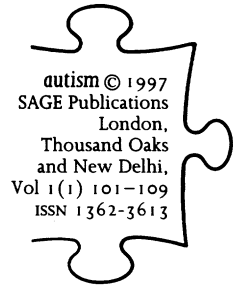


Is there a link between engineering and autism?



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ABSTRACT Autism is a severe childhood neuropsychiatric condition with a substantial genetic component. At the cognitive level children with autism are impaired in the development of their folk psychology, while they are normal or even superior in the development of their folk physics. We predicted that if their parent shared this cognitive phenotype, then they should be over-represented in engineering as an occupation. This prediction was confirmed. Both fathers and grandfathers of children with autism were found more than twice as often in the field of engineering, compared with fathers and grandfathers of other children. This link between autism and engineering may throw light not only on autism itself, but ultimately on the genetic basis of two essential human abilities: folk psychology and folk physics.

KEYWORDS
domain
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Domain specificity

Autism severely disrupts the normal development of social relationships, communication and imagination (American Psychiatric Association, 1994). Evidence that it results from neuropathology is plentiful (Bauman and Kemper, 1994), though the necessary and sufficient aspects of this neuropathology are not yet known. It occurs at a rate of about 1 per 1000 (Baron-Cohen et al., 1996; Gillberg et al., 1991). From family and twin

studies it appears to have a genetic basis (Bailey et al., 1995; Bolton and Rutter, 1990; Folstein and Rutter, 1977, 1988), though the molecular characteristics are not yet known. The genetic theory of autism however leads to the novel suggestion that autism may not strike at random, but rather that some types of parents may have an increased risk of having a child with autism. We report the first large-scale study which tests this idea in relation to occupations of parents. We predicted that engineers might be over-represented among the parents and grandparents of children with autism (or the related condition of Asperger syndrome, AS). This prediction derives from a theory of cognition.

Domain specificity theory suggests there may be at least four universal 'core domains of cognition' (Carey, 1985; Gelman and Hirschfield, 1994; Pinker, in press; Wellman and Gelman, in press). These core domains are *folk biology* (our universal ability to taxonomize the natural world); *folk physics* (our universal ability to understand physical objects in terms of their causal/mechanical properties); *folk psychology* (our universal ability to understand the behaviour of other people in terms of their intentional states); and *folk mathematics* (our universal ability to count and estimate the probability of events).

These core domains of cognition appear to be innate in their 'initial state', in that they develop in the majority of humans, irrespective of culture. They constitute a 'folk science' because they are used in an explanatory way by humans. They are considered 'domain specific' in that they appear to develop relatively independently of one another, such that dissociations in the rate of development can be found across individuals.

These four domains of cognition were probably of considerable adaptive importance during the evolution of the brain. That is, possession of each cognitive domain would have increased the fitness of the individual in different ways. Thus, folk psychology allows for rapid interpretation and prediction of the actions of other animals, and for social manipulation. Folk physics allows for tool use in an open-ended way. Folk biology allows for rapid categorization of individual plants (e.g. as edible or inedible) or categorization of individual animals (e.g. as predators or prey). Finally, folk mathematics allows for estimation of number and probability, essential in planning, for example.

Autism: impaired folk psychology with superior folk physics?

Folk psychology and physics are of special interest in that they involve causal reasoning. Broadly speaking, folk psychology involves understanding *psychological causality*: that people's actions are caused by their intentional states (their beliefs, desires, knowledge, intentions etc.). Folk physics involves understanding *physical causality*: that objects behave in ways

that are predictable from a knowledge of physical/mechanical forces. Here we consider autism in terms of these two types of causal understanding.

Children with autism are known to have major impairments in the development of folk psychological understanding (Baron-Cohen, 1995; Baron-Cohen et al., 1985, 1993) whilst having relatively normal or even superior development in their understanding of folk physics (Baron-Cohen, in press; Baron-Cohen et al., 1986; Frith, 1989; Jolliffe and Baron-Cohen, in press). If this is a good characterization of their cognitive phenotype, then their parent who carries the genes for autism might share this cognitive phenotype, to milder degrees (Baron-Cohen and Hammer, in press). The prediction therefore is that one would expect parents of children with autism to pursue occupations in which a 'talent' for folk physics is essential, whilst a talent for folk psychology is not. Engineering is the paradigm case of such an occupation. This is because it primarily involves a good understanding of objects rather than people, and is not such a low-frequency occupation as theoretical physics, for example.'

