Neurocase (1999) Vol. 5, pp. 475–483

A Mathematician, a Physicist and a Computer Scientist with Asperger Syndrome: Performance on Folk Psychology and Folk Physics Tests

Simon Baron-Cohen, Sally Wheelwright, Valerie Stone and **Melissa Rutherford**

Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB and Department of Psychiatry, University of Cambridge, Clinical School, Box 189, Addenbrooke's Hospital, Hills Road, Cambridge CB2 2QQ, UK

Abstract

We describe three cases of very-high-functioning individuals with Asperger syndrome, two of whom are university students (in physics and computer science, respectively), and the third a professor of mathematics, and winner of the Field Medal (equivalent to the Nobel Prize). The interest in these cases is whether there is a social–cognitive deficit, given their self-evident academic achievements. Such cases provide a rare opportunity to test for dissociations of cognitive skills, since these cases possess exceptionally high ability. These three individuals were given one test of folk psychology, one test of folk physics and one test of executive function. All three cases showed deficits on the adult-level 'theory of mind' (folk psychology) test involving reading mental states from photographs of the eyes, whilst showing no deficits on a control task of judging gender from the same photographs. In addition, all three cases were at ceiling on the test of folk physics and on the most complex test of executive function (the Tower of Hanoi). Fourteen control subjects clarified normative performance on the folk psychology and folk physics tests. These results strongly suggest that theory of mind (folk psychology) is independent of IQ, executive function and reasoning about the physical world.

Asperger syndrome (AS) and high-functioning autism (HFA)

Asperger syndrome (AS) was described over 50 years ago (Asperger, 1944), but did not come to the attention of the English-speaking world until an influential article by Wing (1981). It is considered to be a variant of autism, situated on the autistic spectrum (Wing, 1988). Autism is itself diagnosed in terms of abnormal social, communication and imagination development, together with unusual obsessional interests and repetitive behaviour (DSM-IV, 1994). Autism is a neurodevelopmental disorder involving a range of neuropathology, and is strongly heritable (Bailey *et al.*, 1996). Whereas autism can occur at any point on the IQ continuum, and is more frequently found in individuals with below-average IQ, AS is defined as only occurring in individuals with normal cognitive development, and thus assumed normal IQ. Furthermore, whereas autism is diagnosed when the above features are accompanied by a history of language delay, an AS diagnosis requires that there should have been no history of language delay (ICD-10, 1994). However, the diagnosis of AS also involves a hierarchical rule, namely, that the individual should never have met the criteria for autism. The criteria for autism also involve communication abnormality (which can be separate from language delay), so in practice this means that most people with the diagnosis of AS would also meet criteria for HFA. For this reason, we will use the terms AS and HFA interchangeably.

Autism involves cognitive deficits and these include: (1) deficits in theory of mind (or understanding people in terms of mental states—often referred to as 'folk psychology') (Baron-Cohen *et al.*, 1985, 1993; Baron-Cohen, 1995); (2) executive function (or planning and inhibition) (Ozonoff *et al.*, 1991; Hughes *et al.*, 1994); (3) central coherence (or contextual processing) (Frith, 1989; Shah and Frith, 1993; Happe, 1996; Jolliffe and Baron-Cohen, 1997). There has been some question over whether the theory of mind deficit occurs at all points on the autistic continuum, since adults with AS/HFA can pass child-level theory of mind tests (Ozonoff *et al.*, 1991; Bowler, 1992). However, these tests are designed for individuals with a mental age of 4 or 6 years old (corresponding to first- and second-order levels, respectively), so they cannot be said to be sensitive to subtle deficits, if they exist, in high-functioning adults.

Correspondence to: S. Baron-Cohen, Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK. Tel: +44 (0)1223 333557; Fax: +1 44 (0)1223 333564; e-mail: sb205@cus.cam.ac.uk

Folk psychology and folk physics

The present paper reports results from tests on three cases of very-high-functioning individuals with AS. Two of the tests tap 'folk psychology' and 'folk physics'. Both are thought of as 'folk' domains of cognition because the knowledge base in each is thought not to be explicitly taught by parents or teachers, and is acquired universally (Pinker, 1999). Folk psychology involves our everyday understanding of how people work (how actions are caused by mental/intentional states), whilst folk physics involves our everyday understanding of how things work (understanding the properties of physical objects, including their causal impact on other objects). (We use the terms 'folk psychology' and 'theory of mind' synonymously.) The word 'folk' is sometimes replaced by the word 'intuitive' (Baron-Cohen, 1997), to convey that these are 'naturally' developing forms of knowledge, rather than the result of formal teaching.

