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Are children with autism superior at folk physics?

Simon Baron-Cohen

Departments of Experimental Psychology and Psychiatry,

University of Cambridge, Downing St,

Cambridge, CB2 3EB, UK

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Autism and folk psychology

Just over 10 years ago we asked the question “Do children with autism have a ‘theory of mind’?” (Baron-Cohen, Leslie & Frith, 1985). Using the False Belief Test (Wimmer & Perner, 1983) we arrived at a preliminary answer to this question: The majority of children with autism failed the False Belief Test, and this was suggestive evidence that they were impaired in the development of a theory of mind.

A theory of mind is also called a *folk psychology*, and is the main way in which human beings are held to make sense of action (Carey, 1985; Dennett, 1978; Heider & Simmel, 1944). That is, imputing mental states such as beliefs, desires, intentions, and knowledge states seems to be the automatic way in which we compute the causes of action, and predict of action. John Morton and colleagues (Morton, Frith & Leslie, 1991) coined an incisive, succinct term for this: mentalizing.

In the 10 years since this first test of mentalizing in children with autism, there have been more than 30 further experimental tests of the hypothesis, the vast majority revealing profound impairments in the development of folk psychological understanding in autism. These are reviewed elsewhere (Baron-Cohen, 1995; Baron-Cohen, Tager-Flusberg & Cohen, 1993). This includes deficits in understanding that “seeing-leads-to-knowing (Baron-Cohen & Goodhart, 1994), distinguishing mental from physical entities (Baron-Cohen, 1989a), and making the appearance-reality distinction (Baron-Cohen, 1989a).

This deficit in their folk psychology is thought to underlie the difficulties such children have in social and communicative development (Baron-Cohen, 1988), and the development of imagination (Baron-Cohen, 1987).

Beyond folk psychology

So far, we know something about the development of a folk psychology in autism. But there is more to cognition than folk psychology. In this next section, we introduce the notion of a *folk physics*.

Consider Brentano's (Brentano, 1874/1970) thesis, that in this universe there are only two kinds of entities: those that have intentionality, and those that do not. This roughly corresponds to the distinction between animate and inanimate, in that inanimate things (like rocks and tables) appear to have no intentionality, whilst most animate things (like mice and men) are treated as if they do. Intentionality is defined as the capacity of something to refer or point to things other than itself. A rock cannot point to anything. It just is. In contrast, a mouse can 'look' at a piece of cheese, and can 'want' the piece of cheese. The animate-inanimate distinction doesn't quite cover the intentional/non-intentional distinction in that plants are of course animate (they are alive), so the

distinction is probably better covered by the concept of agency (Premack, 1990).

Agents have intentionality, and non-agents do not.

The task for us as information-processors is to compute the causes of these two classes of entity. Dennett's (1978) claim is that humans, from birth to the grave, use their folk psychology to deduce the cause of agents' actions, and use their folk physics to deduce the cause of the movement of any other entity. Why did the rock roll down the hill? If an agent was involved, then the event is interpreted as being caused by an intention (to throw it, roll it, kick it, etc.). If no agent was involved, then the event is interpreted in terms of a physical causal force (it was hit by another object, gravity, etc.).

Sperber et al (1995) suggest that humans alone have the reflective capacity to be concerned about causality, and that 'causal cognition' broadly falls into these two types¹. Folk psychology (searching for the mental or intentional causes behind agent-type events) appears to be present from at least 12 months of age (Baron-Cohen, 1994; Gergely, Nadasdy, Gergely & Biro, 1995; Premack, 1990). Folk physics (searching for the physical causes of any other kind of event) is present even earlier in human ontogeny (Baillargeon, Kotovsky & Needham, 1995; Leslie & Keeble, 1987; Spelke, Phillips & Woodward, 1995).

(Leslie, 1995) captures this distinction by proposing two independent modules are part of the infant cognitive architecture: a theory of mind mechanism (ToMM) and a theory of

bodies mechanism (ToBy). Baron-Cohen (1994) suggests that although a full-blown theory of mind may take several years to develop, a more restricted Intentionality Detector (or ID) along the lines proposed by Premack (1990) does appear to be part of our causal cognition in infancy.

Let us return to consider autism. Clearly a crucial contrast case in terms of understanding cognition in autism would be to look at their folk physics. We know that in autism there is an impairment in folk psychology. How circumscribed is this? Does it leave their folk physics intact? Or might their folk physics be super-developed, either in compensation or for other (possibly genetic) reasons?