Method and participants

Questionnaires were sent to 1000 parents of children with autism or Asperger syndrome via The National Autistic Society (UK) membership list. Parents were asked to list the occupations of the child's mother and father, and those of the child's four grandparents. Replies were received from 919 parents.

Similar information was also collected from four control groups. The first group was parents of children with Tourette syndrome (TS), via the Tourette Syndrome association (TSA) in the UK ($N = 40$ couples). This served as a control group to test if patterns of occupations of parents of children with autism or Asperger syndrome were a function of the sorts of people who become members of a national charity focusing on a childhood psychiatric disorder. Given that Tourette syndrome can be associated with autism, only 'pure' cases of Tourette syndrome were included. The second group was parents with a child with Down's syndrome suffering from cardiac disease, via the charity Down's Heart in the UK ($N = 464$ couples). Again, this controlled for any sampling bias associated with being a member of a medical charity. The third and fourth groups were parents of children whose language was delayed ($N = 98$ couples), and parents of children whose language was not delayed ($N = 125$ couples). These two groups provided data from a random sample, since the groups were derived from community samples. Information about grandparents was only collected for the autism and Tourette syndrome groups.

The resulting 7068 occupations were coded blind by two independent judges into the 18 mutually exclusive occupational categories shown in Tables 1–4 and defined in the notes to Table 1. Inter-rater agreement was 99 percent.

Results

Results strongly supported the prediction. Fathers of children with autism or Asperger syndrome were found significantly more often in engineering than fathers in any of the four control groups (chi square, $p < 0.001$). Indeed, fathers of children with autism or Asperger syndrome were found more than twice as often in engineering, compared with fathers in the control groups. This was also true of grandfathers of children with autism, compared with grandfathers of children with Tourette syndrome, suggesting that such effects operate across at least two generations in families where there is a child with autism. The percentage of children with autism or Asperger syndrome who had a father or grandfather who was an engineer was 28.4 percent, whereas the percentage of children with Tourette syndrome who had a father or grandfather who was an engineer was only 15 percent. Again, this is a highly significant difference (chi square, $p < 0.001$). Furthermore, among the fathers of children with autism, the ratio of those working in engineering to those working in social fields was 6:1, whereas in the two charity-based control groups this ratio was less than 3:1. This too is highly significant (chi square, $p < 0.001$). There were no differences in the rate of engineers among fathers or grandfathers of children with autism versus Asperger syndrome.

Discussion

This study clearly demonstrates that autism (or Asperger syndrome) does not strike randomly, and suggests that the cognitive phenotype of fathers of children with autism may be broadly characterized in terms of their folk physics being superior to their folk psychology. The finding of an excess of engineers among the fathers and grandfathers of children with autism is not explained by the social class of the sample, since there were no differences of this magnitude found in other professions or occupations. Nor is it explained by the fact that such parents are members of a charity, since it was not found among the fathers or grandfathers of children with a different disorder (Tourette syndrome) or among the fathers of children with Down's syndrome. Finally, it appears to be specific to autism and

