situation but it cannot take an attitude to the situation it depicts. It cannot do this, because a photograph is not an agent. These facts may lead us to expect differences in the neuropsychological organization of knowledge about pictures and beliefs.

If the child's spontaneous understanding of mental representation depends upon propositional attitude concepts, and if these in turn depend upon a domain-specific metarepresentational capacity, then impairment of that capacity will have far reaching but specific effects. In particular, autistic children will have severe problems understanding mental representations *without* a corresponding difficulty in understanding non-mental representations.

To examine the above hypothesis, we tested a group of autistic children on two standard false belief tasks together with their corresponding Zaitchik photograph tasks and compared their performance with that of clinically normal 4-year-olds. Given that we expected autistic children to perform *better* than normal preschoolers on photograph tasks, and given that previous studies have controlled for mental retardation on false belief tasks, there was no particular need in this study to include a group of mentally retarded controls.

EXPERIMENT 1

Method

Design

Two pairs of tasks were used to test the hypothesis of a dissociation between false belief and false photograph tasks. One task in each pair tested false belief understanding, while the other was a corresponding test of understanding a false photograph. The first pair involved the belief or photograph going out of date due to a change in position of an object, while in the second pair the identity of an object in a belief or photograph was at stake. Two groups were given these tasks: normal 4-year-olds and autistic children. False belief and picture tasks were interleaved in eight different orders and randomly assigned to subjects.

Subjects

Twenty normal children were tested along with 15 children and adolescents diagnosed as autistic according to standard criteria (DSM-IIIR; Rutter, 1978) and attending special schools for autism. As far as we know, the autistic subjects had never before been tested formally on theory of mind or false photograph tasks. All children were tested on the British Picture Vocabulary Test. Thus we could ensure that the autistic sample had a minimum verbal mental age (MA) of 4 years 4 months and that the normal children's mean verbal MA was close to this minimum (4 years 5 months). This allows us to make a conservative comparison of false belief performance.[3] Table 1 shows background variables.

Tasks

There were two false belief tasks, both of which have been used previously with autistic children: a variant on the Sally/Anne task (Baron-Cohen et al., 1985; Leslie & Frith, 1988) and the Smarties task (Perner et al., 1989). There were also two photograph tasks closely modelled on Zaitchik (1990): one of these corresponded to the Sally/Anne false belief task and involved a photograph being taken of an object in one position, then the object being moved to a new position; the other involved a photograph being taken of an object in a certain position, then that object being swapped for an object of a different identity. We shall talk about these task pairs as "place change tasks" and "identity tasks".

Previous studies with false belief tasks indicate that the order of control and test questions is not critical to autistic performance. Nevertheless, we had different orders of these questions in the two tasks we administered. Likewise, for the photograph tasks we had different orders: in one, we asked the test question first, and in the other we asked the test question last. Our own results and those of Leekam and Perner (1991) and Zaitchik (1990) suggest that order of questions is not critical in these tasks either.

Table 1. *Background variables for subjects in experiment 1 (years:months)*

	Chronological age		Verbal mental age
Normal	Mean	4:0	4:5
($n = 20$)	Range	3:8–4:5	2:6–7:3
Autistic	Mean	12:0	6:3
($n = 15$)	Range	7:10–18:7	4:4–14:5

[3]For autistic children, the BPVS regularly produces verbal mental ages which are low with respect to their non-verbal ability and often low with respect to their grammatical ability too. It therefore provides a conservative estimate of autistic children's general intellectual level.

Place change, false belief. The child was introduced to a doll character, Billy, and three pieces of toy furniture: a bed, a dressing-table and a toy-box. A story was enacted for the child in which Billy had a ball. Billy put his ball on the dressing-table then went downstairs for breakfast. While Billy was away, his mother came into his room, picked up the ball and put it in the toy-box. The child was then asked four questions: *control question 1*, "Where did Billy leave his ball?"; *know question*, "Does Billy know where his ball is?"; *think question*, "Where does Billy think his ball is?". We used a *think* test question rather than a prediction of behaviour question to be closer to asking directly about a mental representation. Finally, *control question 2*, "Where is the ball really?".

Place change, photograph. Two puppets were introduced to the child along with some toy furniture. A story was enacted for the child in which one puppet (Polly the horse) was to take a photograph of the other (the cat). The cat was placed on the chair and the horse was shown looking into the camera viewfinder and pointing it at the cat. It was made clear to the child that the horse was going to take a photograph of the cat. A photograph was taken and placed face down on the table. Then the cat was moved from the chair to the bed. The child was asked three questions: *Control question 1*, "When Polly took the photograph, where was the cat sitting?"; *photograph question*, "*In the photograph*, where is the cat sitting?"; *control question 2*, "Where is the cat now?".

