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Autism: cognitive deficit or cognitive style?

Francesca Happé

Autism is a developmental disorder characterized by impaired social and communicative development, and restricted interests and activities. This article will argue that we can discover more about developmental disorders such as autism through demonstrations of task success than through examples of task failure. Even in exploring and explaining what people with autism find difficult, such as social interaction, demonstration of competence on contrasting tasks has been crucial to defining the nature of the specific deficit. Deficit accounts of autism cannot explain, however, the assets seen in this disorder; for example, savant skills in maths, music and drawing, and islets of ability in visuospatial tests and rote memory. An alternative account, reviewed here, suggests that autism is characterized by a cognitive style biased towards local rather than global information processing – termed 'weak central coherence'. Evidence that weak coherence might also characterize the relatives of people with autism, and form part of the extended phenotype of this largely genetic disorder, is discussed. This review concludes by considering some outstanding questions concerning the specific cognitive mechanism for coherence and the neural basis of individual differences in this aspect of information processing.

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Autism is a devastating developmental disorder affecting at least one in a thousand children and adults. Although biologically based, with a strong genetic component, diagnosis of autism is still made by behavioural criteria: qualitative impairments in social and communicative development, with restricted and repetitive activities and interests[1]. It is not difficult to find things that people with autism have difficulty with – indeed, most autistic people also have general learning difficulties and low IQ. However, I will argue in this review that progress in understanding this disorder, and its implications for normal development, will arise chiefly through exploration of what people with autism are *good* at.

Understanding preserved and impaired abilities in autism

Much progress has been made in the last 15 years in understanding the nature of the social and communicative handicaps in autism. Primary in this has been the notion that people with autism fail to represent the mental states of others (and possibly of self) – a deficit in what has been called 'theory of mind' (see Box 1). This account can explain why children with autism have such difficulty with simple behaviours such as joint attention, pretend play and even telling lies[2]. However, these deficits, and failure on key tasks such as false-belief tests, are only informative when viewed against a background of task success. Clearly, (behavioural) task failure is ambiguous with regard to underlying (cognitive) deficits; a child might fail a test for any number of uninteresting reasons, such as lack of motivation, attention or task comprehension. To isolate the reason for task failure and to rule out alternative explanations, closely-matched control tasks have been used. So, for example, the autistic failure to understand deception (manipulating beliefs) is interesting only when contrasted with success on control tasks involving sabotage (manipulating behaviour)[2]. This research, showing preserved as well as deficient social skills, has clarified the nature of the social impairment in autism;

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Box 1. Theory of mind

'Theory of mind' refers to the everyday ability to infer what others are thinking (believing, desiring) in order to explain and predict their behaviour. The ability to represent thoughts has been tested, classically, with 'false belief' tests. For example: when Sally leaves her ball in her basket and goes out, Ann moves it to her own box; now Sally returns and wants her ball – where will she look for it? The correct answer – in the basket – is based on our representation of her mistaken belief: that is where she *thinks* it is. Most normally developing four-year-olds pass such tests, but most people with autism, even quite bright adolescents with this diagnosis, answer that Sally will look in the box, where the ball really is. This failure to represent Sally's belief has been taken as evidence of impaired theory of mind in autism (Ref. a).

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autism is not rightly characterized as a lack of sociability, rather it is a disorder of social *ability* of a specific sort – representing thoughts.

The theory of mind account of autism has been of enormous theoretical and practical benefit in understanding, recognizing and addressing the social and communicative difficulties in this disorder[2]. It clearly allows for areas of preserved skill, predicting deficits only on tasks requiring 'mind-reading'. However, the theory of mind account, and indeed all deficit accounts of autism (e.g. executive dysfunction[3]; see Box 2) fail to explain why people with autism show not only preserved but also superior skills in certain areas. Consider, for example, the young man with autism who draws like a master although unable to fasten his coat or add five and five; or the girl with autism who has perfect pitch and can play any tune by ear after a single hearing; or the boy with autism who can tell you, within seconds, what day of the week any past or future date will fall upon[4]. Or, less spectacularly but more commonly, the children who can construct jigsaw puzzles at lightening speed, even picture-side down; the adults who, despite generally low cognitive ability, recall the exact date and time of your last meeting 20 years ago[5]. How can we explain these abilities, some of which are not simply at mental-age level (which in itself would be a strength relative to theory of mind) but exceed expectations based on chronological age?