In the three cases reported here, we used a modified version of the Reading the Mind in the Eyes Test (Baron-Cohen *et al.*, 1997) to probe for folk psychology competence in two adult students with AS/HFA and in a professor of mathematics with AS/HFA. We used a new test of folk physics (shown in full in Appendix A). Finally, we gave them a challenging test of executive function (the 127-move version of the Tower of Hanoi). These three cases were selected because of their self-evidently very high IQ. This makes them similar to 'idiot savant' cases in scientific terms (Hermelin and O'Connor, 1986) in that they can teach us which cognitive skills might be independent of IQ. The primary question driving this research was whether social intelligence (folk psychology) is independent of folk physics, executive function and general intelligence. Specifically, our aim was to test whether folk psychology dissociates from folk physics, executive function, and IQ, in these cases. We predicted that folk psychology would dissociate from folk physics, executive function and IQ, but that these latter abilities would not dissociate from each other.

Although previous studies have suggested that folk psychology may be an independent cognitive ability (Baron-Cohen, 1995; Happe and Frith, 1996), critics have rightly argued that, in the majority of cases of autism, folk psychology deficits co-occur with other cognitive deficits (e.g. in executive function; Russell, 1997), suggesting that the deficit in folk psychology may simply be an upstream consequence of a deficit in an aspect of cognition that is not specifically social. Part of the interest in testing the three cases reported here lay in investigating extreme cases, where a single individual might demonstrate intact executive function and folk physics, in the presence of impaired folk psychology.

Case 1: GC

GC is a second-year student, studying physics at a northern university in England. He is 18 years old.

Developmental history

He is reported to have talked on time, and achieved his major developmental milestones on time. He was, however, reading and telling the time at 4 years old, which is advanced. He was initially misdiagnosed as having attention deficit with hyperactivity disorder (ADHD), but later diagnosed with AS at the age of 10 years, on the basis of his long-standing social and communication abnormalities, despite his obvious intelligence. His educational psychologist measured his intelligence as superior. He completed his first GCSE (high-school leaving) exams at 13 years old, taking other GCSEs yearly until age 16 years, and his A-level (advanced level, university entrance requirement) exams at 16 years old (approximately 2 years earlier than normal). At the age of 10 years, his father recalls that he could recite pi to 37 decimal places, and had an outstanding memory for numbers. At 13 years old, he received a silver medal in the UK National Physics Challenge (a special award made by the Institute of Physics), 2 years in a row, and received the gold medal in the UK intermediate Mathematical Challenge at the same age. He also received a distinction in the Mathematics Challenge of the Canadian Mathematical Competition and a silver award in the junior Mathematics Olympiad at the age of 13–14 years. He was known to be the best at mathematics in his school.

University career

He was accepted by his university at 16 years old, which is approximately 2 years earlier than normal. Three departments vied with each other to acquire him, since he was offered a place in the maths, engineering and physics departments. He ended up choosing physics. In the admissions interview, the interviewers were scribbling down notes from his answers to questions because they were so original and suggested new avenues for research ideas. Indeed, his interviewing style was delivered more as a lecture on the next generation beyond turbo engines. In his first 2 years, he has received 'first class' degree marks in his physics course. His tutors regard him as brilliant, and that his level of understanding of physics is at cutting edge research level, despite being a second-year undergraduate. He is top of his year in theoretical physics.

Hobbies

Outside of his studies, his hobbies include designing control panels for aircraft, which he displays on his web page. These are receiving international recognition for the novelty of engineering design.

Current social functioning

Socially, he is considered very gauche and abnormal. For example, his college tutor reported that, on a few occasions, if he wanted to use a computer, he could not wait his turn, but simply threw the other person off, physically. In lectures, he has sometimes interrupted the lecturer to put his point of view, sometimes forcefully. He reports being able to understand physical systems with ease, but has little idea of how even to begin to understand people. He finds that communication is fine if it is on technical matters, but has no desire to discuss things of a non-technical nature. He speaks in a very loud, unmodulated tone, as if giving a public lecture, even in a one-to-one situation where the listener is sitting right next to him. He holds strong views on most subjects, expressed as absolutes, whether discussing politics, football or other subjects. (GC's strong interest in politics may strike the reader as socially quite sophisticated. However, it is possible that a good understanding of politics is independent of the kind of empathic skills involved in more intimate social relationships.)

