Clinical case studies, family studies, and experimental evidence show that children with autism show both deficits in folk psychology and superiorities in folk physics.

Are Children with Autism Superior at Folk Physics?

Simon Baron-Cohen

Just over ten years ago my colleagues and I asked the question "Do children with autism have a 'theory of mind'?" (Baron-Cohen, Leslie, and Frith, 1985). Using a false-belief test (Wimmer and Perner, 1983) we arrived at a preliminary answer. The majority of children with autism failed the test, which suggested that they were indeed impaired in the development of a theory of mind.

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

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

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between appearance and reality (Baron-Cohen, 1989a). This deficit in autistic children's folk psychology is thought to underlie the difficulties they 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 section I introduce the notion of a *folk physics.*

Consider Brentano's thesis ([1874] 1970) 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 objects, in that inanimate things (like rocks and tables) appear to have no intentionality, but most animate things (like mice and men) are treated as if they do. Intentionality is defined as the capacity to refer or point to things other than oneself. A rock cannot point to anything. It just is. In contrast, a mouse can *look at* a piece of cheese, it can *want* the piece of cheese, and so on. The animate-inanimate distinction does not quite cover the intentional-nonintentional 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 nonagents do not.

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

Sperber, Premack, and Premack (1995) suggest that humans alone have the reflective capacity to be concerned about causality and that "causal cognition" falls broadly into the two domains of folk psychology and folk physics. (These are the two "big" cognitive domains, but of course others do exist, such as folk biology and folk mathematics. It remains to be seen if or when in development folk mathematics or biology are independent of folk physics rather than being a subset of it. In this chapter I confine myself to folk psychology versus folk physics.) Folk psychology (explanations of the mental or intentional causes behind agent-initiated events) appears to be present from at least twelve months of age (Baron-Cohen, 1994; Gergely, Nadasdy, Gergely, and Biro, 1995; Premack, 1990). Folk physics (explanations of the physical causes of any other kind of event) is present even earlier in human ontogeny (Baillargeon, Kotovsky, and Needham, 1995; Leslie and Keeble, 1987; Spelke, Phillips, and Woodward, 1995).

Leslie (1995) captures this distinction by proposing that two independent modules are part of the infant's 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 (ID), along the lines proposed by Premack (1990), does appear to be part of our causal cognition in infancy.

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

Autism and Folk Physics

If children with autism have an impaired folk physics, this might suggest that the cause of their problems in discerning intentionality is a problem with "theory building" per se (Carey, 1985). However, there are reasons to suspect that not only is their folk physics intact, it may even be superior to that of normally developing children.

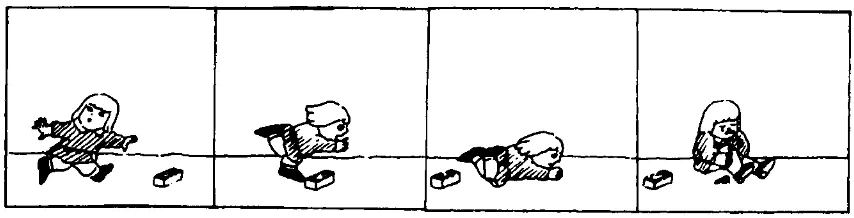
Two classes of evidence can be brought to bear on this claim of superior folk physics in autistic children: clinical anecdotes and experimental results. Regarding the former, there is no shortage of clinical descriptions of autistic children who are fascinated by machines (the paragon of nonintentional systems). One of the earliest clinical accounts was by Bettelheim (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 point of view into his interpretation of these drawings, but we can leave such interpretations to one side. The bare facts are that the boy was obsessed with machines. On the face of it, this would suggest that 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 in children that does *not* involve the child's being obsessed by some machine or another. Typical examples include extreme fascination with electrical towers, 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 (a system of drain pipes, the designs of windows, and so on).

Of course, being fascinated by a machine does not necessarily imply understanding it, but in fact most of these anecdotes reveal that children with autism also have a precocious understanding of machines. Autistic children (at least, those with enough language) have been described as holding forth, like "little professors," on their favorite subject or area of expertise, often failing to detect that their listener has long since become bored by the subject. The apparently precocious mechanical understanding of such children suggests that their folk physics might be outstripping their folk psychology in development.