Identity change, false belief. The child was shown a "Smarties" box and asked what it contained. All children replied "Smarties". The top was then removed and the child shown that actually it contained a pencil. The pencil was then replaced in the box and the top put back. The child was asked three questions: "*Other*" *question*, "Now, [name of child's friend] has not seen this box before. When I show this box to [name of child's friend] – just like this" (box held up) "before I take the top off – what will [name of friend] say is in here?"; "*self*" *question*, "When I showed you this box in the beginning, what did you say was in here?"; *control question*, "What is really in here?". We were incidently interested in previous findings that autistic subjects found the "say-for-self" question easier than "say-for-other".

Identity change, photograph. This time the cat puppet got to take a photograph of the horse sitting on the toy-box. The photograph was placed face down on the table. The horse was then removed from the toy-box and a mouse puppet took its place. The child was then asked three questions: *control question 1*, "Who was sitting on the toy-box when the cat took the photograph"; *control question 2*, "Who is sitting on the toy-box now?"; *photograph question*, "*In this photograph*, who is sitting on the toy-box?"

Procedure

Children were tested individually in a quiet room. Children were tested on two occasions about a month apart. On the first session, the children were tested on BPVS.

In the second session, each child was first introduced to the polaroid camera and acquainted with how it worked, closely following Zaitchik's pretraining. Thus, the child took a photograph of an object in the room, watched the photograph develop and talked with the experimenter about what was in the photograph. None of the children had any problems with this introduction. The tasks then followed in one of the eight orders. All sessions were videotaped and scored later.

Results

Figure 2 shows the percentage passing in each pair of tasks by groups. The results shown are in answer to the think question in false belief (place change), "other" question in false belief (identity) and the photograph questions in the respective photograph tasks. The graphs show a striking cross-over effect in both pairs of task. Especially impressive is the autistic children's performance on the photograph identity task. Here not a single autistic child failed.

Preliminary analysis indicated that there was no significant difference in performance between the pairs of tasks, so results for these were combined. We awarded each child 1 point for passing a single task and 2 points for passing both

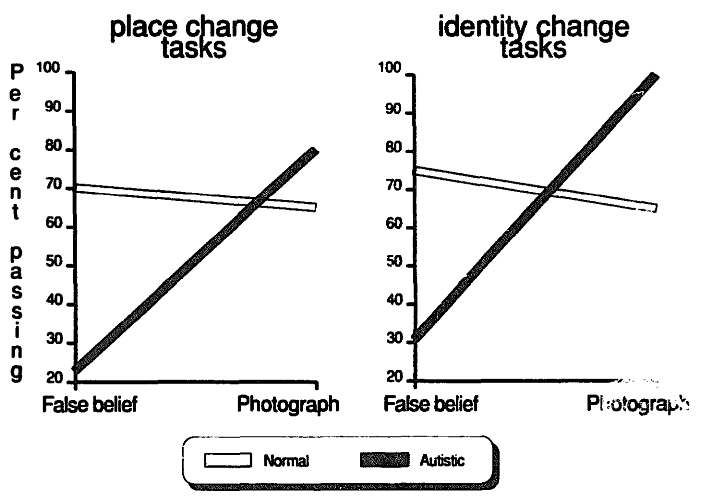

Figure 2. *Autistic and normal 4-year-old children's performance on two pairs of false belief and photograph tasks.*

tasks, and zero points for failing both. Four autistic children and three normal children failed control questions affecting a total of 8 data points. We eliminated these seven children and analysed the remaining data by 2-way MANOVA with factors Group (autistic vs. normal) × Task (false belief vs. photograph). There was no significant main effect of Group. There was main effect of Task, $F_{(26, 1)} = 11.3$, $p < .01$, subsumed under a highly significant Group × Task interaction, $F_{(26, 1)} = 16.85$, $p < .001$.

Although the above interaction effect is large, we wished to check it non-parametrically. Excluding control failures, 65% of the normal children passed both false belief tasks, while only 23% of the autistic children did so ($\chi^2 = 4.0$, $p < .025$, one tailed). This result is firmly in line with the previous findings. However, the question we are interested in is the following. Does performance of the groups on the false belief tasks predict their performance on the photograph tasks? The null hypothesis says it will. Our experimental hypothesis says it will not and that the direction of difference between groups will reverse. We tested this by entering the frequency of children passing and failing on false belief as the expected frequency for the photograph tasks. The observed frequencies were significantly different in the predicted directions ($\chi^2 = 7.89$, $p < .005$, one-tailed). The non-ordinal interaction for subjects passing both versions of false belief and photograph tasks is visualized in Figure 3.

Further analysis showed significantly more autistic children passed the photograph task than false belief in both the place change version (McNemar test of change, binomial, $p = .008$) and in the identity version (McNemar, $p = .004$). These differences were not significant for the normal children.

