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The Weak Coherence Account: Detail-focused Cognitive Style in Autism Spectrum Disorders

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"Weak central coherence" refers to the detail-focused processing style proposed to characterise autism spectrum disorders (ASD). The original suggestion of a core deficit in central processing resulting in failure to extract global form/meaning, has been challenged in three ways. First, it may represent an outcome of superiority in local processing. Second, it may be a processing *bias*, rather than deficit. Third, weak coherence may occur alongside, rather than explain, deficits in social cognition. A review of over 50 empirical studies of coherence suggests robust findings of local bias in ASD, with mixed findings regarding weak global processing. Local bias appears not to be a mere side-effect of executive dysfunction, and may be independent of theory of mind deficits. Possible computational and neural models are discussed.

KEY WORDS: Autism spectrum disorders; central coherence; cognitive style; individual differences; local–global processing.

Some individuals with autism spectrum disorders (ASD) can name the pitch of the "pop" as a cork comes out of a bottle, or identify dozens of brands of vacuum cleaner from their sound alone. Others can spot a misaligned book in a bookcase in seconds, or mimic foreign speech distinctions not usually noticeable to non-native speakers. These exceptional perceptual abilities may be maladaptive in so far as they may lead to distress at small changes in the environment. Kanner's original description of autism highlighted this attention to detail and 'inability to experience wholes without full attention to the constituent parts' as one factor in the characteristic insistence on sameness: '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. If the slightest ingredient is altered or removed, the total situation is no longer the same and therefore is not accepted as such...' (Kanner, 1943, p. 246). Indeed, a 'persistent preoccupation with parts of objects' is one of the diagnostic criteria for autistic disorder in current practice (DSM-IV, APA, 1994).

Understanding perceptual processes in ASD may involve explaining both disordered and superior processing. One cognitive theory that has specifically sought to address both deficits and assets in ASD is the "weak coherence" account. Frith (1989) drew attention to the tendency for typically developing children and adults to process incoming information for meaning and gestalt (global) form, often at the expense of attention to or memory for details and surface structure. This tendency, referred to by Bartlett (1932) as "drive for meaning", was termed

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"central coherence" by Frith. Individuals with ASD were hypothesised to show "weak central coherence"; a processing bias for featural and local information, and relative failure to extract gist or "see the big picture" in everyday life. This processing bias was evident in early work on verbal memory, showing relatively little benefit from meaning (Hermelin & O'Connor, 1967), and exact rather than corrected repetition (Aurnhammer-Frith, 1969). In early work using visuo-spatial tasks, ASD groups showed superiority at disembedding (Shah & Frith, 1983), greater reliance on adjacent elements in pattern extraction (Frith, 1970), and a reduced inversion effect in face processing (Langdell, 1978).

Interest in the coherence account of ASD has grown rapidly since the early work by Frith (1989) and Happé (1999; Frith & Happé, 1994), with more than 60 publications relating to this topic published since 1999, a fourfold increase on the previous 10-year period. In that time, and in response to empirical findings, the coherence account has been modified from Frith's original conception in three important ways. First, the original suggestion of a core deficit in central processing, manifest in failure to extract global form and meaning, has changed from a primary problem to a more secondary outcome—with greater emphasis on possible superiority in local or detail-focused processing. Second, the idea of a core deficit has given way to the suggestion of a processing bias or cognitive style, which can be overcome in tasks with explicit demands for global processing. Last, the explanatory remit of the account has changed, with a recognition that weak coherence may be one aspect of cognition in ASD alongside, rather than causing/explaining, deficits in social cognition (e.g. "theory of mind"; Frith, 1989, revised 2003).

Along with increased research interest, the notion of weak coherence or detail-focused processing style, has been received with enthusiasm and immediate recognition by the ASD community (affected individuals and their families). Autobiographical accounts of autism often describe fragmented perception (Gerland, 1997). Weak coherence is seen as addressing aspects of ASD that some other accounts have neglected, such as areas of talent, super-acute perception, and lack of generalisation. For example, perceptual abnormalities such as hypersensitivity, clinically/anecdotally reported but little studied in research to date, may relate to context-free processing as expectations and context-based interpretation are known to modulate experience of sensory stimuli in "neurotypicals" (people without ASD). Just as there is a higher than usual occurrence of perfect pitch in ASD (Miller, 1999), so absolute, rather than relative, coding of other sensory stimuli may underlie some aspects of perceptual discomfort or fascination. Problems with generalisation of skills would follow from weak coherence, if experiences are coded in terms of details. If people with ASD remember each exemplar rather than extracting prototypes (Klinger & Dawson, 2001), this would render recognition of situations that are "alike" problematic: only if a situation shares the key detail(s) with a previous experience, will generalisation of skills occur (Plaisted, 2001; Rincover & Koegel, 1975).