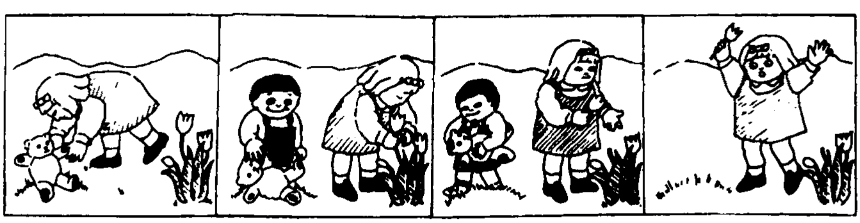
The anecdotal evidence includes not just an obsession with machines but also an obsession with other kinds of physical systems. Examples include obsessions with the weather (meteorology), the formation of mountains (geography), the motion of the planets (astronomy), and the classification of lizards (taxonomy). That is, the folk physics of autistic children embraces both artifactual and natural kinds. In this chapter I use the term *folk physics* both in a narrow way, to refer to people's understanding of physical causality, and in a broader way, to encompass all nonintentional aspects of the physical world, whether causal or not.

Figure 3.1. Example of a Physical-Causal Story Sequence



Source: Based on Baron-Cohen, Leslie, and Frith, 1986.

Figure 3.2. Example of an Intentional-Causal Story Sequence



Source: Based on Baron-Cohen, Leslie, and Frith, 1986.

Experimental Evidence

Experimental studies have revealed evidence leading toward the same conclusion as the anecdotal clinical evidence just described, that children with autism not only have an intact folk physics but also in fact demonstrate accelerated or superior development in this domain (relative to their folk psychology). First, using a picture-sequencing method we found that children with autism performed significantly better than mental age–matched controls in sequencing stories involving physical causation (Baron-Cohen, Leslie, and Frith, 1986). The children with autism also described more physical causes in their verbal accounts of the picture sequences, compared to intentional causes. An example of a physical explanation, or cause, in a story sequence is shown in Figure 3.1 (tripping and falling), and an example of a contrasting intentional cause in a story sequence is shown in Figure 3.2 (a false belief causing surprise).

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 a child was shown a scene in which an object was located in one position (A). The child was encouraged to take a photo of this scene, using a Polaroid camera. While the experimenter and the child were waiting for the photo to develop, the scene was changed: the object was moved to a new position (B). The experimenter then turned to the child and asked where in the photo the object would be, position A or B? These studies found that children with autism could accurately infer what would be depicted in the photograph even though the photograph was at odds with the current visual scene. This contrasted with their poor performance on a false-belief test.

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 psychology–based) false-belief test a *person* sees the scene, and then the object is moved from A to B while that person is absent. Hence the person holds a belief that is at odds with the current visual scene. In the false-photo task a *camera* records the scene, and then the object is moved from A to B while the camera is not in use. Hence the camera contains a picture that is at odds with the current visual scene. The pattern of the autistic children's results on these two tests was interpreted to demonstrate that although their understanding of mental representations was impaired, their understanding of physical representations was not. Similar patterns have been found on tests of drawings and models (Charman and Baron-Cohen, 1992, 1995). But the false-photo test is also evidence that the mechanical understanding of individuals with autism (their folk physics) outstrips their folk psychology.

Let us now 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 than mental age–matched controls mentioned the brain's functional (physiological) role in producing action (Baron-Cohen, 1989a). In contrast, in the same study children with autism were significantly less likely to mention mentalistic functions of the brain or mind. Once again the same pattern of superior folk physics and inferior folk psychology among autistic children is seen. Our concept of the brain involves physical-causal events, while 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 objects: 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 search problem at the normal point in development) (Sigman, Ungerer, Mundy, and 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 Syndrome (AS)—an alternative diagnosis thought to characterize a subgroup of high-functioning autistics—all selected to be of normal intelligence, are *faster* on the Embedded Figures Test than matched controls (Jolliffe and Baron-Cohen, forthcoming). In contrast, such able subjects show persisting impairments on an adult-level test of folk psychology (Baron-Cohen, Jolliffe, Mortimore, and Robertson, forthcoming). This replicates and extends a similar finding using the Embedded Figures Test with children with autism (Shah and Frith, 1983). Although this does not index their physical-causal cognition, it again shows that aspects of their folk physics (spatial abilities) are actually superior to those of normal people and certainly outstrip their own folk psychology. (In this example the concept of folk physics is used more broadly to refer to understanding of the physical world, whether causal or otherwise.)