Beyond preserved skills: superior performance

Savant skills, in recognized areas such as music, art, calculation and memory, are ten times more common in people with autism than in others with mental handicap, occurring in approximately one in ten individuals with autism. If skills outside these areas are included, such as doing jigsaw puzzles remarkably well, then the great majority of people with autism would be classed as showing some specific talent. How can we account for these assets that deficits in theory of mind, executive function, and so forth appear to be unable to explain?

One current account of autism proposes that a different, rather than merely deficient, mind lies at the centre of autism. Frith, prompted by a strong belief that assets and deficits in autism might have one and the same origin, proposed that autism is characterized by weak 'central coherence'[5]. Central coherence (CC) is the term she coined for the everyday tendency to process incoming information in its context – that is, pulling information together for higher-level meaning – often at the expense of memory for detail. For example, as Bartlett's classic work showed, the gist of a story is easily recalled, while the detail is effortful to retain and quickly lost[6]. Similarly, global processing predominates over local processing in at least some aspects of perception[7,8]. This preference for integration and global processing also characterizes young children and individuals with (non-autistic) mental handicap who, unlike those with autism, show an advantage in recalling organized versus jumbled material[9]. Indeed, recent research suggests that global processing might predominate even in infants as young as three months[10,11].

Frith has suggested that this feature of human information-processing is disturbed in autism, and that people with autism show detail-focused processing in which features are perceived and retained at the expense of global configuration and contextualized meaning[5]. Clinically, children and adults with autism often show a preoccupation with details and parts, while failing to extract gist or configuration. Kanner, who named autism, commented on the tendency

Box 2. Executive function

A currently influential deficit account of autism proposes that executive dysfunction underlies many of the social and non-social impairments. 'Executive function' is an umbrella term covering a range of higher-level capacities necessary for the control of action, especially action in novel contexts. Planning and monitoring of behaviour, set-shifting, inhibiting automatic actions, and holding information on-line in working memory, are all included among executive functions. Executive impairment, presumed to reflect frontal-system abnormalities, is proposed to explain the repetitive and restricted behaviour in autism. While executive impairments are widespread in a number of developmental disorders, deficits in set-shifting and in planning appear to be characteristic of autism. There is debate concerning the possible causal relationship between such impairments and social handicaps, and whether problems in executive control or in theory of mind are primary (Ref. a).

Reference

a Russell, J., ed. (1998) *Autism as an Executive Disorder*, Oxford University Press