Self-report

He describes his mind as being 'hardwired in technical mode', meaning that anything technical is easily understood. He characterizes the difference between his mind and other people's in an interesting way: 'My mind is like a digital computer: it is either on or off. Information is either true or false. Other people's minds are like analog computers, with smoothly varying voltages, and manifesting fuzzy logic'. An example of this difference is that, for him, the distance between two cities is a precise amount (32 miles), and it is never thought of as approximately 30 miles, or 'a long way', etc. He cannot understand why other people would think in terms of approximations, indefinites or broad brush strokes when the world is full of specific, definite information and precise detail. His memory for numbers is far better than his memory for names, or at least the former come naturally to him, whilst the latter do not. Thus, he would think of the lecture theatre as Room PH8 or CG85 (the numbers on the doors), whereas most people would think of them by the theatre name (the Sheldon Theatre, etc.). Road signs are the same. He would think of each road by its numeric name (the A181) and could give long directions in these terms ('Take the A181 to the A19, then turn off on the A1231, etc.') rather than using names of places ('Take the Washington Highway...').

He is largely unaware of why his behaviour seems odd to others, but benefits from people giving him rules such as 'Do not talk in a very loud voice to your neighbour during a lecture'. He applies these rules quite rigidly.

Family history

GC's father attended the interview, and has been unemployed since 1992. Previously, he had worked in the Durham mines, which were closed following the miners' strike of 1984–85. The father left school without qualifications, and no one else in GC's family has shown any academic talent. However, whilst his father does not have GC's technical knowledge, he is interested in aircraft (recognition, not mechanisms), and has a prodigious memory for pop music. He can list not only his vast record collection, but the lyrics of most of the songs. GC has a sister with autism. His mother left school with three O levels. There is no other family history of note.

Case 2: CW

CW is a second-year student in computer science, in an Oxbridge university. He is 19 years old and is considering switching to engineering.

Developmental history

He is also reported to have talked on time, and achieved his major developmental milestones on time. At kindergarten, he spent all his time alone, never speaking to anyone. At primary school, he was an avid reader, but had no friends. His co-ordination was poor and so he avoided sports. He had, and still has, trouble drawing a straight line. He was not diagnosed with AS until arriving at university, after he saw a television programme about AS and referred himself to the adult psychiatric services where this was confirmed. He reports long-standing social and communication abnormalities. He could not understand his brother's behaviour and would end up fighting him. He was a loner at school, spent playtimes indoors alone, and preferred to spend hours on computers rather than participate in any social interaction. He could not understand why he did not fit in, and says that the diagnosis comes as a huge relief in finally providing him with an explanation for this continued isolation. He performed well at school in science, maths and computing, achieving good A levels, but found history and literature difficult. His memory of childhood was of being bullied for his social and sporting ineptitude; and whilst he can recall places and smells, he cannot recall people or faces.

University career

He was accepted by his university at 18 years old, to read computer science, but has switched to engineering. He feels equally at home in either. He spends most of his time alone in his room in college, and has suffered from some depression.

Hobbies

Outside of his studies, his hobbies include creating web pages and computing. His computing hobby started at age 6 years.

Current social functioning

Socially, he is also considered very gauche and abnormal. He says he has no idea how to have a small-talk conversation, what on earth one is meant to talk about to people, and cannot tell when he is boring someone by talking about his own technical interests. He also reports being able to understand physical systems with ease, but to have little idea of how even to begin to understand people. His body language is awkward and ungainly, and his facial expressions are noticeably not quite natural. He has once tried to take his own life, because of the depression caused by feelings of social failure.

There are no family history data available.

Case 3: DB

DB is a professor of pure mathematics at an Oxbridge university. He is 38 years old. He was awarded the Fields Medal, which is the equivalent of the Nobel Prize for mathematics. It is awarded once every 4 years.

Developmental history

He is also reported to have talked on time, and achieved his major developmental milestones on time. At primary school, he was an avid reader of maths and chess books, but always felt he was on the periphery of any social group. He could handle one-to-one social interaction, but not larger groups than this. He admits to being obsessed with maths, but this is his chosen profession. He meets the formal criteria for AS, but does not see any benefit in his case of being diagnosed, as he has now found a very successful lifestyle. He recognizes that it would have been useful to have had the diagnosis in childhood, when he had more marked difficulties, but this was not identified at the time. He reports long-standing social and communication abnormalities. He was a loner at school, spent playtimes indoors alone, and preferred to spend hours on chess rather than participate in any social interaction. He could not understand why he did not fit in. He performed well at school in maths, but failed English language. After being shown a typical marking scheme for an English exam, he was able to pass subsequent exams in this. He therefore puts his initial failure in English language down to not knowing what was expected.