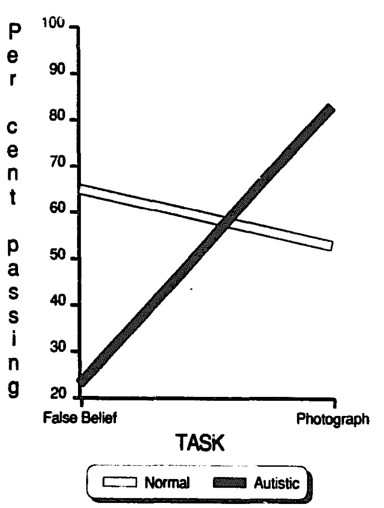

Figure 3. *Autistic and normal 4-year-old children passing both false belief and both photograph tasks.*

We were also interested in the pattern of answers children gave to the two test questions in the Smarties task, one asking the children to report what they themselves had previously said was in the tube and one asking them to predict what another person would say. We looked therefore at the relationship between the "self" and "other" test questions in the Smarties task (see Table 2). There was no significant difference for the normal children between these two questions: 4 correctly predicted what the other would say was in the tube while failing to report correctly what they themselves had said, and 2 showed the opposite pattern. The autistic children, however, mostly succeeded in reporting what they themselves had said while mostly failing to predict what the other would say. Six autistic children correctly reported for "self" while failing prediction for "other" and none showed the opposite pattern (McNemar binomial, $p = .016$). Autistic children performed significantly worse than normal children on the "other" test question ($\chi^2 = 7.29$, $p < .005$) but no differently on the "self" test question ($\chi^2 = 0.1$, n.s.).

Discussion

The main finding concerned the dissociation in autistic children between performance on two "representation" tasks – beliefs and pictures. The relationship we found is never obtained in normal development. Zaitchik (1990) showed that 3-year-olds perform worse and 5-year-olds better, but at no point in normal development does performance on standard false belief tasks lag behind that on the "standard" picture tasks. This contrast shows two things. First, autistic children are not simply delayed but have an abnormal pattern of development (Baron-Cohen, 1991; Leslie & Frith, 1990; Roth & Leslie, 1991). Second, it undermines the idea that normal children first understand public representations, then apply that understanding to mental states and thus come to pass false belief tests.

Table 2. *Performance of autistic children and normal 4-year-olds on "self" and "other" test questions, false belief (identity) task*

		Autistic "Other"				Normal "Other"	
		Fail	Pass			Fail	Pass
"Self"	Pass	6	4	"Self"	Pass	2	11
	Fail	5	0		Fail	2	4
		11	4			4	15

Although the performance of the 4-year-olds on false belief and photographs did not differ significantly, the direction of difference in two pairs of task coincided with that found by Zaitchik (1990) in three experiments which allowed the comparison. The direction of difference in 5 out of 5 experiments suggests that this small difference is nevertheless reliable ($p = \cdot 031$). Autistic performance provides a striking contrast. While only 23% passed the false belief tasks, their performance on false photographs was at or near ceiling. Together, these findings show that understanding false photographs is neither necessary nor sufficient for understanding false belief. The two sets of tasks tap dissociable mechanisms.

Cross-over

The pattern of performance we found is particularly interesting given the near correspondence between the problem-solving characteristics of the tasks. This allows us to clarify a number of points. The cross-over effect rules out a whole class of explanations for the poor autistic performance on false belief. For example, we cannot say that they are worse than normals on false belief because they are mentally retarded, for, then, how do we explain their superiority on the pictures tasks? A similar argument applies to explanations such as: they fail to tune into the experimental situation; they fail to cooperate; they fail to understand instructions; they lack motivation; etc.

Or take the idea that autistic children fail theory of mind tasks because of poor "verbal comprehension skills" (e.g., Boucher, 1989; Prior, Dahlstrom, & Squires, 1990). It is hard to fit a psycholinguistic explanation to the pattern of results obtained here. Bear in mind that autistic difficulties in these tasks do not just relate to sentences with sentential complements. Previous work shows they have as much trouble with the question, "Where will she look for x?" Moreover, a "say" question (like a "think" question) requires a sentential complement in answer. Recall then the good performance when asked what they themselves had said was in the Smarties box. Or again, consider the picture sequencing task of Baron-Cohen, Leslie, and Frith (1986): this required no more "verbal skill" for the mental state condition than for the social behaviour condition. Yet the autistic children performed very poorly in the former but as well as the normal children in the latter. Finally, a number of the studies already referred to have found that other clinical groups with verbal MAs as low or lower than the autistic children perform quite well on these tasks. Therefore, the general notion "verbal skills" will not explain these results. The challenge is to develop specific impairment models.

Utterances and attitudes

The results from the Smarties task were broadly in line with Perner et al. (1989), despite the higher minimum verbal MA in the present autistic group. In that previous study, only 17% of the autistic sample correctly predicted the other person's false belief, while 100% correctly remembered what they themselves had said was in the tube. The present study found 31% correctly predicting what the other person would say, while 67% correctly reported what they themselves had said, a pattern significantly different from the normal 4-year-olds.