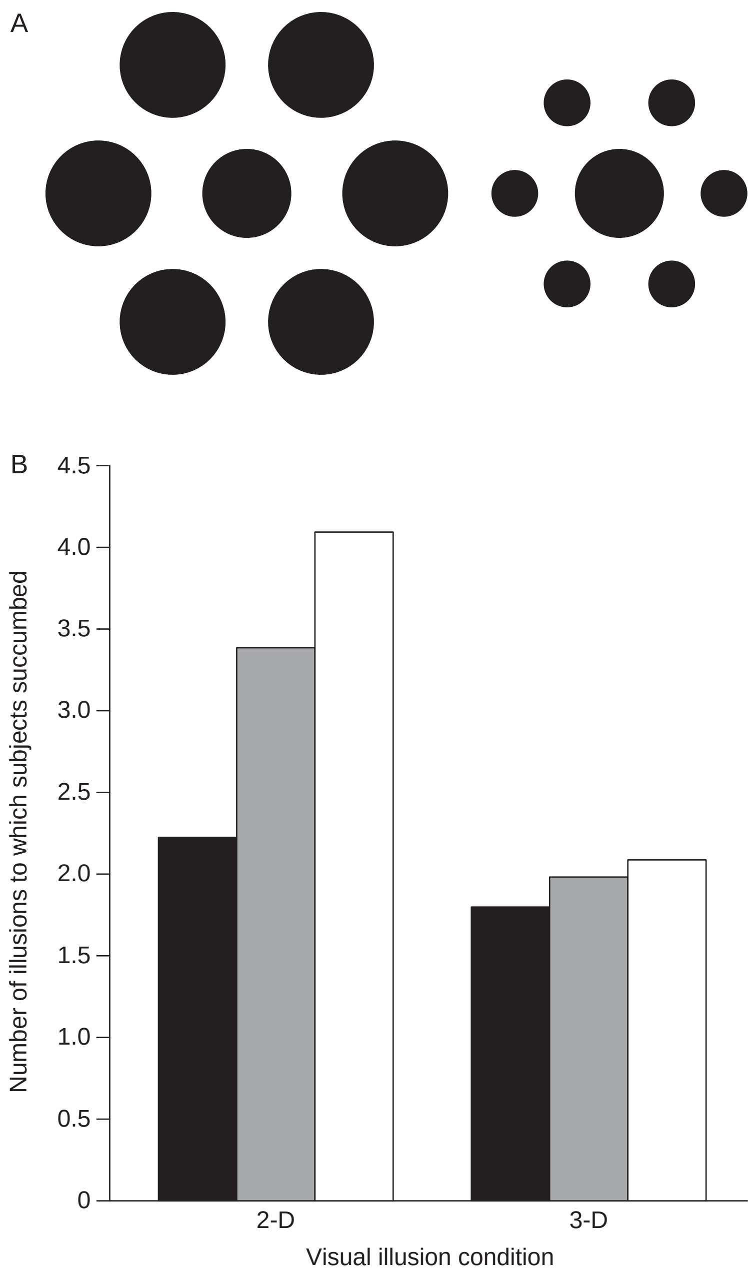

Fig. 1. Individuals with autism are less fooled than others by standard visual illusions. In **(A)**, the Titchener Circles, the presence of the surrounding circles affects our ability to judge whether the two inner circles are really the same size. People with autism, who appear to perceive such figures in a less unified way, are better able to resist this 'inducing context', and so succumb less to such illusions[14] when normally presented (2-D condition) **(B)**. When the figures are artificially disembedded (3-D condition), control groups perform as well as the autism group. Black bars, autism group; grey bars, mild learning difficulties (MLD) group; white bars, normal control group.

for fragmentary processing in relation to the children's characteristic resistance to change; '...a situation, a performance, a sentence is not regarded as complete if it is not made up of exactly the same elements that were present at the time the child was first confronted with it'[12]. Indeed, Kanner saw as a universal feature of autism the 'inability to experience wholes without full attention to the constituent parts', a description akin to Frith's notion of weak CC.

One of the most positive aspects of Frith's notion of CC is the ability to explain patterns of excellent and poor performance with one cognitive postulate. Weak CC predicts relatively good performance where attention to local information (i.e. relatively piecemeal processing) is advantageous, but poor performance on tasks requiring the recognition of global meaning or integration of stimuli in context. The CC account of autism, then, is better characterized in terms of cognitive *style* than cognitive deficit.

Weak central coherence: evidence at three levels of processing

In recent years the notion that children with autism show weak CC has received empirical support from a growing number of studies. Detail-focused processing has been demonstrated at several levels, reviewed below. The division into perceptual, visuospatial–constructional, and verbal–semantic levels is, of course, largely for convenience. An interesting issue for future research concerns possible high-level or top-down effects on processes that are apparently peripheral and perceptual[13].