OVERVIEW OF RESEARCH

Table I summarises published experimental group studies in which weak coherence in ASD is addressed, and those directly relevant studies described below. A number of studies, both within and beyond those explicitly addressing coherence, are directly relevant to perceptual processing in ASD. Relevant to perception in the auditory modality, are demonstrations of stable memory for exact pitches (Bonnel *et al.*, 2003; Heaton, Hermelin, & Pring, 1998), enhanced local processing (with intact global processing) of musical stimuli (Heaton, 2003; Mottron, Peretz, & Menard, 2000), reduced interference from melodic structure (combining pitch and timing effects) in music processing (Foxton *et al.*, 2003), and a reduced McGurk effect (i.e. less influence from visual to auditory speech perception; DeGelder, Vroomen, & Van der Heide, 1991).

Relevant to perception in the visual modality, individuals with ASD show raised thresholds for perceiving coherent motion (Bertone, Mottron, Jelenic, & Faubert, 2003; Milne *et al.*, 2002; Spencer *et al.*, 2000), and reduced susceptibility to visually induced motion (Gepner, Mestre, Masson, & Schonen, 1995; Gepner & Mestre, 2002). Superior visual search (Plaisted, O'Riordan, & Baron-Cohen, 1998a; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001), and superior discrimination learning of highly confusable patterns (Plaisted, O'Riordan, & Baron-Cohen, 1998b), have also been reported. Active processes of visual grouping may be affected, shown in reduced gestalt grouping (Brosnan, Scott, Fox, & Pye, 2004), reduced susceptibility to visual illusions (Happé, 1996; but see, Ropar & Mitchell, 1999,

Table I. Published Group Studies Assessing Central Coherence in Autism Spectrum Disorders

Reference	Participants (group means)	Tasks	Main findings
Visuo-spatial		*EFT*	
Shah and Frith (1983)	20 ASD CA 13, MA NV 9.6 20 TD MA-matched 20 MH CA and MA match	CEFT	ASD group accuracy > MH, TD Qualitative evidence of more immediate success
Brian and Bryson (1996)	16 ASD CA 20, Ravens raw 39, 34%ile, PPVT st score 77, raw 120 15 TD CA 12, Ravens score 39, 55%ile 16 TD CA 12, PPVT st score 103, raw score 119	Disembedding: adapted (meaningful) CEFT items plus abstract and fragmented items Recognition: as above plus distractor items	No group differences of group × condition interactions RT to disembedded Meaningful > Abstract > Fragmented in all groups Recognition accuracy Meaningful > Abstract = Fragmented (at chance) in all groups
Jolliffe and Baron-Cohen (1997)	17 HFA CA 31, FIQ 105 17 AS CA 28, FIQ 107 17 TD CA and FIQ matched	EFT Modified Rey drawing task	HFA and Asperger groups faster than TD on EFT. No group differences on drawing task
Ropar and Mitchell (2001)	19 autism CA 14, VMA 7 11 AS CA 12, VMA 10 20 MH CA 13, VMA 7 37 TD CA 8 & 11	EFT, Block design	Autism > MH, TD on EFT and Block Design (AS = TD 11-year-old group)
Jarrold *et al.* (2000)	17 ASD CA 10, VMA 8 24 TD CA 5 60 T Adults CA 18–25	CEFT, DAS BD (+ Belief tasks) Preschool EFT, DAS BD (+ Belief tasks) EFT and Eyes Task	In ASD and TD children, EFT and BD negatively correlated with ToM scores once VMA and CA partialled out EFT negatively correlated with Eyes Test score
Morgan *et al.* (2003)	21 ASD CA 4, VMA 33 months, Leiter (NVIQ) 95 21 TD/MH CA and nVIQ matched	Preschool EFT Pattern Construction (DAS) (+ joint attention, pretend play ratings)	ASD faster than controls on EFT (accuracy ns) ASD > Controls on Pattern Construction Correlations coherence × joint attention, pretend play ns
		Block Design	
Shah and Frith (1993)	10 High IQ ASD PIQ 97 10 Low IQ (< 85) PIQ 71 17 older TD CA 16, PIQ 100 16 younger TD CA 11 matched low IQ ASD WISC nV raw score, PIQ 105 12 MH CA 17, PIQ m76	Wechsler Block Design Experimental Un/Segmented Block Design task	7/10 Hi IQ (scaled scores 13–19) and 6/10 lo IQ ASD (ss 9–15) BD personal peak subtest ASD groups derive less benefit (time taken) from presegmentation of design to be copied: HiIQ ASD faster than older TD on whole designs only LoIQ ASD faster than younger TD& MH on whole designs only
Happé (1994)	51 ASD CA 15, FIQ 64 (split by ToM)	Wechsler Block Design in full WISC or WAIS	Block Design > mean Performance subtest score for 85%, regardless of ToM performance