Table 1 Percentage of fathers in each occupation category

	NAS	TS	Language delay	Normal	Down's
Engineers	12.5 ^a	5.0	2.0	5.6	5.4
Social	2.6	5.0	0.0	0.8	2.4
Surveyors	2.2	2.5	2.0	3.2	0.6
Law	1.5	2.5	0.0	0.0	1.7
Medical	5.4	10.0	2.0	0.0	2.4
Teachers	7.1	2.5	3.0	5.4	6.0
Arts/media	2.9	0.0	3.1	0.8	1.7
Clergy	0.9	2.5	0.0	0.0	0.4
Science	5.4	5.0	1.0	2.4	2.4
Computing	4.7	2.5	3.1	5.6	3.2
Accountants	6.2	5.0	2.0	2.4	3.7
Business	10.2	7.5	8.2	12.8	11.6
Clerks	13.5	10.0	8.2	8.8	11.4
Skilled manual	15.7	32.5	29.6	31.2	23.9
Forces	3.8	2.5	4.1	0.0	3.2
Unskilled manual	5.2	2.5	12.2	8.8	7.1
Housewife	0.0	0.0	0.0	0.0	0.0
Missing	0.1	2.5	19.4	11.2	12.7
Total ^b	100	100	100	100	100

^a NAS versus other groups, $p < 0.001$.

^b Totals do not exactly add up to 100 because of rounding up or down.

Groups

NAS: autism/Asperger syndrome (National Autistic Society)

TS: Tourette syndrome

Language delay: language delayed

Normal: language not delayed

Down's: Down's syndrome

Occupational categories

Accountants: chartered accountants, finance officers, bank clerks.

Arts/media: all the arts, music, writers, journalists, media producers, media performers.

Business: shopkeepers, company directors, shop employees, brokers.

Clergy: vicars and missionaries.

Clerks: all administrative and clerical staff.

Computing: programmers and hardware specialists.

Engineers: narrowly defined as professional engineers, including structural, electrical, civil, chemical engineers only.

Forces: army, air force, navy, police, prison officers, customs officers, fire brigade.

Housewife: any parent not occupied outside the home.

Law: solicitors, barristers, judges, magistrates.

Medical: all branches of medicine and nursing.

Missing: unknown or unemployed individuals, the former because of single parenthood, for example.

Science: all the natural sciences, and pharmacy, but excluding medicine and engineering.

Skilled manual: all manual occupations requiring some training, except engineering, e.g. auto mechanics, plumbers, carpenters, builders.

Social: social workers, probation officers, welfare and youth workers, crèche workers, counsellors, diplomats, personnel officers, and customer relations.

Surveyors/architects: surveyors, architects, draughtsmen.

Teachers: all teachers and lecturers whose subject was not listed and who were therefore not coded into any of the specialist areas above.

Unskilled manual: all manual occupations requiring little or no training, e.g. cleaners, factory workers, farm workers, milkmen, postmen.

Table 2 Percentage of mothers in each occupation category

	NAS	TS	Language delay	Normal	Down's
Engineers	0.2	0.0	0.0	0.0	0.0
Social	4.7	2.5	11.2	3.2	5.6
Surveyors	0.2	0.0	0.0	0.0	0.0
Law	0.7	0.0	1.0	0.8	0.0
Medical	13.4	15.0	3.1	5.6	12.5
Teachers	15.6	10.0	4.1	8.8	9.7
Arts/media	2.3	0.0	0.0	2.4	1.1
Clergy	0.0	0.0	1.0	0.0	0.0
Science	5.2	2.5	1.0	0.8	0.9
Computing	1.7	5.0	0.0	0.8	1.3
Accountants	6.6	2.5	3.1	0.0	2.8
Business	4.0	12.5	1.0	4.8	2.8
Clerks	24.6	22.5	7.1	10.4	10.3
Skilled manual	5.5	5.0	2.0	2.4	2.2
Forces	0.2	0.0	0.0	0.0	0.2
Unskilled manual	1.8	10.0	14.3	9.6	0.9
Housewife	13.2	12.5	51.0	50.4	49.1
Missing	0.0	0.0	0.0	0.0	0.6
Total ^a	100	100	100	100	100

^a Totals do not exactly add up to 100 because of rounding up or down.

For groups and occupational categories see notes to Table 1.