University career

He has been a Research Fellow at an Oxbridge university and held research positions in North America. He now has an established Chair in Oxbridge. He spends most of his time in his room in the maths department.

Hobbies

Maths takes up all of his time.

Current social functioning

He is married to another mathematician. Before his marriage, he was aware of his social ineptness, and isolation, and made the deliberate decision to try to ameliorate this by taking up the study of Scottish dancing. This was only limitedly successful. Socially, he is very withdrawn. He also says he has little idea how to have a small-talk conversation, what on earth one is meant to talk about to people, and avoids talking on the telephone because of not being sure what to say. He says he is fine in giving lectures, but dislikes small group supervision or tutorials because of not knowing what people expect him to talk about.

During the meeting with him, he sat on his hands, on his desk, rocking gently back and forth. His eye contact is odd, making fleeting sideways glances at unexpected moments. He admits that his teaching style is not patient, in that he becomes irritated if someone cannot understand what he says after one explanation. He is unsure what counts as normal social behaviour, and benefits from feedback about his own behaviour. For example, until he was told it was odd, he would run everywhere—down corridors, streets, etc., even if he was not in a hurry, just because it seemed efficient. He still does this even when apparently strolling with other people. Equally, until he was told it was odd, he would carry on wearing the same clothes, even if they had holes in them, and even when he could afford a new piece of clothing. He can understand mathematical problems with ease, but recognizes he has little idea of how even to begin to understand people. His body language/gestures are awkward. At parties or in social groups, he often finds a book and withdraws into a corner. (His wife tells him off for this.) In the past, he has also looked at several books on human interactions, such as books on body language and 'How to make friends and influence people', etc., in a more or less deliberate attempt to figure out how the social world works. He admits to having tried to reduce social behaviour to a set of formal rules, as one might use in mathematics or physics, for example.

Family history

He has a brother with autism, who is low functioning and has additional physical disabilities. Two other brothers are maths teachers, and his father is a lecturer in physics.

Control group

Fourteen adult male controls were tested, who were in the same age range as the three cases, and who all had normal or above average scores on the National Adult Reading Test (Nelson, 1991), as a brief indication of their general intelligence. All but four of these had university degrees, in the physical sciences. They came from a range of socio-economic classes. Their mean age was 28 years (SD = 9.0 years). Their mean NART (predicted full-scale IQ) score was 130.9 (SD = 6.4). This is in the same range as the three cases.

Cognitive testing

Experimental tests

The test of folk physics (see Appendix A). By folk physics, we mean problem solving about physical world situations, without being dependent on taught physics. This comprises 20 questions taken from a variety of sources, and with a multiple-choice format. This was self-administered. Children with AS have been found to be superior on this relative to age-matched controls (Baron-Cohen *et al.*, in preparation).

The adult test of folk psychology, based on the Reading the Mind in the Eyes test (Baron-Cohen et al., 1997). This comprises 36 photographs of the eye region of the face, taken from magazines, and presented as black and white images (see Fig. 1 for examples). The subject is also presented with a choice of words with each picture, and is asked to choose which word best describes what this person in the photograph is thinking or feeling.

The test was modified from the published version in six ways. (a) Pictures which could be solved by using a simple behavioural cue were eliminated (e.g. a picture depicting 'Noticing you' with a face whose gaze direction was directly at the subject; in fact, gaze direction was not available as a useful cue in any of the modified set of pictures). (b) Aside from the target word, there were three other foil words, and these were chosen also to be complex mental state terms, at least some of which were the same valence as the target word. This meant that chance correct performance on any item would be 0.25. (c) There were an equal number of male and female faces (18 of each), randomly presented, so that familiarity with one sex could not confound performance, and so that a control task could be run of judging gender from the eyes alone. (d) Terms referring to basic mental states were eliminated, so that the test was a test of mapping complex mental state terms on to expressions around the eyes. (e) Comprehension of the terms was checked by providing a glossary of these terms, so that any errors could not be attributed to word meanings *per se*, but to the mapping of the terms to the face. (f) Performance was timed, so that both accuracy and speed could be determined. This test was constructed by using a panel of eight normal adults. The target term had to be identified by at least six out of eight of these. Since this is a modified task, the control data below serve as initial norms.