Table I. Continued

Reference	Participants (group means)	Tasks	Main findings
Pring, Hermelin, & Heavey (1995)	18 ASD CA 26, Ravens MA 12 18 TD MA matched Both grouped by artistic ability	Block design task; meaningful scenes, and Wechsler-like designs	Artistically talented TD faster than ASD on meaningful scenes. Artistically talented TD and all ASD (regardless of artistic talent) faster than nonartistic TD
		Hierarchical figures	
Ozonoff, Strayer, McMahon, & Filloux (1994)	14 ASD, CA 12, FIQ 100 14 TD CA and IQ matched 14 Tourette syndrome CA and IQ matched	Navon Hierarchical Figures task; large letter composed of smaller same or different letter (selective attention)	No group differences; all groups showed global advantage and interference
Mottron *et al.* (1999)	11 HFA CA 15, Ravens IQ 110	Navon Hierarchical Figures (divided attention)	HFA, but not TD, group show a global advantage
	11 TD CA and IQ matched	Palmer mental synthesis task	No group differences in effect of goodness of Palmer figures
Plaisted *et al.* (1999)	17 ASD CA 10, raven's score 33 17TD CA and Raven's raw score matched	Navon Hierarchical Figures in Divided and Selective attention conditions	No group differences in selective attention condition ASD show no global advantage in divided attention condition (TD do make fewer errors for targets at global than local level)
Rinehart *et al.* (2000)	12 HFA CA 10, FIQ 94 12 AS CA 12, FIQ 104 12 + 12 TD CA and IQ matched	Navon Hierarchical (numbers) Figures (selective attention)	All groups showed expected global advantage and interference HFA, but not AS group, showed more local interference than TD
Rinehart *et al.* (2001)	12 HFA CA 10, FIQ 94 12 AS CA 12, FIQ 104 12 + 12 TD CA and IQ matched	Navon Hierarchical (numbers) Figures (divided attention)	HFA RT to global level targets slowed when previous target at local level, compared with TD group (deficit moving from local to global processing) No such group difference for AS group
Mottron *et al.* (2003)	12 HFA CA 16, IQ 105–110 10–12 TD matched on CA & IQ	Hierarchical figures Fragmented letter recognition Silhouette identification Long- short-range grouping Disembedding	No gp difference (but also no global advantage in TD group) No gp difference (but also no main effect of condition) No gp difference (but also no main effect of condition) No gp difference ASD > TD, embedding effects TD group only
		Visual Illusion	
Happé (1996)	25 ASD CA 13, VMA 7 21 TD CA 7 26 MH CA and VMA matched	Judge illusions in 2D and 3D forms (verbal response to illusions on cards)	ASD succumb to fewer illusions than MH and TD ASD show less benefit from 3D disembedding than do MH and TD ASD = MH, TD number correct for 3D illusions

