Autism

Two new theories of autism: hyper-systemising and assortative mating

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Commentary on the papers by Williams *et al* (see page 8) and Harrison *et al* (see page 16)

The autistic spectrum comprises four subgroups: Asperger's syndrome (AS),[1 2] and high, medium, and low functioning autism.[3] They all share the phenotype of social difficulties and obsessional interests.[4] In AS, the individual has normal or above average IQ and no language delay. In the three autism subgroups there is invariably some degree of language delay, and the level of functioning is indexed by overall IQ.* These four subgroups are known as autism spectrum conditions (ASC).

Williams and colleagues[5] searched electronic databases and bibliographies to carry out a meta-analysis of 42 studies of prevalence of autism spectrum conditions (ASC). From this, their most generous estimate was 20 per 10 000, or 0.2%. Harrison and colleagues[6] used the ''capture–recapture'' technique in Lothian, Scotland, and their prevalence estimate was 44.2 per 10 000, or 0.44%. This corresponds to 1 child in 225. These estimates are clearly much higher than was the case in the past, where prevalence was traditionally estimated to be 4 in 10 000.

BEYOND COUNTING AND PREVALENCE ESTIMATES

Now we know that ASC are common. How should we understand their causes? Harrison and colleagues[6] find that the 13–15 year old age group who would have received their MMR during the data collection phase were actually less numerous than the 4–10 year old age group, suggesting this high rate cannot be due to the MMR vaccine (since both age groups were exposed to the MMR). Instead they argue that these data suggest better recognition, better recording of cases, and growth of services.

In terms of causes, the consensus is that ASC have a genetic aetiology,[7] which leads to altered brain development,[8–11] affecting social and communication development and leading to the presence of unusual narrow interests and extreme repetitive behaviour.[4] The model we can use involves multiple levels (see fig 1). In what follows I will elaborate on the two new ideas, shown in bold in the model.

HYPER-SYSTEMISING

A universal feature in the environment that the brain has to react to is *change*. There are two types of structured change:

- *Agentive change*: If an object change is perceived to be self-propelled, the brain interprets the object as an agent, with a *goal*.[12 13] Such change cannot easily be predicted in any other way. To interpret agentive change, humans have specialised neurocognitive mechanisms, collectively referred to as the ''empathising system''.[14–16] The neural circuitry of empathising is now quite well mapped.[9–11] Key brain areas involved in empathising include the amygdala, the orbito and medial frontal cortex, and the superior temporal sulcus.
- *Non-agentive change*: Any structured change that is *not* self-propelled is interpreted by the brain as a non-agentive change. ''Structured'' means non-random, for example that there is a precipitating event, or some other pattern. The brain doe not deploy the empathising mechanisms to predict such change. Instead, the human brain engages in ''systemising'', that is, it searches for structure (patterns, rules, regularities, periodicity) in data, to test if the changing data are part of a system. Systemising involves observation of *input–operation–output* relationships, leading to the identification of laws to predict that event x will occur with probability p.[17]

Some systems are 100% lawful (for example, an electrical light switch, or a mathematical formula) (see table 1). Systems that are 100% lawful have zero variance, or only 1 degree of freedom, and can therefore be predicted (and controlled) 100%. A computer might be an example of a 90% lawful system: the variance is wider or there are more degrees of freedom. Growing hydrangeas may be a system with 80% lawfulness (see table 2). The social world may be only 10% lawful. This is why systemising the social world is of little predictive value.

Systemising involves five phases:

- Phase 1 = *Analysis*: Single observations of input (for example, hydrangea type) and output (colour) are recorded in a standardised manner at the lowest level of detail.
- Phase 2 = *Operation*: An operation is performed on the input and the change to the output is noted.
- Phase 3 = *Repetition*: The same operation is repeated over and over again to test if the same pattern between input and output is obtained.
- Phase 4 = *Law derivation*: A law is formulated of the form If X (operation) occurs, A (input) changes to B.
- Phase 5 = *Confirmation/disconfirmation*: If the same pattern of input–operation–output holds true for all instances, the law is retained.