Evidence from Family Studies

Family studies add to this picture. Parents of children with 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 and Hammer, "Parents of Children with Asperger Syndrome," forthcoming). According to the current argument, since autism and AS appear to have a strong heritable component (Bailey and others, 1995; Bolton and others, 1994; Folstein and Rutter, 1977; Le Couteur and others, 1996), one should expect that parents of children with autism or AS should be overrepresented among occupations in which possessing superior folk physics would be an advantage but having a deficit in folk psychology would not necessarily be a disadvantage. The paradigm occupation for such a cognitive profile is engineering.

A recent study of one thousand families found that fathers and grandfathers (patrilineal 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 and others, forthcoming). Table 3.1 summarizes these results. Indeed, 28.4 percent of children with autism or AS had at least one relative (father or grandfather) who was an engineer. (This percentage cannot be derived directly from Table 3.1, because in some families there was more than one relative who was an engineer.)

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

Conclusions

Pinker (forthcoming) argues that the evolution of the human mind should be considered in terms of its ability to adapt to its 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 environments.

One possibility is that a cognitive profile that includes superior folk physics alongside impaired folk psychology could arise for genetic reasons, in that some brains are better adapted to understanding the physical environment while 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 experimental studies of sex differences (Halpern, 1982). In this view, the autistic brain may be an extreme form of the male brain (Baron-Cohen and Hammer, "Is Autism and Extreme Form of the Male Brain?" forthcoming).

The human brain can be construed as a causation-focused cognitive machine that searches for both intentional and physical causes underlying observable events. By this account, if a brain has a genetic-based impairment in folk psychology, this will cause that 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

Table 3.1. Percentage of Fathers and Grandfathers of Children With and Without Autism in Two 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

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 behavior, a strong desire for routines, and a need for sameness. To date the only cognitive theory that has attempted to explain this aspect of the syndrome is the executive dysfunction theory (Ozonoff, Rogers, Farnham, and Pennington, 1994; Pennington and others, forthcoming; Russell, 1996). This paints an essentially negative view of this behavior, one that assumes that it is a form of "frontal lobe" perseveration or an inability to shift attention.

Although some forms of low-level repetitive behavior in autistics, such as stereotypies (for example, twiddling the fingers rapidly in peripheral vision) may be due to executive deficits or understimulation, the executive dysfunction account has traditionally ignored the *content* of repetitive behavior. The theory outlined in this chapter draws attention to the fact that much repetitive behavior involves autistic children's "obsessional" or strong interests in mechanical systems (such as light switches and water faucets) or other systems that can be understood in physical-causal terms. (The term *obsession* can only be used with difficulty in the context of autism [Baron-Cohen, 1989b]. Although obsessions are traditionally defined as "egodystonic," or unwanted, there is no evidence that an autistic's strong interests are unwanted. Rather, they appear to provide some pleasure and are therefore probably egosyntonic.) Rather than being a sign of executive dysfunction, these behaviors may reflect autistic children's intact or even superior development of folk physics. Autistic children's "obsession" with machines and systems, and what is often described as their "need for sameness" in attempting to hold their environment constant, might be signs that autistics are superior folk physicists, conducting miniexperiments in their 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 most extreme case, severe autism may be characterized by almost no folk psychology (and thus "mindblindness"). But just as cases of autism and AS vary in degree, so might different points on the autistic spectrum involve different degrees of deficits in folk psychology. For those autistic children who have no accompanying mental handicap (that is, those whose intelligence is in the normal range), their folk physics will develop not only normally but at a superior level. This could be the result of both a genetic liability and the development of expertise in nonsocial 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 (such as tool use, construction, and so on). Indeed, it is a tautology that without highly developed folk physics (for example, engineering), Homo sapiens would still be preindustrial.

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