The best estimate of normal 3-year-olds' performance on Smarties tasks is that "self" and "other" questions are about equally difficult (Gopnik & Astington, 1988; Lewis & Osborne, 1990; Perner, Leekam, & Wimmer, 1987; Wimmer & Hartl, 1991). Autistic children are like 4-year-olds on "say-for-self" questions but like 3-year-olds on "say-for-other". In short, their pattern of performance is abnormal.

According to the metarepresentational model, autistic subjects are impaired in understanding those aspects of a situation which involve mental states. This allows autistic adolescents to understand and remember a sentence as a description of a situation. However, they will not relate the *uttering* of a sentence to the speaker's underlying propositional attitude: for example, they will not connect assertion with belief. The findings of Roth and Leslie (1991) support this idea. They showed that, in a modified false belief task, normal 3-year-olds related speaker's utterance to speaker's attitude (e.g., speaker believes what she said). This implies that, for 3-year-olds, say-for-self questions inherit the difficulty of belief questions. Roth and Leslie's autistic sample, however, treated the speaker's utterance simply as informative or uninformative (i.e., as a representation) and did not relate it to speaker's attitude. For them, it was not equivalent to a belief question. Finally, we assume that say-for-other questions can only be answered correctly by calculating other's belief. Thus, we can account for the dissociation in autistic samples between say-for-self and say-for-other. Interestingly, Baron-Cohen (1991) found that autistic children do badly on a "*think*-for-self" question.

We have obtained evidence that autistic subjects can understand pictorial representations and, apparently, also sentential representations. We wanted to broaden these findings further by looking at a diagrammatic form of representation that is partly pictorial and partly symbolic, namely a simple map. This will also allow us to examine the influence that knowledge about cameras may have had on these results.

EXPERIMENT 2

Method

We used the same model room. Instead of a photograph, we made a diagrammatic map. Black lines represented the three walls of the room, a series of blue crosses showed the positions of its windows, while coloured line shapes represented the positions of the bed (triangle), toy-box (square) and dresser (circle). We could place a puppet on a piece of furniture in the room and mark its position on the map with a coloured sticker. The child was told the sticker stood for or "meant" the puppet. The puppet in the room could then change position, rendering the map out of date.

Subjects were given pretraining on the use and meaning of the map and pretested to check that they had understood basic use of the map.[4] Given that maps usually show where things are, the place-change scenario seemed more appropriate to maps than identity change. The place-change false belief task from the previous experiment was also presented. All the normal children were new to this study, but half the autistic subjects were from experiment 1. With this latter subgroup, rather than repeat the false belief task, the previous results were used. Order of tasks was counterbalanced where relevant.

The general procedure was the same as the previous experiment.

Map task

This task was modelled on the "place-change" photograph task. The child was introduced to two named puppets and to the model room. In the scenario, a horse puppet had a map of the doll's house showing where the furniture was. The puppet reminded the child again of the correspondence between furniture in the room and the symbols in the map. A dog puppet appeared and announced that he would take a nap on the bed. The horse then took a sticker, emphasizing that it "means" the dog, and said he was putting it in the right place to show *where* the dog was. The sticker was placed on the map in such a way that the child could not see it. The map was then turned faced down on the table. The dog then moved from the bed onto the toy-box. The child was asked three questions: *control question 1*, "Where was [the dog] sitting when [the horse] made the map? – when she put the sticker on the map?"; *control question 2*, "Where is [the dog] sitting now?"; *map question*, "*In the map*, where is [the dog] sitting?".

Subjects

Twenty-one normal children and 18 autistic children diagnosed according to

[4]In pretraining, the model room, its furniture and windows were carefully pointed out to the child. Then the map was introduced with the explanation that it showed where everything was in the room. Each feature of the map was pointed out together with its corresponding feature in the room. The child was told for each feature of the map that it "meant" its corresponding feature in the room. A toy alligator was introduced together with a sticker that "meant" the alligator. The alligator was placed on the dresser and the child asked to place the sticker on the map "to show where the alligator is in the house". If the child failed this pretest then training was repeated. None of the autistic and 5 of the normal children had to have repeat training.

standard criteria (DSM-IIIR; Rutter, 1978) and attending special schools were tested. Nine of these autistic children had also participated in the photograph study. All of the normal children and the new autistic children were tested on the British Picture Vocabulary Test. Table 3 shows the background variables for these two groups.

Results

Three autistic subjects were eliminated for failing control questions. Figure 4 shows the percentages of remaining subjects in each group passing the false belief and maps tasks. A similar cross-over effect to that found previously is readily apparent.