If a single instance does not fit the law, phases 2–5 are repeated, leading to modification of the law, or a new law.

Systemising non-agentive changes is effective because these are *simple* changes: the systems are at least moderately lawful, with narrow variance (or limited degrees of freedom). Agentive change is less suited to systemising because the changes in the system are *complex* (wide variance, or many degrees of freedom).

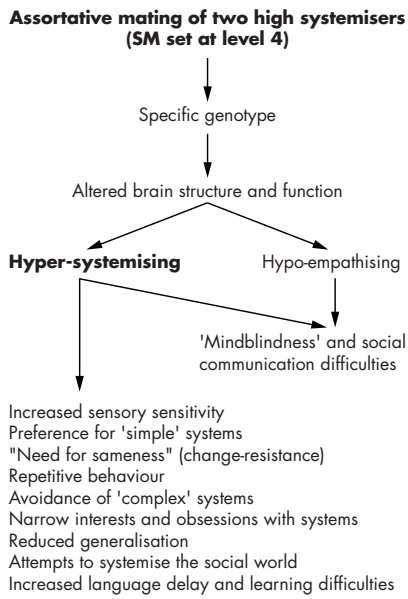

Figure 1 Multi-level model of autism spectrum conditions.

* High functioning autism (HFA) can be thought as within one standard deviation of population mean IQ (that is, IQ of 85 or above); medium functioning autism (MFA) can be thought of as between one and three standard deviations below the population mean (that is, IQ of 55–84). Low functioning autism (LFA) can be thought of below this (that is, IQ of 54 or below).

Table 1 Two examples of 100% lawful systems: (a) An electricity switch, and (b) a mathematical rule

Input	Operation and output
Input = switch position	**Operation = switch change** **Output = light**
Up	On
Down	Off
Input = number	**Operation = add 2** **Output = number**
2	4
3	5
4	6

The systemising mechanism (SM)

The hyper-systemising theory of ASC posits that human brains have a systemising mechanism (SM), and this is set at different levels in different individuals. In people with ASC, the SM is set too high. The SM is like a volume control. Evidence suggests that within the general population, there are eight degrees of systemising:

- *Level 1*: Such individuals have little or no drive to systemise, and consequently they can cope with rapid, unlawful change. Their SM is set so low that that they hardly notice if the input is structured or not. While this would not interfere with their ability to socialise, it would lead to a lack of precision over detail when dealing with structured information. We can think of this as *hypo-systemising*. Such a person would be able to cope with agentive change easily, but may be challenged when dealing with highly lawful non-agentive systems.
- *Levels 2 and 3*: Most people have *some* interest in lawful non-agentive systems, and there are sex differences in this. More females in the general population have the SM set at Level 2, and more males have it set at Level 3. For example, on tests of map reading or mental rotation or mechanics, or on the systemising quotient, males perform higher than females.[16 18–20]
- *Level 4*: Level 4 corresponds to individuals who systemise at a higher level than average. There is some evidence that above-average systemisers have more autistic traits. Thus, scientists (who by definition have the SM set above average) score higher than non-scientists on the autism spectrum quotient (AQ). Mathematicians score highest of all scientists on the AQ.[21] Parents of children with ASC also have their SM set higher than average[22 23] and have been described as having the ''broader phenotype'' of autism. At Level 4 one would expect a person to be talented at understanding systems with moderate variance or lawfulness.
- *Level 5*: People with AS have their SM set at Level 5: the person can easily systemise lawful systems such as calendars or train timetables.[24] Experimental evidence for hyper-systemising in AS includes the following: (i) people with AS score higher than average on the systemising quotient (SQ);[19] (ii) people with AS perform at a normal or high level on tests of intuitive physics or geometric analysis;[20 25–27] (iii) people with AS can achieve extremely high levels in domains such as mathematics, physics, or computer science;[28] and (iv) people with AS have an ''exact mind'' when it comes to art[29] and show superior attention to detail.[30 31]
- *Levels 6–8*: In people with high functioning autism (HFA), the SM is set at Level 6, in those with medium functioning autism (MFA) it is at Level 7, and in low functioning autism (LFA) it is at the maximum setting (Level 8). Thus, people with HFA try to socialise or empathise by ''hacking'' (that is, systemising),[32] and on the picture sequencing task, they perform above average on sequences that contain temporal or physical-causal information.[33] People with MFA perform above average on the false photograph task.[34] In LFA, their obsessions cluster in the domain of systems,† such as watching electric fans go round;[35] and given a set of coloured counters, they show extreme ''pattern imposition''.[36] Box 1 lists 16 behaviours that would be expected if an individual had their SM turned up to the maximum setting of Level 8.

