Autism: deficits in folk psychology exist alongside superiority in folk physics

SIMON BARON-COHEN

This volume concerns our everyday understanding of other minds, and how neurodevelopmental factors can interfere with this ability. Our understanding of other minds is sometimes referred to as our folk psychology. According to Pinker, among others, the evolution of the human mind should be considered in terms of its evolved adaptedness to the environment (Pinker 1997). On this view, the brain needed to be able to maximize the survival of its host body in response to at least two broad challenges: predicting the physical and the social environment. The specialized cognitive domains of folk physics and folk psychology can be seen as adaptations to each of these. In this chapter I explore the possibility that a cognitive profile of superior folk physics alongside impaired folk psychology could arise for genetic reasons. This assumes that some brains are equally well adapted to understanding both the social and physical environment, whilst others are better adapted to understanding the physical environment and yet others are better adapted to understanding the social environment. Both clinical and experimental tests of this profile in children with autism and Asperger's Syndrome (AS) will be reviewed.

Brentano's thesis is that in this universe there are only two kinds of entities: those that have intentionality, and those that do not (Brentano 1874/1970). This roughly corresponds to the distinction between animate and inanimate, in that inanimate things appear to have no intentionality, whilst most animate things 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 animate, so the distinction is probably better covered by the concept of agency (Premack 1990). Agents have intentionality, and non-agents do not. This also means that when agents and non-agents move, their motion has different causes. Agents can move by self-propulsion, driven by their goals, whilst non-agents can be reliably expected not to move unless acted upon by another object (e.g. following a collision).

The task for us as information processors is to compute the causes of these two classes of motion. Dennett's (1978) claim is that humans from birth use their *folk* (or *intuitive*) *psychology* to deduce the cause of agents' actions, and use their *folk* (or *intuitive*) *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 types.

DEVELOPMENTAL EVIDENCE

Folk psychology (searching for the mental or intentional causes behind agent-type events) appears to be present at least from twelve months of age (Baron-Cohen 1994; Gergely *et al.* 1996; Premack 1990; Rochat *et al.* 1997). Thus, infants show dishabituation to actions of 'agents' that appear to violate goal-directedness. They also expect agents to 'emote' (express emotion), and expect this to be consistent across modalities (between face and voice). They are also highly sensitive to where another person is looking, and will strive to establish joint attention.

Folk physics (searching for the physical causes of any other kind of event) is present even earlier in human ontogeny (Baillargeon *et al.* 1995; Leslie and Keeble 1987; Spelke *et al.* 1995) as manifested in the infant's sensitivity to apparent violations of the laws of physics. Thus, infants show dishabituation to the unexpected events of larger objects going into smaller ones, objects being unsupported, two objects occupying the same space, one object passing through another, or one inanimate object moving without being touched by another. Leslie (1995) interprets these data by proposing that two innate, independent modules are part of the infant cognitive architecture: a theory of mind mechanism (ToMM) and a theory of bodies mechanism (ToBy)[1].

AUTISM: PREDICTIONS

Since the first test of folk psychology in children with autism (Baron-Cohen *et al.* 1985), there have been more than thirty further experimental tests, the vast majority revealing profound impairments in the development of folk psychological understanding in autism. These are reviewed in Chapter 1, this volume, and elsewhere (Baron-Cohen 1995; Baron-Cohen *et al.* 1993). These include deficits in understanding that 'seeing-leads-to-knowing' (Baron-Cohen and Goodhart 1994; Leslie and Frith 1988), distinguishing mental from physical entities (Baron-Cohen 1989*a*; Ozonoff *et al.* 1990), and making the appearance–reality distinction (Baron-Cohen 1989*a*). This deficit in their folk psychology is thought to underlie the difficulties such children have in social and communicative development (Baron-Cohen 1988; Tager-Flusberg 1993), and the development of imagination (Baron-Cohen 1987; Leslie 1987).

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: CLINICAL EVIDENCE

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 not only that their folk physics is intact, but that it may even be *superior*, relative to normally-developing children.

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 (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 behaviour and that of others in purely mechanical terms. 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).

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, such as is seen in children with Asperger's Syndrome (AS)) 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 hearing more on the subject. Showing an apparently precocious mechanical understanding, whilst being relatively 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 article we use the term 'folk physics' both in the narrow way, to refer to our understanding of physical causality, and in the broader way, to encompass all of these non-intentional aspects of the physical world, whether causal or not.

AUTISM AND FOLK PHYSICS: EXPERIMENTAL EVIDENCE

Leaving clinical/anecdotal evidence to one side, experimental studies converge on the same conclusion, that children with autism not only have an intact folk physics, but also 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 *et al.* 1986). The children with autism also produced more physical–causal justifications in their verbal accounts of the picture sequences they made, compared with intentional accounts.

Second, two studies (Leekam and Perner 1991; Leslie and 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 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 and Baron-Cohen 1992, 1995). But the False Photo Test is also evidence of their mechanical understanding (their folk physics) outstripping their folk psychology.

A third piece of evidence is 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 with matched MA controls (Baron-Cohen 1989*a*). 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 1989*a*) it was found that school age children with autism were perfectly able to distinguish two different kinds of moving object: mechanical versus animate. ... things like vacuum cleaners and cars. Animate objects

were things like mice and men). This is additional evidence that their folk physics was intact.

Two final clues that there may be superior folk physics in autism spectrum conditions come from an experimental investigation, and a postal survey. In the former, fifteen children with AS were given a physics test and results found that they outperformed age- and IQ-matched controls on this, whilst not differing in terms of a control test of general (Baron-Cohen *et al.*, submitted). Regarding the latter, we have collected information from parents on the content of their children's obsessions, and found that children with either autism or AS tended to have obsessions that would fall into the area of folk physics far more often than any other folk domain (Baron-Cohen and Wheelwright, in press).

