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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", whilst 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 to 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".

Autism severely disrupts the normal development of social relationships, communication, and imagination (APA, 1994). Evidence that it results from neuropathology is plentiful (Bauman & 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, Steffenberg & Schaumann, 1991). From family and twin studies it appears to have a genetic basis (Bailey et al., 1995; Bolton & Rutter, 1990; Folstein & Rutter, 1977; Folstein & Rutter, 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's Syndrome [AS]). This prediction derives from a theory of cognition.

<u>Domain Specificity theory</u> suggests there may be at least 4 universal, "core domains of cognition" (Carey, 1985; Gelman & Hirschfield, 1994; Pinker, in press; Wellman & 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 4 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 (eg. as edible or inedible), or categorization of individual animals (eg. 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, Leslie & Frith, 1985; Baron-Cohen, Tager-Flusberg & Cohen, 1993) whilst having relatively normal or even superior development in their understanding of folk physics (Baron-Cohen, in press; Baron-Cohen, Leslie & Frith, 1986; Frith, 1989; Jolliffe & 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 & Hammer, in press a). 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.[1]

Method and Participants

[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 these do require a talent for folk mathematics or folk physics. However, mathematics is a low frequency

Questionnaires were sent to 1000 parents of children with autism or AS, via the National Autistic Society (UK) membership list. Parents were asked to list the occupation of the child's mother and father, and those of the child's 4 grandparents. 919 replies were received.

Similar information was also collected from 4 control groups: (a) 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 AS were a function of the sorts of people who become members of a national charity focusing on a childhood psychiatric disorder. Given that TS can be associated with autism, only "pure" cases of TS were included. (b) Parents with a child with Downs Syndrome suffering from cardiac disease, via the charity, Downs Heart, in the UK (n = 464 couples). Again, this controlled for any sampling bias associated with being a member of a medical charity. (c) Parents of

children whose language was delayed (n = 98 couples), and (d) parents of children whose language was not delayed (n =125 couples). These latter two groups provided data from a random sample, since these 2 groups were derived from community samples. Information about grandparents was only collected for the autism and TS groups. The resulting 7,068 occupations were coded blind by 2 independent judges into the 18

occupation, whilst these days computing is part of almost every occupation. Hence our prediction regarding engineering.

mutually exclusive occupational categories shown in Tables 1-4, and as defined in the Legend to the Tables. Inter-rater agreement was 99%.

insert Tables 1-4 here

Results

Results strongly supported the prediction. Fathers of children with autism or AS were found significantly more often in engineering than fathers in any of the 4 control groups (Chi Square = $p < 0.001$). Indeed, fathers of children with autism or AS were found more than twice as often in engineering, compared to fathers in the control groups. This was also true of grandfathers of children with autism, compared to grandfathers of children with TS, suggesting that such effects operate across at least 2 generations in families where there is a child with autism. The percentage of children with autism or AS who had a father or grandfather who was an engineer was 28.4%, whereas the percentage of children with TS who had a father or grandfather who was an engineer was only 15%. 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 2 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 AS.

Discusssion

This study clearly demonstrates that autism (or AS) 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 AS 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%, which reflects national levels (Office of Population and Census Survey, 1990). 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 TS, reflecting a professional sample, and fewer absentee fathers in the NAS and TS 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 these two most fundamental 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.

Table Legends

Tables 1-4 show the percentage of fathers', mothers', grandfathers', and grandmothers' occupations, respectively, coded into 1 of the following 18 categories, listed alphabetically here:

Accountants (including chartered accountants, finance officers, and bank clerks); *Arts/Media* (including all the arts, music, writers, journalists, media producers, and media performers); *Business* (including shop keepers, company directors, shop employees, and brokers); *Clerks* (including all administrative and clerical staff); *Clergy* (including vicars and missionaries);*Computing* (including programmers and hardware specialists); *Engineers* (narrowly defined as professional engineers, including structural, electrical, civil, and chemical engineers only); *Forces* (including the army, airforce, navy, police, prison officers, customs officers, and the fire brigade); *Medical* (including all branches of medicine and nursing); *Law* (including solicitors, barristers, judges, and magistrates); *Skilled Manual* (including all manual occupations requiring some training, except engineering - e.g.: auto-mechanics, plumbers, carpenters, builders, etc.,); *Missing* (including unknown or unemployed individuals, the former because of single parenthood, for example); *Surveyors/Architects* (including surveyors, architects, and draughtsmen); *Science* (including all the natural sciences, and pharmacy, but excluding medicine and engineering); *Social* (including social work, probation officers, welfare and youth workers, crèche workers, counsellors, diplomats, personnel officers, and customer relations); *Teachers* (including all teachers and lecturers whose subject was not listed and who were therefore not coded into any of the specialist areas above).*Unskilled Manual* (including all manual occupations requiring little or no training (e.g.: cleaners, factory workers, farm workers, milkman, postman); and *Housewife* (including any parent not occupied outside the home).

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	NAS	TS	LANG	NORMAL	DOWNS
ENGINEER	12.5*	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
LAWYERS	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
ACCOUNTS	6.2	5.0	2.0	2.4	3.7
BUSINESS	10.2	7.5	8.2	12.8	11.6
CLERICAL	13.5	10.0	8.2	8.8	11.4
SKILL MAN	15.7	32.5	29.6	31.2	23.9
FORCES	3.8	2.5	4.1	0.0	3.2
UNSKIL MAN	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 N =	100	100	100	100	100

Table 1: Percentage of fathers in each occupation category

*** NAS vs other groups, $p < 0.001$**

	NAS	TS	LANG	NORMAL	DOWNS
ENGINEER	0.2	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
LAWYERS	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
ACCOUNTS	6.6	2.5	3.1	0.0	2.8
BUSINESS	4.0	12.5	1.0	4.8	2.8
CLERICAL	24.6	22.5	7.1	10.4	10.3
SKILL MAN	5.5	5.0	2.0	2.4	2.2
FORCES	0.2	0.0	0.0	0.0	0.2
UNSKIL MAN	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 N =	100	100	100	100	100

Table 2: Percentage of mothers in each occupation category

	NAS maternal	NAS paternal	TS maternal	TS paternal
ENGINEER	11.5*	9.7*	5.0	5.0
SOCIAL	0.8	0.2	0.0	2.5
SURVEYORS	2.0	2.4	0.0	0.0
LAWYERS	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
ACCOUNTS	3.5	2.5	0.0	2.5
BUSINESS	11.0	13.1	12.5	12.5
CLERICAL	12.3	12.3	10.0	5.0
SKILL MAN	26.6	27.6	37.5	32.5
FORCES	5.7	5.2	10.0	10.0
UNSKIL MAN	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 N =	100	100	100	100

Table 3: Percentage of grandfathers in each occupation category

*** NAS vs TS, $p < 0.001$**

	NAS maternal	NAS paternal	TS maternal	TS paternal
ENGINEER	0	0.2	0	0
SOCIAL	1.0	0.8	0.0	2.5
SURVEYORS	0.1	0.0	0.0	0.0
LAWYERS	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
ACCOUNTS	2.8	2.3	0.0	2.5
BUSINESS	7.0	8.2	7.5	2.5
CLERICAL	14.8	12.6	15.0	7.5
SKILL MAN	9.7	8.9	10.0	17.5
FORCES	0.1	0.1	0.0	0.0
UNSKIL MAN	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 N =	100	100	100	100

Table 4: Percentage of grandmothers in each occupation category