Fig. 1. The 'Reading the Mind in the Eyes' Test (Revised). (a) Female: correct answer = preoccupied. (b) Male: correct answer = serious.

The AQ (Autism-Spectrum Quotient) questionnaire. Each of the three cases also completed this questionnaire which measures the extent to which an individual of normal intelligence shows autistic traits (Baron-Cohen and Wheelwright, in preparation). It comprises 50 questions (therefore the maximum score = 50), tapping five domains relevant to the diagnosis of AS: social, communication, imagination, attention switching deficits and attention to detail. It has been validated on diagnosed cases of AS (n = 24), 83.3% of whom score at least 32 out of 50 on the AQ. Only 1% of randomly selected controls (n = 172) score at this high level.

Background variables

The three cases of AS also completed the following tests:

1. The Tower of Hanoi (the hardest version involving five pegs and seven discs) as a measure of executive function. This requires 127 moves.
2. The short WAIS-R (Block Design, Picture Completion, Vocabulary and Comprehension), the pro-rated IQ scores from which are reported to correlate with full-scale IQ at r = 0.91 (Crawford *et al.*, 1992).

Results

Experimental tests

The results are shown in Table 1. This indicates that whilst all three subjects scored at the same level as the controls on the Gender Judgements on the Eyes Task (itself a control condition for the Folk Psychology Task), they all scored >1 SD below the mean of the control group on the Folk

Table 1. Results of cognitive testing

Subject	Folk physics	Folk psychology	Gender recognition	AQ
	(maximum = 20)	(maximum = 36)	(maximum = 36)	(maximum = 50)
GC	20	18	36	44
CW	18	22	36	33
DB	19	25	35	32
Controls				(n = 75)
(n = 14)				
Mean	13.2[b]	32.6[a]	36	17.8[c]
SD	3.2	3.7	0	6.9

[a]More than 1 SD above the three cases.
[b]More than 1 SD below the three cases.
[c]Less than 1% of randomly selected controls score 32+ on the AQ.

Psychology Task (Reading the Mind in the Eyes Task), and all scored >1 SD above the mean of the control group on the Folk Physics Task. On the AQ, they all scored 32 or above, but only 1% of randomly selected controls did so (Baron-Cohen and Wheelwright, in preparation). A larger sample of cases of AS shows that 83% of patients with this diagnosis score at or above this level (Baron-Cohen and Wheelwright, in preparation).

Background variables

All three cases of AS solved the Tower of Hanoi. It was not possible to score the number of moves because of how fast they did this, but the total time taken was recorded. DB took 2 min 17 s, GC took 9 min 28 s and CW took 8 min 42 s. DB commented that it was simply a test of his manual dexterity. Neither GC nor CW had seen the task before, and yet solved it on the first trial with few, if any, errors. The majority of controls (10 out of 14) refused to complete the Tower of Hanoi on the grounds that it was too difficult. Of the four who completed, all took at least 15 min, with considerable self-correction. The pro-rated IQ scores of the three cases of AS were unremarkable, given their academic attainments: CW had a pro-rated verbal IQ (VIQ) of 122 and performance IQ (PIQ) of 131, with a full-scale IQ (FSIQ) of 130. GC had a VIQ of 126, a PIQ of 150 and an FSIQ of 143. Finally, DB had a VIQ of 124, a PIQ of 147 and an FSIQ of 137. These are in the same range as the control subjects, although the clinical cases show greater VIQ–PIQ discrepancies.

Discussion

We report three cases of what could be considered 'pure social deficit' in a pair of university students and a Nobel Prize-equivalent-level maths professor, all with AS. These are pure in that they have otherwise very high intelligence, and no deficits in non-social cognition, as tapped by tests of folk physics reasoning. Note that the social deficit is restricted to 'mentalizing' or folk psychology—the ascription of mental states to (the eye region of) faces. It does not extend to non-mentalistic social judgements, such as gender recognition. This supports earlier work (Baron-Cohen, 1991).

It might be objected that in selecting these three cases, the results are to some extent circular. All three cases have achieved considerable heights in the sciences or mathematical fields, so it is not surprising that their performance on the folk physics test was so good. We would agree that this is unsurprising, though note that in our recent study even children with AS, unselected for their scientific or mathematical proficiency, show superior folk physics on these tests (Baron-Cohen *et al.*, in preparation). The possibility exists then that superior folk physics is part of the cognitive profile of individuals with AS. We suspect that folk physics is not the same as academic physics because the children with AS in that study had not studied academic physics. Of course, their good folk physics could be the result of practice and specialization, focusing on such non-social aspects of cognition simply because of deficits in their folk psychology. This is not ruled out. An alternative possibility is that the good folk physics in AS in fact indicates good visualization skills.