FAMILY STUDIES

Family studies add to this picture. Parents of children with AS also show mild but significant deficits on an adult folk psychology task, mirroring the deficit in folk psychology seen in patients with autism or AS (Baron-Cohen and Hammer 1997*b*). 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 and Rutter 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 with control groups (Baron-Cohen *et al.* 1997). Indeed, 28.4% of children with autism or AS had at least one relative (father and/or grandfather) who was an engineer. Related evidence comes from a survey of students at Cambridge University, studying either sciences (physics, engineering, or maths) or humanities (English or French literature). When asked about family history of a range of psychiatric conditions (schizophrenia, anorexia, autism, Down's Syndrome, or manic depression), the students in the science group showed a six-fold increase in the rate of autism in their families, and this elevation of risk was specific to autism (Baron-Cohen *et al.* 1998).

CONCLUSIONS

In this chapter, we have summarized predictions from the model that the human brain has evolved two modes of causal cognition: folk psychology and folk physics[3]. In the extreme case, severe autism may be characterized by almost no folk psychology (and thus 'mindblindness'), but as autism spectrum conditions (including AS) 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 retardation (i.e. whose intelligence is in the normal range), the child's folk physics could develop not only normally, but at a superior level. We tested this most directly in a group of children with Asperger's Syndrome (AS). Children with AS were functioning significantly above their mental age (MA) in terms of folk physics, but significantly below their MA in terms of folk psychology (Baron-Cohen *et al.*, submitted). This could be the result of both genetic liability and the development of expertise in non-social learning environments.

If it was partly the result of a genetic liability, 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, hunting skills, construction skills). Indeed, it is a tautology that without highly developed folk physics (e.g. engineering), Homo Sapiens would still be pre-industrial. It may be that the 'male brain' is an instance of this cognitive profile, given the evidence from the experimental studies of sex differences (female superiority in folk psychology, and male superiority in folk physics) (Baron-Cohen and Hammer 1997*a*; Halpern 1992). On this view, the autistic brain may be an extreme form of the male brain (Asperger's 1944; Baron-Cohen and Hammer 1997*a*).

If a brain has a genetically-based impairment in folk psychology, or a genetically-based talent for folk physics, this could lead the individual 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 (i.e. a gene-environment interaction) could then explain why such a brain, developing along an abnormally one-sided trajectory, could then lead to a superiority in folk physics. Alternatively, if we take seriously the notion of a module for folk physics (Leslie 1995), then it is possible that in autism spectrum conditions we see the twin genetically-based anomalies of impaired folk psychology co-occurring with superior folk physics. Future research will need to attempt to test the extent of learning and innate factors in this profile.

What is the extra explanatory scope of documenting superior folk physics in autism spectrum conditions, over and above the (now standard) demonstration of a theory of mind (or folk psychology) deficit in autism? The theory of mind account has been virtually silent on why such children 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 *et al.* 1994; Pennington *et al.* 1997; Russell 1997). 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 repetitive behaviour in autism, such as 'stereotypies' (e.g. twiddling the fingers rapidly in peripheral vision) may be due to executive deficits, the executive account has traditionally ignored the *content* of 'repetitive behaviour'. The current account draws attention to the fact that much repetitive behaviour involves the child's 'obsessional'[4] 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 his or her surroundings, in an attempt to identify physical–causal principles underlying events. Certainly, our recent study of obsessions suggests that these are not random with respect to content (which would be predicted by the content-free executive dysfunction theory), but that these test to cluster in the domain of folk physics (Baron-Cohen and Wheelwright, in press).

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 and Inagaki 1994; Sperber *et al.* 1995; Wellman 1990) other universal cognitive domains may also exist. The principal others are folk mathematics (counting) and folk biology (classification of the animate world into species, predators, prey, etc.). We remain to be convinced that these are independent domains, since it is plausible that folk mathematics is simply part of folk physics, for example. However, in the same way that a deficit in folk psychology should leave folk physics either unaffected or superior in autism, by the same arguments it should lead to unaffected or superior development of folk mathematics and folk biology in such individuals. This model of the independence of folk physics and folk psychology (corresponding to social and non-social intelligences) also predicts the existence of very high-functioning individuals with AS, who may be extreme high achievers in domains such as mathematics and physics but with deficits in folk psychology. Some recent single case studies confirm the existence of such pure cases (Baron-Cohen *et al.*, in press).

Finally, Happé (this volume, Chapter 9) notes that the superior folk physics theory may explain some islets of ability in the visual domain, but is limited in not being able to explain other patterns of skills in non-visual domains such as language. She makes the case for the weak central coherence theory having greater explanatory power. Note that folk physics relies on analysis of contingencies in the physical world, noticing spatial and temporal relations which may be causal. This is not confined to the visual world. More important, these two accounts are not necessarily mutually exclusive, as it may well be the case that weak central coherence is a prerequisite for having good folk physics. Future experiments could test the relationship between these two aspects of cognition.

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Notes

1. 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.

2. Asperger's Syndrome is thought to be a subgroup of high-functioning individuals on the autistic spectrum.
3. In this paper we have used the terms 'folk psychology', 'intuitive psychology', 'theory of mind', and 'mentalizing' interchangeably. We also intend 'folk physics' and 'intuitive physics' to be interchangeable terms.
4. Elsewhere (Baron-Cohen, 1989*b*) we review the argument for why the term 'obsession' can only with difficulty be used in the context of autism. This centres 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.

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