Autism and folk physics

If children with autism had an impairment in their folk physics, this might suggest that the cause of their problems in the intentional domain was a problem in ‘theory-building’ per se (Carey, 1985). However, there are reasons to suspect that not only is their folk physics intact, but that it may even be *superior*, relative to normally developing children.

Two classes of evidence can be brought to bear on this superior folk physics claim: clinical anecdote, and experimental results. Regarding the former, there is no shortage of clinical descriptions of children with autism being fascinated by machines (the paragon of non-intentional systems). One of the earliest clinical accounts was by Bettelheim

¹ Folk psychology and folk physics are the two “big” causal cognition domains. But of course other cognitive domains

(Bettelheim, 1968) who describes the case of “Joey, the mechanical boy”. This child with autism was obsessed with drawing pictures of machines (both real and fictitious), and with explaining his own behavior and that of others in purely mechanical terms. Bettelheim injected his psychoanalytic interpretation to these drawings, but we can leave such interpretation to one side. The bare facts are that the boy was obsessed with machines. On the face of it, this would suggest he had a well-developed folk-physics.

The clinical literature reveals hundreds of cases of children obsessed by machines. Parents’ accounts (Hart, 1989; Lovell, 1978; Park, 1967) are a rich source of such descriptions. Indeed, it is hard to find a clinical account of autism that does *not* involve the child being obsessed by some machine or another. Typical examples include extreme fascinations with electricity pylons, burglar alarms, vacuum cleaners, washing machines, video players, trains, planes, and clocks. Sometimes the machine that is the object of the child’s obsession is quite simple (e.g. the workings of drain-pipes, or the designs of windows, etc).

Of course a fascination with machines need not necessarily imply that the child *understands* the machine, but in fact most of these anecdotes also reveal that children with autism have a precocious understanding too. The child (with enough language) may be described as holding forth, like a “little professor”, on their favourite subject or area of expertise, often failing to detect that their listener may have long since become bored of the subject. The apparently precocious mechanical understanding, whilst being relatively

exist. These include folk biology and folk mathematics. We return to this wider picture at the end of the chapter.

oblivious to their listener's level of interest, suggests that their folk physics might be outstripping their folk psychology in development.

The anecdotal evidence includes not just an obsession with machines, but with other kinds of physical systems. Examples include obsessions with the weather (meteorology), the formation of mountains (geography), motion of the planets (astronomy), and the classification of lizards (taxonomy). That is, their folk physics embraces both artefactual and natural kinds. In this chapter we will use the term “folk physics” in a narrow way, to refer to our understanding of physical causality, and in a broader way, to encompass all of these non-intentional aspects of the physical world, whether causal or not .

Experimental evidence

Leaving clinical anecdotal evidence to one side, experimental studies reveal evidence that converges on the same conclusion, that children with autism not only have an intact folk physics, they have accelerated or superior development in this domain (relative to their folk psychology). First, using a picture sequencing paradigm, we found that children with autism performed significantly better than mental-age matched controls in sequencing physical-causal stories (Baron-Cohen, Leslie & Frith, 1986). The children with autism also produced more physical causal justifications in their verbal accounts of the picture sequences they made, compared to intentional accounts. Examples of the physical-causal story sequences are shown in Figure 1, and examples of the contrast intentional-causal story sequences are shown in Figure 2.

insert Figures 1 and 2 here

Second, two studies (Leekam & Perner, 1991; Leslie & Thaiss, 1992) found that children with autism showed good understanding of a camera. In these studies, the

child is shown a scene where an object is located in one position (A). The child is encouraged to take a photo of this scene, using a polaroid camera. Whilst the experimenter and the child are waiting for the photo to develop, the scene is changed: the object is now moved to a new position (B). The experimenter then turns to the child and asks where in the photo the object will be. These studies found that children with autism could accurately infer what would be depicted in a photograph, even though the photograph was at odds with the current visual scene. Again, this contrasted with their poor performance on False Belief tests.