Single cases challenge certain theories of theory of mind, such as the claim that theory of mind deficits reflect executive dysfunction (Russell, 1997). In the three cases reported here, intact or even superior executive function (measured with the advanced version of the Tower of Hanoi) was seen, alongside their folk psychology deficits. Such single cases do not rule out, of course, that theory of mind and executive function may interact in development. We note that these three cases of AS were only tested on one aspect of executive function (EF) planning. Further testing of EF in such cases will be important. Their intact performance on the Tower of Hanoi might be thought to be due to aspects of EF correlating with IQ (Duncan, 1995), but in this study the IQ-matched controls were not at ceiling on the EF test. Rather, it appears that performance on the EF test may have benefited from the considerable mathematical and physics skills possessed by these three cases of AS.

The present results are consistent with the notion of theory of mind being modular, given the pattern of dissociation in these subjects. Modularity is, of course, notoriously difficult to demonstrate conclusively, and also begs the question of what kind of modularity is being claimed (Fodor, 1983; Baron-Cohen, 1999a). However, the pattern of results strongly suggests that social intelligence is independent of other kinds of intelligence, and may therefore have its own unique evolutionary history (Brothers, 1990; Whiten, 1991; Baron-Cohen, 1995, 1999b). The existence of such pure cases of social intelligence deficits was predicted on the basis of our earlier studies of folk physics and folk psychology in children with AS (Baron-Cohen *et al.*, in preparation). Finally, such cases illustrate that, in the right environment, the condition of AS need not be a disability or interfere with remarkable levels of achievement.

Acknowledgements

S. B.-C. and S. W. were supported by the MRC during the period of this work. V. S. was supported by CAN (Cure Autism Now) and M. R. was supported by the Fullbright Commission Graduate Fellowship Programme. We are grateful to Sam Stoker and Eileen Sparham for their assistance in relation to one of these cases.

References

Asperger H. Die 'Autistischen Psychopathen' im Kindesalter. Archiv für Psychiatrie und Nervenkrankheiten 1944; 117: 76–136.

Bailey A, Phillips W, Rutter M. Autism: Towards an integration of clinical, genetic, neuropsychological, and neurobiological perspectives. Journal of Child Psychology and Psychiatry 1996; 37: 89–126.

Baron-Cohen S. The theory of mind deficit in autism: how specific is it? British Journal of Developmental Psychology 1991; 9: 310–4.

Baron-Cohen S. Mindblindness: an essay on autism and theory of mind. MIT Press/Bradford Books, 1995.

Baron-Cohen S. Are children with autism superior at folk physics? In: Wellman H, Inagaki K, editors. Children's theories. New Direction for Child Development Series. Jossey-Bass, 1997.

Baron-Cohen S. Does the study of autism justify minimalist innate modularity? Learning and Individual Differences 1999a; 10: 179–91.

Baron-Cohen S. The evolution of mindreading. In: Corballis M, Lea S, editors. Evolution of the hominid mind. Oxford: Oxford University Press, 1999b.

Baron-Cohen S, Leslie AM, Frith U. Does the autistic child have a 'theory of mind'? Cognition 1985; 21: 37–46.

Baron-Cohen S, Tager-Flusberg H, Cohen D, editors. Understanding other minds: perspectives from autism. Oxford: Oxford University Press, 1993.

Baron-Cohen S, Jolliffe T, Mortimore C, Robertson M. Another advanced test of theory of mind: evidence from very high functioning adults with autism or Asperger Syndrome. Journal of Child Psychology and Psychiatry 1997; 38: 813–22.

Bowler DM. 'Theory of Mind' in Asperger Syndrome. Journal of Child Psychology and Psychiatry 1992; 33: 877–95.

Brothers L. The social brain: a project for integrating primate behaviour and neurophysiology in a new domain. Concepts in Neuroscience 1990; 1: 27–51.

Crawford JR, Allan KM, Jack AM. Short forms of the UK WAIS-R: Regression equations and their predictive validity in a general population sample. British Journal of Clinical Psychology 1992; 31: 191–202.

DSM-IV. Diagnostic and statistical manual of mental disorders, 4th edn. Washington DC: American Psychiatric Association, 1994.