We tested the hypothesis that group differences on false belief reverse on maps by deriving the expected frequency for passing and failing on the map task from the children's passing and failing on false belief. The observed frequencies were different as predicted at a high level of significance ($\chi^2 = 22.4$, $df = 1$, $p < .0005$, one-tailed). Further analysis showed significantly more normal than autistic

Table 3. *Background variables for subjects in experiment 2 (years:months)*

	Chronological age		Verbal mental age
Normal	Mean	4:0	4:8
	Range	3:7–4:6	3:0–7:4
Autistic	Mean	11:5	6:8
	Range	8:5–16:7	4:6–14:10

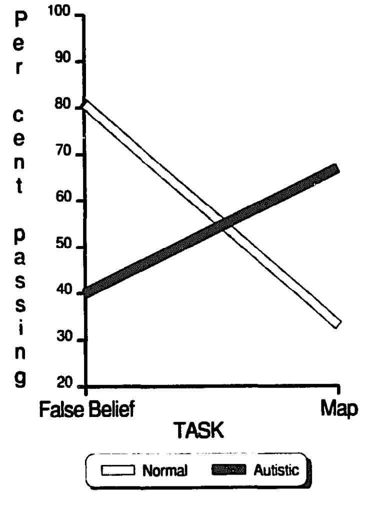

Figure 4. *Autistic and normal 4-year-old children's performance on a false belief and on a map task (both place change).*

children passing the false belief task ($\chi^2 = 4.71$, $df = 1$, $p < .025$, one-tailed), while autistic children do better on the false map ($\chi^2 = 2.68$, $df = 1$, $p = .051$, one-tailed).

Although the autistic children's advantage over the normal group on the map task is less pronounced than their advantage on photographs previously, the same overall pattern recurred. Both groups show poorer performance on the map task than on the photograph tasks, despite not having to understand cameras and photograph taking. Only a third of the 4-year-olds passed the map task, while over 80% passed false belief.

General discussion

Our results support the idea that false belief and representation tasks do not tap the same cognitive mechanisms. It seems there are two sets of concepts, one relating to mental representations and another set relating to non-mental representations, and that it is possible to develop one set without the other. The present study, together with Zaitchik's results, shows that normal children can develop a certain understanding of false belief without a corresponding understanding of pictures or diagrams. On the other hand, autistic children understand pictures, sentences, and diagrams as representations without understanding false belief.[5]

These results do not support the idea that the normal preschooler develops a representational theory of belief in Perner's sense. If we assess the child using "standard" tasks, then understanding public representations is neither necessary nor sufficient for developing an understanding of belief. The 4-year-old does not apparently pass standard false belief tasks by employing a concept of belief as a picture- (map-) in-the-head.

Representational theory of mind: A red herring?

Perner (1988, 1991) argues that the 4-year-old's understanding of false belief tasks is the result of the child making a radical theory shift from a propositional attitude

[5]Leekam and Perner (1991) obtained similar results to those reported here. However, these authors misinterpret Leslie's metarepresentational theory and then fail to see that their results provide support for that theory. Part of their mistake (see also footnote 2) is to concentrate exclusively on decoupling. The present results suggest that autistic children are able to "decouple" only in the *general* sense of being able to think about imaginary or possible states of affairs. However, the suggestion in Leslie (1987) that autism involves a failure of decoupling was made specifically within the context of his metarepresentation theory. It would not be surprising, then, on that account if a decoupling impairment were domain specific. However, this is not the only possibility, and Leslie and Frith (1990) outline some additional hypotheses within the same framework. At the same time, success on the photograph and map tasks shows that autistic children do not suffer a general impairment in problem solving or "executive functioning", though there may well be a domain-specific impairment in theory of mind reasoning.

(PA)-based view to an RTM. Given that he uses the same grounds for distinguishing between propositions and representations that we have used here, the question arises: on what does he base his claim that 4-year-olds project a representational medium into the minds of others? The pivotal argument for Perner (1991, p. 301) in favour of a radical shift comes from observations by Barwise and Perry (1983). Barwise and Perry point out that to understand a report of a false belief, such as "Sally believes the marble is in the box", it is necessary to understand that Sally's belief, though misplacing a specific marble, is nevertheless a belief about that marble: that Sally believes *of that marble* that it is in the box. The italicized phrase is, in Barwise and Perry's terminology, an *anchor* for the variable "it" in the proposition "it is in the box". Sally, then, has an attitude to the truth of the proposition in relation to a particular aspect of a real-world situation. Thus, the propositional attitude *believes* is analysed as a three-term relation between an agent, an anchoring aspect of reality, and (the truth of) a proposition. From this Perner wants to conclude that to understand false belief, the child (or anyone) must necessarily employ a representational theory of mind.