Table 3 Percentage of grandfathers in each occupation category

	NAS maternal	NAS paternal	TS maternal	TS paternal
Engineers	11.5 ^a	9.7 ^a	5.0	5.0
Social	0.8	0.2	0.0	2.5
Surveyors	2.0	2.4	0.0	0.0
Law	1.2	1.6	0.0	0.0
Medical	2.7	2.1	2.5	2.5
Teachers	4.1	3.5	5.0	0.0
Arts/media	1.4	1.7	2.5	0.0
Clergy	1.3	0.3	0.0	0.0
Science	3.7	2.3	0.0	0.0
Computing	0.1	0.1	0.0	0.0
Accountants	3.5	2.5	0.0	2.5
Business	11.0	13.1	12.5	12.5
Clerks	12.3	12.3	10.0	5.0
Skilled manual	26.6	27.6	37.5	32.5
Forces	5.7	5.2	10.0	10.0
Unskilled manual	11.0	13.9	15.0	22.5
Housewife	0.0	0.0	0.0	0.0
Missing	0.9	1.4	0.0	5.0
Total ^b	100	100	100	100

^a NAS versus TS, $p < 0.001$.

^b Totals do not exactly add up to 100 because of rounding up or down.

For groups and occupational categories see notes to Table 1.

Table 4 Percentage of grandmothers in each occupation category

	<i>NAS maternal</i>	<i>NAS paternal</i>	<i>TS maternal</i>	<i>TS paternal</i>
Engineers	0.0	0.2	0.0	0.0
Social	1.0	0.8	0.0	2.5
Surveyors	0.1	0.0	0.0	0.0
Law	0.1	0.2	0.0	0.0
Medical	7.4	5.5	7.5	0.0
Teachers	7.8	6.7	0.0	2.5
Arts/media	1.5	0.9	0.0	0.0
Clergy	0.0	0.0	0.0	0.0
Science	1.4	1.2	0.0	0.0
Computing	0.3	0.2	2.5	0.0
Accountants	2.8	2.3	0.0	2.5
Business	7.0	8.2	7.5	2.5
Clerks	14.8	12.6	15.0	7.5
Skilled manual	9.7	8.9	10.0	17.5
Forces	0.1	0.1	0.0	0.0
Unskilled manual	9.5	7.8	15.0	17.5
Housewife	36.1	43.1	42.5	42.5
Missing	0.3	1.2	0.0	5.0
Total ^a	100	100	100	100

^a Totals do not exactly add up to 100 because of rounding up or down.

For groups and occupational categories see notes to Table 1.

Asperger syndrome in that it was not seen among fathers of a related childhood condition, language delay. In all of these control groups, the percentage of fathers in engineering was around 5 percent, which reflects national levels (Office of Population Censuses and Surveys, 1991). Mothers and grandmothers of children with autism were not different to female controls. Note that selection biases appear to be present in the charity-based samples (more doctors among the fathers of children with Tourette syndrome, reflecting a professional sample, and fewer absentee fathers in the NAS and Tourette syndrome samples, reflecting the kinds of parents who join charities), but that neither of these biases can easily explain the link between engineering and autism across two generations.

There thus seems to be a small but statistically significant link between autism and engineering. We wish to stress however that the majority of engineers have no connection with autism, and the majority of parents of autism have no connection with engineering. Nevertheless, this link between the two phenomena merits further research.

The results of this study fit predictions from domain specificity theory, as applied to autism. The current results might also help explain why a condition like autism persists in the gene pool: the very same genes that lead an individual to have a child with autism can lead to superior

functioning in the domain of folk physics. Engineering and related folk physics skills have transformed the way in which our species live, without question for the better. Indeed, without such skills, *Homo sapiens* would still be pre-industrial.

There is considerable interest in identifying the genetic basis of those two most fundamental of human abilities, folk psychology (also known as mind-reading) and folk physics (or open-ended tool use), since these two abilities are thought to have played a major role in primate evolution (Mithen, 1997; Whiten, 1991). The study of the genetics of autism may throw light not only on the condition itself but also on the molecular basis of these important human abilities.

Note

1. A different prediction might have been that parents would be over-represented in occupations involving mathematics and/or computing since these do not necessarily require a talent for folk psychology, but do require a talent for folk mathematics or folk physics. However, mathematics is a low-frequency occupation, whilst these days computing is part of almost every occupation. Hence our prediction regarding engineering.

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