Duncan J. Attention, intelligence, and the frontal lobes. In: Gazzaniaga MS, editor. The cognitive neurosciences. Cambridge, MA: MIT Press, 1995.

Fodor J. The modularity of mind. MIT/Bradford Books, 1983.

Frith U. Autism: explaining the enigma. Oxford: Basil Blackwell, 1989.

Happe F. Studying weak central coherence at low levels: children with autism do not succumb to visual illusions. A research note. Journal of Child Psychology and Psychiatry 1996; 37: 873–7.

Happe F, Frith U. The neuropsychology of autism. Brain 1996; 119: 1377–400.

Hermelin B, O'Connor N. Idiot savant calendrical calculators: rules and regularities. Journal of Child Psychology and Psychiatry 1986; 16: 885–93.

Hughes C, Russell J, Robbins T. Specific planning deficit in autism: evidence of a central executive dysfunction. Neuropsychologia 1994; 32: 477–92.

ICD-10. International classification of diseases. Geneva: World Health Organization, 1994.

Jolliffe T, Baron-Cohen S. Are people with autism or Asperger's Syndrome faster than normal on the Embedded Figures Task? Journal of Child Psychology and Psychiatry 1997; 38: 527–34.

Nelson H (1991) The National Adult Reading Test (NART). Berkshire, Windsor: NFER-Nelson.

Ozonoff S, Rogers S, Pennington B. Asperger's Syndrome: evidence of an empirical distinction from high-functioning autism. Journal of Child Psychiatry and Psychology 1991; 32: 1107–22.

Pinker S. How the mind works. London: Penguin Books, 1999.

Russell J, editor. Autism as an executive disorder. Oxford: Oxford University Press, 1997.

Shah A, Frith U. Why do autistic individuals show superior performance on the block design test? Journal of Child Psychology and Psychiatry 1993; 34: 1351–64.

Whiten A. Natural theories of mind. Oxford: Basil Blackwell, 1991.

Wing L. Asperger Syndrome: a clinical account. Psychological Medicine 1981; 11: 115–30.

Wing L. The autistic continuum. In: Wing L, editor. Aspects of autism: biological research,. London: Gaskell/Royal College of Psychiatrists, 1988.

Received on 9 October, 1998; resubmitted on 14 January, 1999; accepted on 11 May, 1999

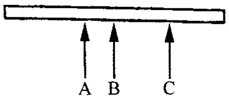
Appendix A: The Folk Physics Test

This section aims to find out whether you can easily understand how things work and function.

Each question has a diagram by it, from which the answer can be worked out. After each question there is a choice of answers. Only one is correct. When you think you have found the correct answer, please indicate your choice by putting a circle around it. An example is shown below.

The section should not take any more than 10 minutes. Please try to answer all the questions as quickly and as accurately as you can, and then enter the *total time taken to complete this section* in the box at the end.

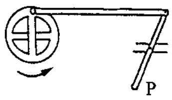
Example



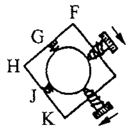
Which arrow will balance the beam?
(a) A (b) B (c) C (d) all equal

NOTE THE TIME BEFORE YOU START!

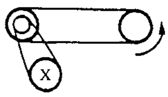
Questions

1. 

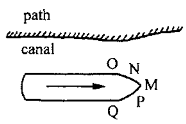
If the wheel rotates as shown, P will
(a) move to the right and stop
(b) move to the left and stop
(c) move to and fro
(d) none of these

2. 

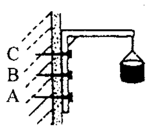
When the two screws are turned the same amount as shown, the ball will move towards
(a) F (b) G (c) H (d) J (e) K

3. 

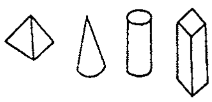
Which way does wheel X move?
(a) either (b) ↶ (c) ↷ (d) stays still

4. 

To move the boat easily in the direction shown, the rope would be best attached to
(a) M (b) N (c) O (d) P (e) Q

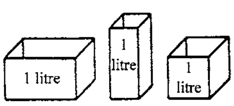
5. 

Which nail is most likely to pull out of the wall?
(a) A (b) B (c) C (d) all equally likely

6. 

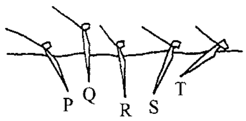
A B C D

If each block weighs the same, which one will be most difficult to push over?
(a) A (b) B (c) C (d) D

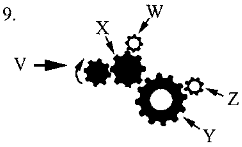
7. 