What was particularly important about these experiments was that the structure of the “false photo task” exactly paralleled the structure of the false belief task. The key difference is that in the (folk psychological) false belief test, a person sees the scene, and then the object is moved from A to B whilst that person is absent. Hence the person holds a belief that is at odds with the correct visual scene. In the false photo task a camera records the scene, and then the object is moved from A to B whilst the camera is not in use. Hence the camera contains a picture that is at odds with the current visual scene. The pattern of results by the children with autism on these two tests was interpreted as

showing that whilst their understanding of mental representations was impaired, their understanding of physical representations was not. This pattern has been found in other domains (Charman & Baron-Cohen, 1992; Charman & Baron-Cohen, 1995). But the False Photo Test is also evidence of their mechanical understanding (their folk physics) outstripping their folk psychology.

Let us turn to a third piece of evidence. In a study examining children's understanding of the functions of the brain, significantly more children with autism mentioned the brain's causal role in action, compared to matched MA controls (Baron-Cohen, 1989a). In contrast, in the same study, children with autism were significantly less likely to mention mentalistic functions of the brain. Once again the same pattern of superior folk physics and inferior folk psychology is seen. Our concept of the brain involves physical-causal events, whilst our concept of the mind involves intentional-causal events.

Fourth, in a study of the animate-inanimate distinction in autism (Baron-Cohen, 1989a) it was found that school age children with autism were perfectly able to distinguish two different kinds of moving object: mechanical versus animate. (Mechanical objects were things like vacuum cleaners and cars. Animate objects were things like mice and men). This is additional evidence that their folk physics is intact.

Fifth, there is evidence that children with autism show no delays in reaching object permanence (they solve the A-not-B error at the normal point in development) (Sigman, Ungerer, Mundy & Sherman, 1987). This latter finding also shows that their

understanding of physical objects is normal. It is incidentally inconsistent with a general executive dysfunction account of autism (Russell, 1996), which would predict perseveration at location A.

Sixth, high-functioning adults with autism or Asperger Syndrome² (all selected to be of normal intelligence) are *faster* on the Embedded Figures Test than matched controls (Jolliffe & Baron-Cohen, in press). In contrast, such able subjects show persisting impairments on an adult level test of folk psychology (Baron-Cohen, Jolliffe, Mortimore & Robertson, in press a). This replicates and extends a similar finding using the Embedded Figures Test with children with autism (Shah & Frith, 1983). Whilst this does not index their physical-causal cognition, it again shows that aspects of their folk physics (spatial abilities) are actually superior to normal people and certainly outstrip their folk psychology. In this example, the concept of folk physics is used more widely to refer to our understanding of the physical world, whether causal or otherwise.

Evidence from family studies

Family studies add to this picture. Parents of children with Asperger Syndrome [AS] also show mild but significant deficits on an adult mentalizing task, mirroring the deficit in folk psychology seen in patients with autism or AS (Baron-Cohen & Hammer, in press a). Of critical relevance to the current argument, since autism and AS appear to have a strong heritable component (Bailey et al., 1995; Bolton et al., 1994; Folstein & Rutter,

² Asperger Syndrome is thought to be a subgroup of high-functioning individuals on the autistic spectrum.

1977; Le Couteur et al., 1996), one should expect that parents of children with autism or AS should be over-represented in occupations in which possession of superior folk physics would be an advantage, whilst a deficit in folk psychology would not necessarily lead to any disadvantage. The paradigm occupation for such a cognitive profile is engineering.

A recent study of 1000 families found that fathers and grandfathers (patri- and matrilineal) of children with autism or AS were more than twice as likely to work in the field of engineering, compared to control groups (Baron-Cohen, Wheelwright, Stott, Bolton & Goodyer, in press). Indeed, 28.4% of children with autism or AS had at least one relative (father and/or grandfather) who was an engineer. Table 1 summarizes these results.

insert table 1 here

This raises the possibility that the cognitive phenotype of the parents (one or both of whom carry the genes for autism/AS) involves a superiority in folk physics alongside a relative deficit in folk psychology.

Conclusions

(Pinker, in press) argues that the evolution of the human mind should be considered in terms of its evolved adaptedness to the environment. In his view, the brain needed to be able to maximize the survival of its host body in response to at least two broad challenges: the physical environment and the social environment. The specialized cognitive domains of folk physics and folk psychology can be seen as adaptations to each of these.

One possibility is that a cognitive profile of superior folk physics alongside of impaired folk psychology could arise for genetic reasons, in that some brains are better adapted to understanding the physical environment whilst other brains are better adapted to understanding the social environment. The ‘male brain’ may be an instance of the former, and the ‘female brain’ an instance of the latter, given the evidence from the experimental studies of sex differences (Halpern, 1992). On this view, the autistic brain may be an extreme form of the male brain (Baron-Cohen & Hammer, in press b).