Table 2 An example of systemising hydrangea colour

	Operation (type of soil)		
	Acidic	**Neutral**	**Alkaline**
Input (type of hydrangea)	**Output (colour of hydrangea)**		
Annabelle	White	White	White
Blauer prinz	Blue	Purple	Purple
Bouquet rose	Blue	Purple	Pink
Deutschland	Purple	Red	Red
Enziandom	Blue	Purple	Red

From http://www.hydrangeasplus.com.
Systemising involves recording input and output and deriving the rules how an operation changes the output.

UNEXPECTED CONSEQUENCES OF HYPER-SYSTEMISING

The hyper-systemising theory can also explain why some people with autism may have more or less language, or a higher or lower IQ, or differing degrees of mind blindness.[14] According to the theory, turning the SM *downwards* from the maximum level of 8, at each point on the dial the individual should be able to tolerate an increasing amount of change or variance in the system. Thus, if the SM is set at Level 7, the person will be able to deal with systems that are less than 100% lawful, but still highly lawful. The child could achieve a slightly higher IQ (since there is a little more possibility for learning about systems that are less than 100% lawful), and the child would have a little more ability to generalise than someone with classic autism.†† The higher the level of the SM, the less generalisation,[37] since systemising involves identifying laws that might only apply to the current system under observation.‡

At Level 7, one would expect some language delay, but this might only be a moderate (since someone whose SM is set at Level 7 can tolerate a little

†This may help to explain why videos like *Thomas the Tank Engine* are favourites for many children with autism: there is no agentive change and almost all the non-agentive change is mechanical and linear, with close to 100% lawfulness.

††I am indebted to Nigel Goldenfeld for suggesting this connection between hyper-systemising and IQ.

‡Reduced generalisation is seen as a consequence of hyper-systemising. Systemising presumes that one does not generalise from one system to another until one has enough information that the rules of system A are identical to those of system B. Good generalisation may be a feature of average or poor systemisers, while ''reduced'' generalisation can be seen as a feature of hyper-systemising.

variance in the way language is spoken and still see meaningful patterns). And the child's mindblindness‡‡ would be less than total. If the SM is set at Level 6, such an individual would be able to deal with systems that were slightly less lawful. This would therefore be expressed as only mild language delay, mild obsessions, mild delay in theory of mind, and stilted social behaviour, such as attempts at systemising social behaviour.

THE ASSORTATIVE MATING OF TWO HIGH SYSTEMISERS

The evidence for systemising being part of the phenotype for ASC includes the following: fathers and grandfathers of children with ASC are twice as likely to work in the occupation of engineering (a clear example of a systemising occupation), compared to men in the general population.[39] The implication is that these fathers and grandfathers have their SM set higher than average (Level 4). Students in the natural sciences (engineering, mathematics, physics) have a higher number of relatives with autism than do students in the humanities.[40] Mathematicians have a higher rate of AS compared to the general population, and so do their siblings.[41]

The evidence that autism could be the genetic result of having *two* high systemisers as parents (assortative mating) includes the following: (a) both mothers *and* fathers of children with AS have been found to be strong in systemising on the Embedded Figures Test;[22] (b) both mothers and fathers of children with autism or AS have increased rates of systemising occupations among their fathers;[39] and (c) both mothers and fathers of children with autism show hyper-masculinised patterns of brain activity during a systemising task.[42] Whether the current high rates of ASC simply reflect better recognition, growth of services, and widening of diagnostic categories to include AS, or also reflect the increased likelihood of two high-systemisers have children, is a question for future research.