Perceptual coherence

Taken to its extreme, the notion that people with autism fail to integrate information predicts difficulty in perceiving the physical environment in terms of coherent arrays of objects. This seems implausible: after all, people with autism negotiate their way around the physical world without difficulty, and appear to see whole objects, rather than disjointed surfaces, lines and angles. In order to explore coherence at a perceptual level, individuals with autism (aged 8–16, IQ 40–92) were asked to make simple judgments about standard text-book visual illusions[14]. The logic behind the choice of materials was that some illusions can be analysed into a 'to-be-judged' figure and an inducing context[15] (see Fig. 1). If people with autism have a tendency towards fragmented perception, and focus on the to-be-judged parts without integrating them with the surrounding illusion-inducing context, they should succumb to the typical misperceptions to a lesser degree. This proved to be the case – people with autism were better able to make accurate judgments of the illusions than were normal or developmentally delayed controls. This superior ability seemed to be related to a disembedding skill, because when the figures were artificially disembedded (by highlighting the to-be-judged parts with raised coloured lines; 3-D condition, Fig. 1B) control groups performed as accurately as the autism group. The autism group, however, were little helped by this artificial disembedding. Other evidence of a local perceptual bias in people with autism includes reduced benefit from canonical pattern in dot counting[16], unusually high occurrence of absolute pitch[17], reduced susceptibility to visually induced motion[18], and a reduced McGurk effect (i.e. less influence of visual over auditory speech perception)[19]. Moreover, autobiographical accounts of autism often describe fragmented perception[20].

Visuospatial–constructional coherence

An elegant demonstration of weak coherence was given by Shah and Frith, who showed that the well-documented facility of people with autism on the standard Wechsler Block Design task (see Fig. 2) is due specifically to segmentation abilities[21]. A sizable advantage was gained from pre-segmentation of designs over no segmentation for normally