The brain can be construed as a causal-cognition machine, which searches for both intentional and physical causes underlying observable events. On this account, if a brain has a genetically-based impairment in folk psychology, this will lead the individual brain to spend less time interacting with the social environment, and more time interacting with the physical environment, since at least it can understand the latter. A simple mass-practice or expertise model could then explain why such a brain, developing along an abnormally one-sided trajectory, could end up showing a superiority in folk physics.

What is the extra explanatory scope that this account provides, over and above the (now standard) theory of mind account of autism? The theory of mind account has been virtually silent on why children with autism should show “repetitive behaviour”, a strong desire for routines, and a “need for sameness”. To date, the only cognitive account to attempt to explain this aspects of the syndrome is the executive dysfunction theory (Ozonoff, Rogers, Farnham & Pennington, 1994; Pennington et al., in press; Russell, in press) . This paints an essentially negative view of this behaviour, assuming that it is a form of ‘frontal lobe’ perseveration or inability to shift attention.

Whilst some forms of low-level repetitive behaviour in autism, such as ‘stereotypies’ (e.g., twiddling the fingers rapidly in peripheral vision) may be due to executive deficits or understimulation, the executive account has traditionally ignored the *content* of “repetitive behaviour”. The current account draws attention to the fact that much repetitive behavior involves the child’s ‘obsessional’³ or strong interests with mechanical systems (such as light switches or water faucets) or other systems that can be understood in physical-causal terms. Rather than these ‘behaviours’ being a sign of executive dysfunction, these may reflect the child’s intact or even superior development of their folk physics. The child’s “obsession” with machines and systems, and what is often described as their “need for sameness” in attempting to hold the environment constant, might be signs of the child as a superior folk-physicist: conducting mini-experiments in

³ Elsewhere (Baron-Cohen, 1989b) I review the argument for why the term “obsession” can only be used in the context of autism with difficulty. This centers on the traditional definition of an obsession being “egodystonic” (or unwanted). In autism, there is no evidence that the child’s strong interests are unwanted. Rather, those individuals with autism or AS who can report on why they engage in these activities report that they often derive some pleasure from them. They are therefore probably egosyntonic.

his or her surroundings, in an attempt to identify physical-causal principles underlying events.

In summary, the argument advanced here is that the brain basically has only two modes of causal cognition: a folk psychology and a folk physics. In the extreme case, severe autism may be characterized by almost no folk psychology (and thus “mindblindness”), but as autism and AS itself come by degrees, so different points on the autistic spectrum may involve degrees of deficit in folk psychology. In those individuals who have no accompanying mental handicap (i.e., whose intelligence is in the normal range), the child’s folk physics will develop not only normally, but at a superior level. This could be the result of both genetic liability and the development of expertise in non-social learning environments. There is every reason to expect that individuals with this sort of cognitive profile would have been selected for in hominid evolution, since good folk physics confers important advantages (e.g., tool use, construction, etc.). Indeed, it is a tautology that without highly developed folk physics (e.g., engineering), homo sapiens would still be pre-industrial.

This article has focused on folk physics and folk psychology, because they are the two forms of causal cognition. But as has been widely discussed (Hatano & Inagaki, 1994; Sperber, Premack & Premack, 1995; Wellman, 1990), other universal cognitive domains also exist. The principal others are folk mathematics (counting) and folk biology (classification of the animate world into species, predators, prey, etc). In the same way that a deficit in folk psychology should leave folk physics either unaffected or superior in

autism, the same arguments should lead to unaffected or superior development of folk mathematics and folk biology in such individuals. It remains to be proven that folk mathematics and folk biology are independent of folk physics, rather than being a subset of it.

Figure 1: An example of a physical-causal story sequence, based on (Baron-Cohen et al., 1986).

Figure 2: An example of an intentional-causal story sequence, based on Baron-Cohen et al (1986).

Table 1: Percentage of fathers and grandfathers of children with and without autism, in some key, contrasting occupations.

	Engineering	Social Work
Fathers of children with autism	12.5	2.6
Grandfathers of children with autism	10.6	0.5
Fathers of children without autism	5.6	5.0
Grandfathers of children without autism	5.0	2.5

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