CONCLUSIONS

The core of autism spectrum conditions (ASC) is both a social deficit and what Kanner astutely observed and aptly named ''need for sameness''.[3] According to the hyper-systemising theory, ASC is the result of a normative systemising mechanism (SM)—the function of which is to serve as a change predicting mechanism—being set too high. This theory explains why people with autism prefer either no change, or appear ''change resistant''. It also explains their preference for systems that change in highly lawful or predictable ways (such as mathematics, repetition, objects that spin, routine, music, machines, collections). Finally, it also explains why they become disabled when faced with systems characterised by ''complex'' or less lawful change (such as social behaviour, conversation, people's emotions, or fiction), since these cannot be easily systemised.

While ASCs are disabling in the social world, hyper-systemising can lead to talent in areas that are systemisable. For many people with ASC, their hyper-systemising never moves beyond phase 1 (massive collection of facts and observations—lists of trains and their departure times, watching the spin-cycle of a washing machine), or phases 2 and 3 (massive repetition of behaviour—spinning a plate or the wheels of a toy car). But for those who go beyond phase 3 to identify a law or a pattern in the data (phases 4 and 5), this can constitute original insight. In this sense, it is likely that the genes for increased systemising have made remarkable contributions to human history.[43–45]

Box 1: Systemising mechanism at Level 8: classic, low-functioning autism

Key behaviours that follow from extreme systemising include:

- *Highly repetitive behaviour* (e.g. producing a sequence of actions, sounds, or set phrases, or bouncing on a trampoline)
- *Self-stimulation* (e.g. a sequence of repetitive body-rocking, finger-flapping in a highly stereotyped manner, spinning oneself round and round)
- *Repetitive events* (e.g. spinning objects round and round, watching the cycles of the washing machine; spinning the wheels of a toy car)
- *Preoccupation with fixed patterns or structure* (e.g. lining things up in a strict sequence, electrical light switches being in either an ON or OFF position throughout the house)
- *Prolonged fascination with systemisable change* (e.g. sand falling through one's fingers, light reflecting off a glass surface, playing the same video over and over again)
- *Tantrums at change*: as a means to return to predictable, systemisable input
- *Need for sameness*: to impose lack of change onto their world, to turn their world into a totally predictable environment, to make it systemisable
- *Social withdrawal*: since the social world is largely unsystemisable
- *Narrow interests*: in systems (e.g. types of planes)
- *Mind blindness*: since the social world is largely unsystemisable
- *Attention to detail*: the SM records each data point in case it is a relevant variable in a system
- *Reduced generalisation*: hyper-systemising means a reluctance to formulate a law until there has been sufficient data collection. This could also reduce IQ and breadth of knowledge
- *Language delay*: since other people's spoken language varies every time it is heard, so it is hard to systemise
- *Islets of ability*: channelling attention into the minute detail of one lawful system (e.g. the script of a video, or prime numbers)

ACKNOWLEDGEMENTS

I am grateful for the support of the MRC and the Nancy Lurie-Marks Family Foundation during this work.

Arch Dis Child 2006;**91**:2–5.
doi: 10.1136/adc.2005.075846

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Competing interests: none declared

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‡‡ Mind blindness in this model (see fig 1) is seen as arising from twin abnormalities: the SM being set too high, such that complex systems such as the social world are hard to predict via systemising; and atypical development of empathising mechanisms[14–16] that in the normal case make it possible to make sense of the social world via an non-SM route.