However, there are no clear grounds for supposing that the above relational analysis is *only* possible if the child projects a representational medium into Sally's mind; nor for supposing that such an analysis is applicable only to *believes*. In fact, Leslie (1987) argued for an almost exactly parallel analysis of understanding *pretends* (for a somewhat more elegant formulation of the relevant aspects of his initial proposal see Leslie, 1988b, Leslie & Frith, 1990, and Introduction above). Thus, for example, Leslie (1987, p. 414) points out that "pretense relates to the actual situation in specific ways . . . it is *this* banana that I pretend is a telephone, it is *this* doll's face I pretend is dirty" (emphasis in original) and goes on to analyse PRETEND as a three-place relation (pp. 419–420). Oddly enough, Perner (1991, pp. 293–294) discusses Leslie's (1987) use of the term "anchor" but without connecting it with his own later discussion of Barwise and Perry's analysis of false belief. This oversight leads Perner to underestimate the expressive power of propositional attitudes.[6]

We have two basic disagreements with Perner then. First, we do not agree that

[6]Perner (1991) allows a PA theory for 2-year-olds, largely on the basis of Leslie (1987)'s arguments about the significance of pretence. However, Perner's rendering of the representational structures underlying pretence is crucially different from Leslie's. In Perner's model there are simply two kinds of situation which the young child can represent: actual and pretend. Although both Leslie's and Perner's models use the word "pretend", they are used in each to represent quite different things. Perner's use of "pretend" is to mark the status of a situation and corresponds to Leslie's use of quotation marks to mark decoupled representations. Leslie's use of "pretend", by contrast, was to represent a relation between three things: an *agent*, an *aspect of reality* (using a primary representation), and an *imaginary situation* (using a decoupled representation). In Leslie's model, PRETEND represents a particular kind of attitude that the agent takes to the truth of the pretend situation in the perceived situation (see Leslie, 1987, pp. 418–419). Revealingly, then, Perner (1991) talks about pretence as a propositional attitude, but the model he offers omits both the agent and the attitude.

only false belief understanding requires a three-argument relational structure. Understanding pretence also requires the same structure (but with a different informational relation, of course). If employing such a relational structure is what is meant by understanding the "representational relation", then we conclude that (some) "representational relations" are understood from around 2 years of age, long before success on standard false belief tasks. Terminologically, we suggest that such a (tacit) theory be referred to as PA based.

However, Perner is not satisfied with the above restricted reading of the notion "representational relation" and proposes the strong hypothesis that 4-year-olds project a representational *medium* into the minds of others and, *by this means only*, achieve success on standard false belief tasks. This is our second disagreement with him. We can find no compelling *a priori* argument for this further claim, while our present findings provide empirical evidence against it. If beliefs are conceived of as representations by normal 4-year-olds, it is not clear what medium the child thinks is involved. Apparently, the child does not think the medium is pictorial or diagrammatic. Perner (1991) favours the idea that the child imagines a kind of model-in-the-head which is partly pictorial and partly diagrammatic. The present results cast doubt on this.

Perhaps the child is a kind of "language of thought theorist" and thinks the medium is sentential. But although young children obviously grasp the meaning of sentences, it is not clear that preschoolers pass false belief tasks by imagining that the characters have misrepresenting sentences-in-the-head.

Might one say that the child conceives of mental representations as *medium-less* – not as pictures, sentences, maps, diagrams or whatever but as wholly abstract "meanings"? Indeed one might, but then, that is exactly what is meant by the term *proposition* – a structured meaning which is true or false without being expressed or tokened in a particular medium. On this interpretation nothing is gained by the child's alleged shift to an RTM.

We do not claim that preschoolers *never* imagine that people have "pictures in the head", though we know of no clear evidence that they do. Nor do we claim that children younger than 4 years do not understand representational artefacts. What we do claim is this. Even if preschoolers do have a rudimentary notion of representation-in-the-head, it is not this concept that is routinely used by the preschooler in solving standard false belief tasks. *Nor is it the lack of such a concept that prevents them passing such tasks*. Thus, solving false belief tasks is not evidence for a preschool RTM.

RTM and common sense

Why is it that the basic common-sense theory of mind does not constitute an RTM? Why is a picture-in-the-head notion not the basis for the child's understanding of belief? RTM is a scientific attempt to explain what sort of things propositional attitudes really are. We believe that intuitive theory of mind is not concerned with this question but with capturing how meaning enters into the causation of behaviour. PA notions do just this. According to the **ToMM** theory, the child is equipped initially with a core system of attitude concepts, supplying a core component of belief-desire reasoning. But if **ToMM** allows the early attribution of propositional attitudes in understanding the behaviour of agents, it does not attempt to explain what propositional attitudes really *are*, as RTM does. In this sense, the outputs of **ToMM** are "shallow".

We also believe that a common-sense RTM could not be complete – it would still require PA notions to do most of the work in explaining and predicting behaviour. Representational theories of mind have an intrinsically mechanistic character (which is why they appeal to cognitive scientists). Thus, a simple RTM view of memory might be: a mental picture is *put* in a box for storage and then *taken out again* later (retrieved). But what mechanistic story can a common-sense RTM tell about how a mental picture comes to cause behaviour? The temptation is to surreptitiously supply the RTM with a concept of belief: to say that the picture-in-the-head causes behaviour because the agent *believes* what the picture says! But then what does the work here is the PA notion, *believes*, not the physical metaphors of RTM.[7]

The problem for common-sense RTM, however, does not end there. Common-sense theory of mind has to have some way of handling the fact that the same representational content can have very different effects (on behaviour). For example, John, Mary and Sally all have in mind a "representation" which says, "It is raining". But John believes it, Mary pretends it, and Sally hopes it; they each behave accordingly. How is a common-sense RTM to reconstruct mechanistically the different effects of each of these different attitudes without simply smuggling them in? Again, a "shallow" PA-based theory which captures how meaning enters into the causation of behaviour is required to do this basic work.