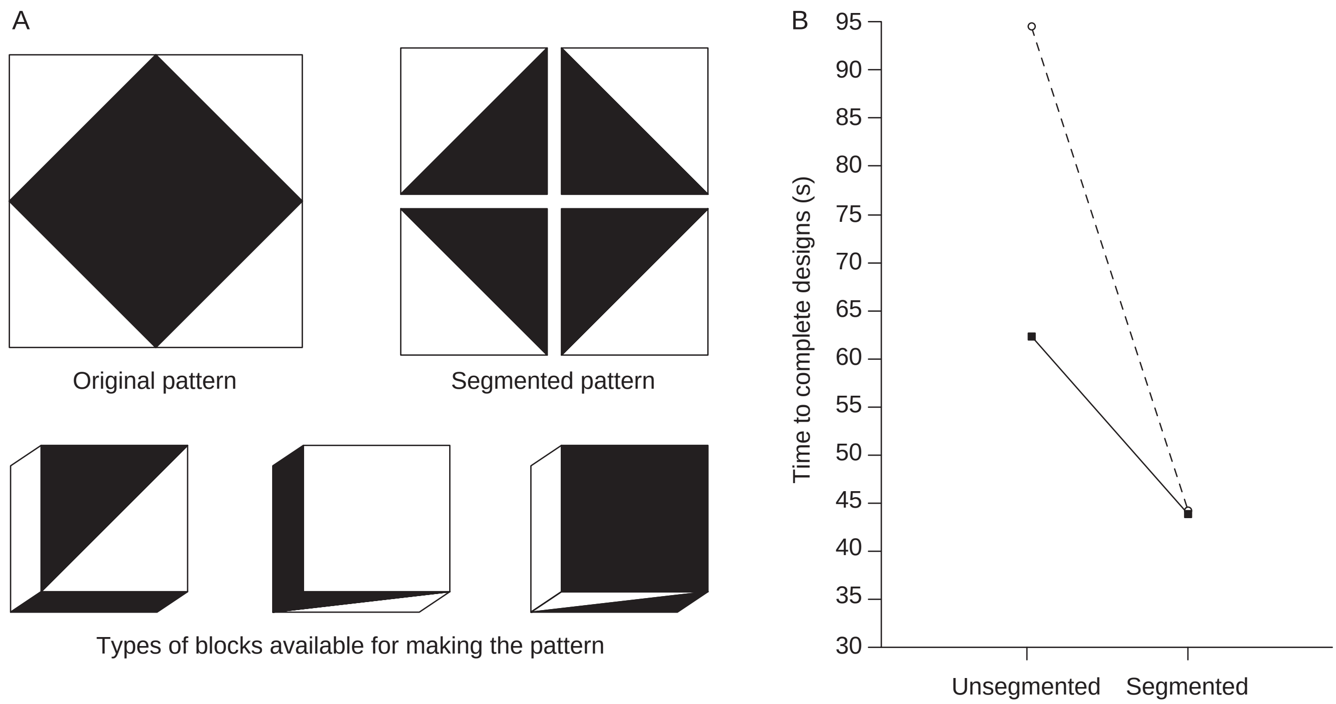

Fig. 2. The Wechsler Block Design task. The subject must copy the design using cubes with differently patterned faces **(A)**. One source of difficulty is our tendency to see the design as a whole, or gestalt – a black diamond rather than the four black triangles of which it must be composed. Pre-segmenting the design therefore aids performance, by breaking the gestalt. People with autism do not succumb to the gestalt, and easily see the design in terms of its constituent blocks. This makes them very good at the standard Block Design test, and little aided by the pre-segmented design condition[21], compared with individuals with general learning difficulties **(B)**. Solid line, autism group; broken line, learning difficulties group.

developing and intellectually impaired subject groups, but was not observed in individuals with autism – suggesting that the latter processed the designs in terms of their constituent blocks. Individuals with both low- and high-functioning autism also excelled at the Embedded Figures Test (EFT), in which a small shape must be found within a larger design[22,23] (see Fig. 3). Weak CC in autism has also been demonstrated in studies that showed good recognition of objects from detail despite poor integration of object parts (modified Hooper test; T. Jolliffe, PhD thesis, University of Cambridge, 1998), detail-by-detail drawing style[24] and facility for copying even globally incoherent ('impossible') figures[25].

Verbal–semantic coherence

In one of several ground-breaking studies of cognition in autism, Hermelin and O'Connor showed that people with autism do not derive the usual benefit from meaning in memory tests[9]. Thus, while control subjects recalled sentences far better than unconnected word strings, this advantage was greatly diminished in the autism group. This work, and subsequent replications[26], suggests that people with autism do not make use of either semantic relations (same category versus assorted words) or grammatical relations (sentences versus word lists) in memory. Preliminary evidence for weak coherence has also been demonstrated by good verbatim but poor gist memory for story material (K. Scheuffgen, PhD thesis, University of London, 1998), and poor inference, disambiguation and construction of narrative (T. Jolliffe, PhD thesis, University of Cambridge, 1998).

Frith and Snowling used homographs (words with one spelling, two meanings and two pronunciations) to examine the use of preceding-sentence context to derive meaning and determine pronunciation[27] (e.g. 'In her eye there was a big tear'; 'In her dress there was a big tear'). If people with autism have weak CC at this level, then reading a sentence might, for them, be akin to reading a list of unconnected words, and sentence context will not be built up to allow meaning-driven disambiguation. In the original studies[27,28], and in a subsequent replication with high-functioning children and adults[29], individuals with autism failed to use preceding-sentence context to determine the pronunciation of homographs. These findings bring to mind Kanner's description of his original cases: '...the children read monotonously, and a story...is experienced in unrelated portions rather than in its coherent totality'[12]. This finding is particularly interesting, in that people with autism (at these levels of intelligence) clearly are able to read for meaning when explicitly required to do so. Indeed, when instructed to read for meaning, group differences on the homograph task disappeared[28]. It seems, then, that weak CC characterizes the spontaneous approach or automatic processing preference of people with autism, and is thus a cognitive 'style' best captured in open-ended tasks.