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Infection

Influenza related hospital admissions in children: evidence about the burden keeps growing but the route to policy change remains uncertain

J S Nguyen-Van-Tam

Commentary on the paper by Beard *et al* (see page 20)

Influenza has long been recognised as a disease which affects children; however, it is only fairly recently that the literature on this subject has switched focus from community settings towards the burden of hospitalisations. This issue carries an article by Frank Beard and colleagues which draws attention to the issue in Sydney, Australia and addresses the issue in a quantitative as well as a qualitative way.[1] It follows on from, and replicates the methodologies employed by similar pivotal studies in the USA and Hong Kong.[2 3]

Most experienced commentators would agree that the foundations of our understanding of the burden of influenza in children, are based on data generated by a series of prospective community studies which took place in the 1960s and 1970s in the USA, all of which combined clinical surveillance with attempts at virus isolation and serological studies, to a greater or lesser extent. They are probably too large and too expensive to ever contemplate repeating in the present era. In Tecumseh, Michigan, between 100 and 300 families with at least one child were studied continuously for six years from 1966 to 1971—a period which included the emergence of influenza A/H3N2, the last pandemic virus, in 1968.[4] In Seattle, Washington, a similar study took place between 1965 and 1969 and again from 1975 to 1979, involving over 215 families with young children.[5] In Houston, Texas, similar observations were made over the period 1976 to

1984, including two influenza B epidemics.[6] The findings of these major studies have consistently shown that the highest serological attack rates for influenza each season occur in children (typically 15–40%) compared with adults (12–20%), although there is far less consensus on whether the peak rate occurs in teenagers, primary age children, or preschoolers.[7–10] From the above studies,[5 7–10] and others,[11 12] there are also convincing data that children act as introducers and spreaders of influenza infection in communities and individual households (presumably because they mix more often and shed viruses in higher titre than adults, and for longer). Glezen and Couch showed an upwards shift in the age distribution of influenza positive patient specimens (from children aged 5–19 years towards adults aged 20–44 years) as two influenza A epidemics progressed over time; similarly, in the same setting, school absenteeism preceded industrial absenteeism by about two weeks and paediatric admissions for pneumonia preceded those in adults by a similar period.[13] Another notable finding from these studies was the disparity between serological and clinical attack rates. Fox *et al* showed that among teenagers and children with serologically proven infection, between 83% and 69% suffered a clinical illness;[9] other studies have estimated that only 58% of infections in teenagers are accompanied by symptoms.[14] What seems clear is that asymptomatic infections in children are not uncommon.

The relative importance of influenza compared with other childhood respiratory viruses, notably RSV, has also been well described in hospital based studies. In Kawasaki, Japan, a study of paediatric admissions over seven winter seasons from 1991 to 1998 revealed that 14% of admissions were attributable to serologically confirmed influenza, compared with 17.5% due to RSV; other respiratory viruses accounted for a much lower proportions of the total burden.[15] In Kiel, Germany, a similar study of acute respiratory admissions over four winter seasons using PCR testing of nasopharyngeal specimens, revealed that 8.3% of such admissions were attributable to influenza infection, compared with 12.7% due to RSV; while RSV was the dominant pathogen in children aged 0–3 months, from the age of 2 years upwards, influenza predominated.[16] Similar contemporary data are also available from Spain[17] and Italy.[18] In Leicester, UK a similar prospective study was carried out over one winter season in children <6 months, hospitalised for a broad variety of acute illnesses (not just acute respiratory illness), and again based on PCR testing of nasopharyngeal specimens. This revealed that 5.4% overall had an influenza infection at the time of admission, but more surprisingly, the proportion of influenza infected children among those presenting with acute respiratory illness (5.0%) was similar to the proportion among children presenting with non-respiratory illness (6.0%).[19] These data suggest that the burden of hospitalisation due to influenza is underestimated by considering only acute respiratory admissions. Further evidence from Lyon, France suggests that during defined influenza epidemic periods the rate of virus isolation from small children who are unwell is probably many times higher.[20]

Attempts have been made to quantify hospital admissions in children due to influenza, since the 1980s. Mullooly and Barker attempted this in 1982, by estimating the excess hospitalisation rate seen in epidemic compared with non-epidemic years in Oregon, using retrospective data.[21] These researchers found an overall excess rate of $9/10^4$ admissions with influenza related diagnoses, but this rose to $32/10^4$ in children with at-risk conditions. Broadly comparable results also emerged from a similar study in Harris County, Texas.[22] However neither of these studies used methods which adequately adjusted for the potential influence of RSV infections. In contrast, the cluster of recent studies, including the current one by Beard *et al*, have paid much closer attention to the possible confounding effects of RSV infection.[1–3 23 24]