A B C

Which tank will cool the water fastest?
(a) A (b) B (c) C (d) all equal

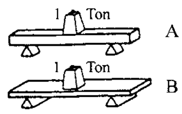
8. 

Which tent peg will give the best hold in soft ground?
(a) P (b) Q (c) R (d) S (e) T

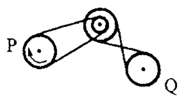
9. 

Which gear wheel goes in the same direction as the driver, V?
(a) X (b) Y (c) Z

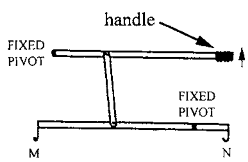
10. In question 9, which gear goes round fastest?
(a) W (b) X (c) Y (d) Z

11. 

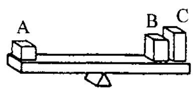
Which plank is more likely to break?
(a) A (b) B (c) either

12. 

Which way will wheel Q turn when wheel P rotates as shown?
(a) ↶ (b) ↷ (c) either

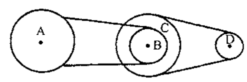
13. 

If the handle is moved as shown, how will the hooks M and N move?
(a) M up, N down
(b) M down, N up
(c) M up, N up
(d) M down, N down
(e) M up, N still

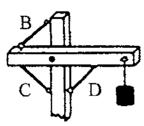
14. 

Which box is the heaviest?
(a) A (b) B (c) C (d) all equal

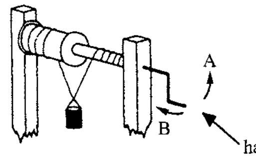
15. The diameter of pulleys A and C is 10cm and the diameter of pulleys B and D is 5cm. When pulley A makes a complete turn, pulley D will turn
(a) once (b) twice (c) 4 times (d) 6 times (e) 8 times



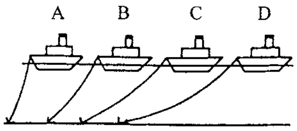
16. If pulley D is the driver, (i.e. pulley D rotates) which pulley turns slowest?
(a) A (b) B (c) C (d) all the same

17. 

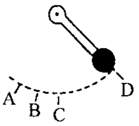
Which chain would support the weight by itself?
(a) any equally (b) B (c) C (d) D

18. 

Which way would the handle have to turn to raise the bucket?
(a) A (b) B (c) either

19. 

Which boat has the safest anchorage?
(a) A (b) B (c) C (d) D

20. 

Where is the pendulum moving fastest?
(a) A (b) B (c) C (d) D

NOTE THE TIME AT THIS POINT

Time taken to complete this section ☐ mins ☐ secs

Folk Physics Answers

1. a
2. c
3. b
4. b
5. c
6. a
7. a
8. d
9. b
10. a
11. b
12. a
13. a
14. a
15. c
16. a
17. c
18. a
19. d
20. c

A mathematician, a physicist and a computer scientist with Asperger syndrome: performance on folk psychology and folk physics tests

S. Baron-Cohen, S. Wheelwright, V. Stone and M. Rutherford

Abstract

We describe three cases of very-high-functioning individuals with Asperger syndrome, two of whom are university students (in physics and computer science, respectively), and the third a professor of mathematics, and winner of the Field Medal (equivalent to the Nobel Prize). The interest in these cases is whether there is a social–cognitive deficit, given their self-evident academic achievements. Such cases provide a rare opportunity to test for dissociations of cognitive skills, since these cases possess exceptionally high ability. These three individuals were given one test of folk psychology, one test of folk physics and one test of executive function. All three cases showed deficits on the adult-level 'theory of mind' (folk psychology) test involving reading mental states from photographs of the eyes, whilst showing no deficits on a control task of judging gender from the same photographs. In addition, all three cases were at ceiling on the test of folk physics and on the most complex test of executive function (the Tower of Hanoi). Fourteen control subjects clarified normative performance on the folk psychology and folk physics tests. These results strongly suggest that theory of mind (folk psychology) is independent of IQ, executive function and reasoning about the physical world.

Journal

Neurocase 1999; 5: 475–84

Neurocase Reference Number:

O171

Primary diagnosis of interest

Asperger syndrome/high-functioning autism

Author's designation of case

GC, CW, DB

Key theoretical issue

- Independence of social intelligence

Key words: theory of mind; folk physics

Language

English