Negative findings

In general, then, people with autism are distinguished from age- and ability-matched comparison groups in showing relative attention to parts and relative inattention to wholes. It is worth noting that people with autism do appear to integrate the properties of a single object (e.g. colour and form in a visual search task)[30], and to process the meaning of individual words (in Stroop tasks)[27,31] and objects (in memory tasks)[32,33]. It seems to be in connecting words or objects that

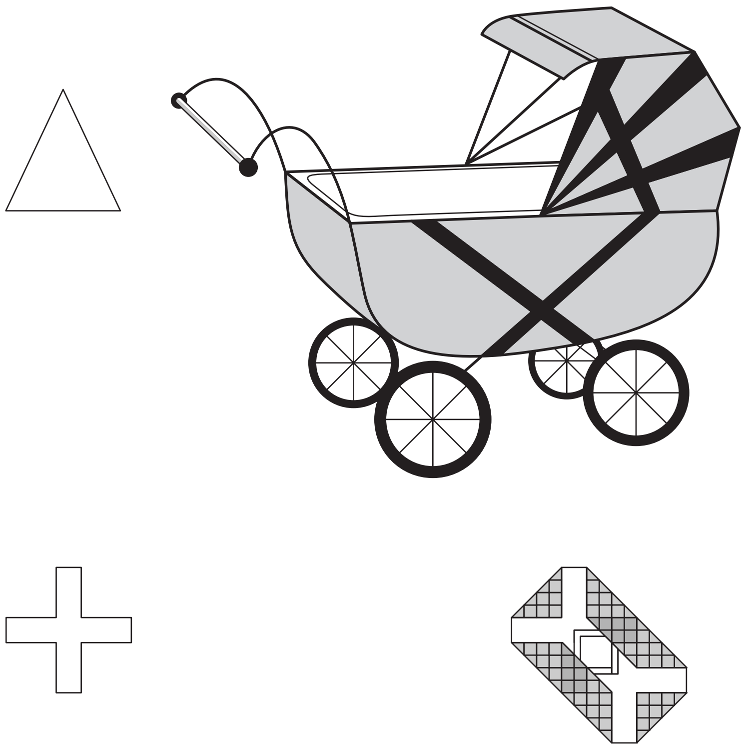

Fig. 3. The Embedded Figures Test (EFT). In this test the subject must find a small part (shown at left) within the whole figure (right). This is made difficult by the salience of the global shape. People with autism excel at both the Children's and Adults' EFT[51] (upper and lower figures, respectively), perhaps because they are not seduced by the gestalt and find the parts as salient as the whole[22].

coherence is weak. In addition, two paradigms have shown results counter to those predicted by the weak-coherence hypothesis. Ozonoff *et al.*[34] failed to find the predicted local advantage using the well-known Navon hierarchical figures; asked to report about large letters composed of smaller letters, people with autism showed the usual tendency to process the global form first and with little interference from the local letters[7]. However, this paradigm is known to be sensitive to small changes of methodology[8] and more recently Plaisted, Swettenham and Rees have found evidence of local advantage and interference from local to global stimuli in a condition where participants were required to divide attention between local and global levels, but not in a selective-attention task[35]. The other counter finding was reported by Brian and Bryson[36], who found normal effects of meaning in a modified Embedded Figures Test (EFT), although they failed to find the well-replicated superiority on the standard EFT, and it is unclear whether different results would have been obtained with groups matched on IQ. It is clear, however, that the CC account requires further research and refinement[25,30].

Coherence and theory of mind

To date, the experimental findings suggest that weak coherence and theory of mind are somewhat independent: the minority of people with autism who do pass theory-of-mind tests (typically the brighter and older individuals) still show detail-focused processing on the homograph task, and excel at the Block Design test[29,37]. However, it is likely that these two aspects of autism interact, and failure to integrate information in context might contribute to everyday social difficulties. Featural processing might play a part in certain social impairments. Piecemeal processing of faces, for example (as reflected in reduced performance decrement with inverted faces in recognition tests[38]) could hamper emotion recognition[39].