Finally, we do, however, want to acknowledge the intimate links there appear to be, for both preschoolers and adults, between the utterances agents make and the attitudes agents take. Roth and Leslie (1991) found that 3-year-olds were, under some circumstances, *more* willing than 5-year-olds to attribute a false belief to a speaker based on her utterance. Such links, which Roth and Leslie hypothesized were intrinsic to **ToMM**, were rarely made by the autistic adolescents in that study. Links between utterance and attitude may be an important force in cross-domain developments in understanding representation.

In summary, we suggest that, as regards normal preschoolers, a PA view

[7]An even more surreptitious wav of supplying an RTM with attitude notions is to use circumlocutions for "believes": "he *takes* the picture *seriously*", "the picture *is true for* him", and so on. Notice that it is what the picture *says* (i.e., the proposition it expresses) that one believes or "takes seriously" or "is true for one", not the actual picture itself.

provides an alternative to RTM which is more conservative in its assumptions. In light of the results on normal children's performance in false belief and representation tasks, it is also more adequate empirically. The triad and related impairments of autism had already suggested limited relevance for RTM in understanding this disorder (see also Charman & Baron-Cohen, in press; Leslie & Frith, 1990; Leslie & Roth, in press; Roth & Leslie, 1991). The autistic child's good performance on representation tasks underlines this. The PA-style metarepresentational theory provides a more promising explanatory framework for autism too.

Domain specificity and metarepresentation

The evidence for a dissociation between beliefs and photographs (maps) would have appeared less compelling if one had considered only normal development. For example, one might dismiss the poorer performance on photographs as due to some additional difficulty of the task or to differences in "experience". Yet, whatever factors like this may be at work, they pale in significance alongside the dissociation found in autism. Let us return then to the four architectural possibilities of Figure 1. Normal development undermines only one of these options (number three). The data from autism, however, militate against two others: options one and two. This leaves only option four still supported.

We propose that the notions of mental state that develop during the preschool period are domain specific; they are tied to an understanding of agents. Agents alone hold attitudes. The challenge now is to characterize the developmental basis of these domain-specific notions. We can see certain features of the kind of account that is required. We need a cognitive mechanism which will spontaneously employ propositional attitude concepts and thus metarepresentation. It will be an inferential engine capable of generating, in real time, analyses of behaviour relative to its theory of the attitudes. It should provide the preschooler with an intuitive understanding of the mental states of agents with minimum reliance on conscious problem solving. Finally, it should have an architecture which allows the possibility of dissociable damage, with the specific effects on development that are seen in autism. These features point to something like the theory of **ToMM**.

ToMM and belief

As Leslie (1987) pointed out, the relation, PRETENDS, is available very early, while the relation, BELIEVES, seems fragile by comparison. Why should this be? Although the present results suggest that standard false belief and false representation tasks engage distinct mechanisms, they by no means rule out a shared general component. For example, both sets of tasks require identifying, for the purposes of inference, a previous state of affairs in the face of a salient, current, changed version of that situation. Roth (in preparation; Leslie & Roth, in press) proposes that a mechanism independent of ToMM is required for accomplishing this selection of input for specific inference processes. Moreover, the maturation of such a device may be responsible for children's increasing success in standard false belief tasks during the preschool period.

The above idea is illustrated in Figure 5. Two distinct components are required to pass a standard false belief task: the more vertical component ToMM, and a more horizontal component,[8] called here the selection processor (SP). Likewise, two cooperating components are required to pass a "standard" false photograph (map) task: knowledge of photographs (maps) and SP.

According to the model, 3-year-olds fail both standard false belief and false representation tasks because SP is as yet poorly developed. They do not fail because they cannot remember the previous and now counterfactual state of affairs – control questions show otherwise – but because they fail to select the appropriate counterfactual or because current reality intrudes. To succeed, the child must identify and select the right premise to enter into an inference process, resisting intrusion from other premises. Some non-standard belief tasks (e.g., Roth & Leslie, 1991; Wellman & Bartsch, 1988; Zaitchik, 1991) either do not require or stress the SP component less, while other tasks may compensate for its lack (e.g., this seems likely in Mitchell & Lacohée, 1991). For example, in