The featured study in this issue[1] illustrates that the estimation of excess hospitalisation in children due to influenza is highly sensitive, not only to the precise mathematical method used, but also to the selection of either a summer baseline or one comprised of winter periods when influenza was not circulating (''periseasonal baseline'').[1] Nevertheless, the study findings illustrate a consistent trend towards the highest rates of influenza related hospitalisation in children <12 months old. The excess hospitalisation rates observed in Sydney were also far higher than those recorded in recent US studies,[2 23 24] but distinctly lower than those calculated by Chiu *et al* in Hong Kong.[3] All three US studies focused on healthy children only, and might therefore be expected to have produced somewhat lower excess rates than in Sydney; but, on its own, this is unlikely to account for such dramatic differences. It is equally as unclear why the rates of excess hospitalisation in Hong Kong are so much higher than in Sydney. Aside from confounding, other possible explanations include true differences in the incidence of influenza in children in different countries, and genuine differences in thresholds for hospital admission of children with acute respiratory illness in different health systems.

Notwithstanding the uncertainties in the data regarding the true burden of influenza related hospital admissions in children, two consistent messages appear to be emerging. First, that the magnitude of hospital admission due to influenza in children is far from trivial and, at times, on a par with excess admission rates in adults at-risk. Second, that the burden of influenza related hospitalisation in children is concentrated among those <5 years, and especially those <12 months. However, in relation to the second point, the same is also true for RSV.[25]

There have been many calls for individual countries to emulate the US policy for routine annual vaccination of young children against influenza.[26] One of the critical factors in deciding on the cost effectiveness of such a policy is being able to establish reliable country specific data on the burden of hospitalisation. The current study and others like it will assist national governments in this task. Nevertheless even if the likelihood of cost effectiveness seems high, there are other equally important considerations which have to be factored in before scientific evidence becomes official policy. Not least of these are the availability of a suitable vaccine; space within the national childhood immunisation schedule to accommodate delivery of an annual seasonal programme (first time vaccinees may require two doses); and finally, parental acceptability.

Arch Dis Child 2006;**91**:5–7.
doi: 10.1136/adc.2005.079087

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Competing interests: none declared

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ARCHIVIST

Psychopathology before and after temporal lobectomy for epilepsy

Children with temporal lobe epilepsy (TLE) commonly exhibit psychopathology but children with severe TLE who are candidates for temporal lobectomy are even more likely to have a psychiatric disorder and many have more than one psychiatric diagnosis. A report from the Great Ormond Street Hospital for Children, London (A McLellan and colleagues. *Developmental Medicine and Child Neurology* 2005;**47**:666–72) includes 60 children who underwent temporal lobectomy between 1992 and 1998. Forty-three children (72%) had at least one psychiatric diagnosis before operation and 27 (45%) had more than one. The main psychiatric diagnoses preoperatively were disruptive behaviour disorder, not otherwise specified (DBD (NOS)), which affected 25 of 60 children; pervasive developmental disorder (PDD), 23 children; attention deficit hyperactivity disorder (ADHD), 14; and oppositional defiant disorder/conduct disorder (ODD/CD), 14. Five children had emotional disorders before operation. Of 57 children followed up after operation 25 had DBD (NOS) (five lost that diagnosis and five gained it), 21 had PDD, 13 ADHD, and 13 ODD/CD. Twelve had emotional disorder, ten for the first time. Overall, 72% had a psychiatric diagnosis before operation and 72% of those followed up had a psychiatric diagnosis after operation. Except for PDD, there was no significant relationship between psychiatric disorders and brain pathology, sex, seizure frequency, or postoperative seizure outcome. PDD was significantly associated with younger age of seizure onset, right sided temporal lobe lesions, and cognitive difficulties, and was non-significantly associated with male sex. Thirty-seven children had no or rare seizures after operation, nine had much fewer seizures, and 11 had an unchanged or worse seizure frequency. Psychiatric outcome after temporal lobectomy is uncertain, unrelated to seizure outcome, and needs to be discussed with parents during the preoperative work-up.