Coherence and savant skills

Weak CC, as a cognitive style, might therefore be capable of explaining autistic assets, as well as deficits, in experimental tasks. But can it explain other perplexing clinical features of the disorder, such as the high rate of savant skills? Perhaps it can – as may be illustrated from suggestive results in two domains. In the area of musical talent, Heaton, Hermelin and Pring have shown that musically naive children with autism are significantly better than matched controls at learning labels (note names) for individual pitches – the ability underlying absolute pitch[17]. Takeuchi and Hulse concluded from a review of research to date that absolute pitch could be learnt by most normally developing children before about age six, after which 'a general developmental shift from perceiving individual features to perceiving relations among features makes [absolute pitch] difficult or impossible to acquire' (Ref. 40, p. 345). If people with autism show a pervasive and persistent local-processing bias, this would explain the high frequency of absolute pitch and the superior ability to learn note-name mappings at later ages.

In the domain of graphic talent, it also appears that the extraordinary ability of some individuals with autism reflects a detail-focused processing style. Mottron and Belleville presented a case study of an artist with autism whose method of production is characterized by proceeding from one contiguous detail to the next, rather than the more usual sketching of outline followed by details[24]. On a number of tasks (e.g. copying of impossible figures), this man showed fragmented perception and a bias towards local processing. Pring, Hermelin and Heavey, who tested part–whole processing (using modified Block Design tasks) in children with autism and normally developing children with and without artistic talent, concluded that there is 'a facility in autism for seeing wholes in terms of their parts, rather than as unified gestalts' (Ref. 41, p. 1073) – and that this ability might be a general characteristic of individuals with an aptitude for drawing, with or without autism.

Central coherence: a normal variation in cognitive style?

Because weak CC provides both advantages and disadvantages, it is possible to think of this balance (between preference for parts versus wholes) as akin to a cognitive style – a style that might vary in the normal population. There might perhaps be a normal distribution of cognitive style from 'weak' CC (preferential processing of parts – for example, good proof reading), to 'strong' (preferential processing of wholes – for example, good gist memory). There is existing but disparate evidence of normal individual differences in local versus global processing, from infancy[42], through childhood[43], and in adulthood[44]. Sex differences have been reported on tasks thought to tap local versus global processing[45], although studies have typically confounded type of processing (local versus global) and domain (visuospatial versus verbal). The possibility of sex differences in coherence is intriguing in relation to autism, which

Box 3. Integrating information in the brain

The right hemisphere has long been implicated in global, integrative and context-sensitive processing. Individuals with acquired right-hemisphere damage show deficits on visuospatial–constructional tasks, maintaining details but missing global configuration (Ref. a). Discourse also becomes piecemeal in such patients, with difficulties in integrating verbal information and extracting gist (Ref. b). Functional imaging work, too, suggests a role for right-hemisphere regions in configural processing. Fink *et al.*, using fMRI, found right lingual gyrus activation during attention to global aspects of a hierarchical figure (e.g. an H made up of Ss), and left inferior occipital activation during local focus (Ref. c). Electrophysiological (ERP) studies, too, suggest increased right-hemisphere activity during global (versus local) tasks (Ref. d).

Because people with autism show piecemeal processing, as well as repetitive stereotyped behaviour (normally suppressed by activity in regions in the right hemisphere; Ref. e), it is tempting to look for the origins of autism in right-hemisphere anomalies. To date, however, there is relatively little conclusive evidence of localized and specific structural damage. At least one brain imaging study to date has found right-hemisphere abnormalities in (three) individuals with a high-functioning form of autism, Asperger syndrome (Ref. f). However, evidence of damage in limbic, frontal and cerebellar regions has also been reported – and it is by no means clear which anomalies are specific and universal to autism (Ref. g).