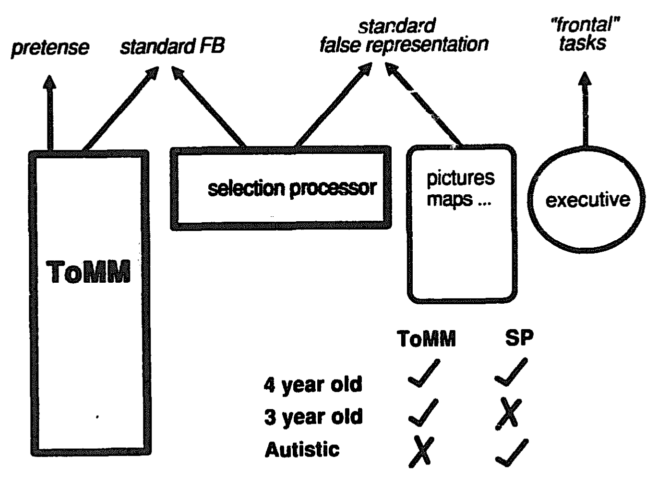

Figure 5. *Model showing some dissociable components involved in normal development. Normal 4-year-olds possess both ToMM and the selection processor (SP) components and can thus pass standard false belief, photograph and map tasks; 3-year-olds possess ToMM but not yet SP and can thus understand pretence and pass certain non-standard false belief tasks; autistic subjects are impaired in ToMM but not in SP, allowing them to pass only false photographs and maps tasks. An "executive" component is also shown as independent of both ToMM and SP. This may be independently impaired in autism.*

[8]See Fodor (1983) for the notion of vertical and horizontal components.

Wellman and Bartsch's (1988) "not own" task, the child does not know for sure where the target object is. The two possible locations thus have equal status, stressing SP less and allowing the 3-year-old greater success. On such non-standard false belief tasks and in understanding pretence, 3-year-olds succeed, showing that they possess the domain-specific component **ToMM**.

According to the theory, **ToMM** has an on-board counterfactual reasoning ability (Leslie, 1987) which is specialized for metarepresenting an agent's behaviour. **ToMM** on its own succeeds to the extent that the imaginary content of the inferred propositional attitude can be "read off" the agent's behaviour, as in pretence (Leslie, 1988a) or as in making an utterance (Roth & Leslie, 1991). Standard false belief tasks do not allow this; solving these problems depends upon reconstructing the imaginary content purely on the basis of the agent's *exposure history*. These cases require SP to identify and select the relevant aspect of past exposure. In false belief tests requiring explanation (rather than prediction) of behaviour (Bartsch & Wellman, 1989), the child could process the agent's behaviour to recover the counterfactual without having to rely solely on exposure history. However, the agent did not directly communicate the mental content (as in Roth & Leslie, 1991). Such cases seem to have an intermediate level of difficulty for the 3-year-old, as might be expected on the **ToMM** plus SP account.

The horizontal component SP becomes increasingly functional around the fourth birthday but perhaps can still be differentially stressed by, for example, our false map task versus false photographs. Finally, autistic children (at least with verbal MAs in excess of 4 years) possess intact the general component SP (and thus pass false representation tasks) but are impaired in the specific component **ToMM**.[9]

According to the above account, normal 3 and 4-year-olds do not differ fundamentally in terms of their concept, BELIEVES. At both ages children share the core adult concept of belief. Dennett (1981) pointed out that our notion of belief is inherently *normative*. Generally speaking, the best guess one can make about someone's belief is that it will be "well founded": a person will believe what they *ought* to believe, that is, what is true, given a set of qualifying conditions (such as an appropriate perceptual system, adequate access to the facts and so on). The qualifying clause can be very long indeed in the case of adult reasoners. It is in the

[9]We believe there are limits to the generality of SP. For example, an analogous mechanism seems to develop in the first year of life as part of an action control system (Diamond, 1988). We do not suppose, however, that SP is that same mechanism. Or again, autistic children have been reported to perform poorly on tests of executive functioning as assessed by, for example, Wisconsin Card Sorting (WCS) (e.g., Ozonoff, Pennington & Rogers, 1991). Whatever this may mean for the neuropsychology of autism, it seems extremely unlikely in light of results reported here that the autistic impairment in "theory of mind" could be linked to a *general* executive functioning problem or to the same executive problem as their performance on WCS (see Figure 5). This suggests (a) that "executive functioning" (and counterfactual reasoning) can be fractionated and (b) that the pattern of fractionation is important for understanding normal and abnormal development.

complexity and make-up of this qualifying clause that we expect the greatest differences between different points in the domain-specific development of "theory of mind". Despite such differences, however, and as a consequence of possessing a normally developing **ToMM**, 3-year-olds already employ the core concept BELIEVES.

Finally, let us reflect on one moral of these results. Our findings underscore the dangers of relying on correlations in normal development alone. Given a normally developing brain, different parts of its architecture may show parallel developments for a variety of reasons. When finding parallel changes in task performances over time, the often irresistible conclusion to jump to is that the parallel changes are evidence for a single cognitive mechanism. In fact, such evidence may say surprisingly little about underlying architecture. Thus, the neuropsychology of mental handicap, as well as being an applied and clinical matter, also carries great importance for developmental cognitive theory.

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