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shows a very high male to female ratio, especially at the high-ability end of the autism spectrum. Might the normal distribution of coherence in males be shifted towards weak coherence and local or featural processing? Perhaps there is an area of increased risk for autism at the extreme weak-coherence end of the continuum of cognitive style – individuals who fall at this extreme end might be predisposed to develop autism if unlucky enough to suffer the additional social deficits (impaired theory of mind) apparent in this disorder.

Central coherence and the extended phenotype of autism

As a cognitive style, rather than deficit, weak CC is an interesting contender for the aspect of autism that is transmitted genetically and characterizes the relatives of individuals with autism. We are currently comparing cognitive style in parents of children with autism, with dyslexia, and without developmental disorder (F. Happé, J. Briskman and U. Frith, unpublished data). Preliminary results suggest that parents, and especially fathers, of children with autism show significantly superior performance on tasks favouring local processing: they excel at the EFT, at (unsegmented) block design, and at accurately judging visual illusions. They are also more likely than fathers in the other groups to give local completions to sentence stems such as, 'The sea tastes of salt and..?' ('…pepper'). In all these respects they resemble individuals with autism, but for these fathers their detail-focused cognitive style is usually an asset, not a deficit. These results fit well with work by Baron-Cohen and colleagues, which showed that fathers of children with autism are fast at the EFT[46], and over-represented in professions such as engineering[47] (but see counter-argument by Jarrold and Routh[48]). However, while Baron-Cohen *et al.* explain their results in terms of superior 'folk physics' (intuitive understanding of physical systems), the hypothesis of weak CC predicts that people with autism and their relatives will be characterized by expertise only with those mechanical systems where focus on detail is an advantage. Weak CC also stretches beyond the visuospatial domain, and predicts piecemeal processing in verbal tasks (see above), not easily accounted for by superior 'folk physics'.

Future directions

Many challenges remain to the CC account, not least of which is to specify the cognitive and neural mechanisms for coherence. Should we think of a single, central mechanism integrating information from diverse modules or systems, for higher-level meaning? Or should coherence be thought of as a property of each subsystem, a setting for the relative precedence of global versus local processing, repeated throughout the brain? This question might be resolved through explorations of individuals' coherence across and within a number of domains – does degree of coherence in a verbal task, for example, predict degree of coherence in a visuospatial task? Neuropsychological lesion and brain imaging studies might also give clues as to the unitary or distributed brain basis of CC (see Box 3).

Outstanding questions

- Is weak or strong coherence a pervasive cognitive style across levels and domains of processing? What is its developmental trajectory?
- What is the neural basis of individual differences in local versus global processing?
- Are there sex differences in coherence that are independent of domain (verbal/visual)?
- Do people with autism lie on the normal continuum of coherence, or are there qualitative differences in their global versus local processing?
- What is the relationship between central coherence and executive function?
- Is extreme weak central coherence specific to individuals with autism, or does it characterize other clinical groups (e.g. Williams syndrome)?

It is unlikely, however, that autism will show itself to be the result of damage confined to one brain region – and the very notion of CC suggests diffuse differences in brain organization. One intriguing finding, in this respect, is that some people with autism have larger or heavier brains than do comparison groups, with increased cell packing in several areas[49]. It is possible that this reflects an abnormal number of neurons, perhaps because of failure of pruning in brain development. In turn, processing with excess neurons could result in a failure to process information for gist – in other words, a lack of drive for cognitive economy, as a result of increased capacity for exemplar-based processing. Cohen has presented a computational model of autism, in which lack of generalization results from an increase in the number of units[50] – an intriguing example of how computational analyses can interact with neuroanatomical data and psychological theory to help solve the puzzle of autism. It is intriguing to think that the cognitive style of weak coherence in autism, with its attendant assets and deficits, might result from an 'embarrassment of riches' at the neural level.

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