Ropar and Mitchell (1999)	23 autism CA 13, VMA 7 13 AS CA 14, VMA 14 17 MH CA 10, VMA 6 41 TD CA 8 & 11, 15 adults	Adjust parts of computerised illusions Verbal response to illusions on cards	Participants in all groups strongly susceptible to illusions in both formats, no significant group differences
Ropar and Mitchell (2001)	19 autism CA 14, VMA 7 11 AS CA 12, VMA 10 20 MH CA 13, VMA 7 37 TD CA 8 & 11	Adjust parts of computerised illusions Rey Figure drawing, BD, EFT, EFT	No group differences in susceptibility to illusions Rey figure gave no evidence of group differences in global approach. Performance on illusions not related to performance on visuo-spatial tasks
		Drawing	
Mottron *et al.* (1999)	10 HFA CA 19, PIQ 112 11 TD CA and PIQ matched	Copying drawings (real objects, non-objects, possible and impossible figures)	HFA group draw more local features at start of copy and are less slowed by impossibility of figure, compared with controls
Booth *et al.* (2003)	30 ASD CA 11, FIQ 100 31 TD CA and FIQ matched 30 ADHD CA and FIQ matched	Drawing from an example	ASD group showed more detail-focused drawing style (25% start with detail, draw fragments, 33% violate configuration) vs. TD and ADHD
		Motion coherence	
Spencer *et al.* (2000)	23 ASD (no CA or IQ details) 50 VMA matched (7–11) 19 T adults	Motion coherence threshold task Form coherence threshold task	ASD raised motion, but not form, coherence thresholds relatives to TD
Milne *et al.* (2002)	25 ASD CA 12, Ravens raw score 41 22 TD CA and Ravens matched	Motion coherence threshold task	ASD raised motion coherence threshold vs. TD
Bertone *et al.* (2003)	12 HFA CA 12, IQ 101 12 TD CA 13	Sensitivity for first- and second-order motion	HFA = TD on first-order (luminance-defined) motion HFA worse than TD at detecting second-order (texture-defined) motion
Pellicano *et al.* (2005)	20 ASD CA 10, Ravens raw score 40 20 TD CA and Ravens matched	Flicker contrast sensitivity Global dot motion (GDM) task CEFT	No group difference ASD higher thresholds than TD ASD faster than TD. Inverse relation CEFT RT x GDM thresholds in ASD only
		Faces (selected studies)	
Hobson, Ouston, and Lee (1988)	17 ASD CA 19, BPVS raw score 65, Ravens raw score 36 17 MH CA 19, BPVS 66, Raven's 22	Upright face identity/emotion matching, blank-mouth/forehead Inverted face identity/emotion matching	ASD emotion matching declined with fewer cues, MH less so ASD > MH matching inverted faces
Teunisse and de Gelder (2003)	17 HFA CA 19, VIQ 90 24 TD CA 9–10 16/24 T adults CA 23	Inversion effect task Composite effect task	All groups worse at recognising inverted than upright faces Non-aligned composites recognised faster than wholes (composite effect) in T adults, TD ($p < .06$), not in HFA (suggesting reduced wholistic processing)

Table I. Continued

Reference	Participants (group means)	Tasks	Main findings
Deruelle *et al*. (2004)	11 ASD CA 9, VMA 7 11 TD CA 6 11 TD CA 9	Face recognition (matching tasks) Matching high-pass filter (local) or low-pass filter (global) faces	ASD < TD on emotion, gener, gaze direction. lipreading ASD = TD on identity recognition ASD better performance with high (local) vs. low (global) spatial frequency stimuli. TD show opposite pattern
Lopez *et al*. (2004)	17 HFA CA 13, FIQ 87 17 TD CA 13, FIQ 97	Face matching, whole vs. part with/out cueing	HFA show 'whole face advantage' only when cued, TD show whole face advantage cued and uncued
Rouse *et al*. (2004)	11 ASD CA 10, VMA 6, Ravens MA 9 15 MH CA & VMA match 15 TD CA match	Thatcher illusion (to test perception of second-order relations) using face photos, house photos, Mooney faces	ASD = MH in showing Thatcher illusion (notice inverted eyes and mouth within upright face > inverted face). TD ceiling effects. Trend for stronger inversion effect in TD vs. ASD, ASD = MH
		Various	
Burack (1994)	12 ASD CA 20, FIQ 50, MA 8 62 MH CA 13, FIQ 60, MA 8 34 TD CA 8, FIQ 104, MA 8	Forced-choice RT task, with/out window around target, with/out distractor stimuli	Without distractors, ASD benefit more than other groups from window ASD more adversely affected than other groups by distractors (near or far from target) when window present
Gepner *et al*. (1995)	5 ASD CA 6 (no IQ information) 12 TD CA 6	Postural reactivity to visually perceived motion	ASD more unstable posturally, but less affected by visually perceived environmental motion
Jarrold and Russell (1997)	22 ASD CA 12,VMA 7 22 TD VMA match 22 MH CA and VMA match	Dot counting in canonical vs. distributed arrays	ASD < TD benefit from canonical arrangement (MH not different from either group) 45% of ASD Ss 'global counters', vs. 68% MH (sig), MH < TD
Plaisted *et al*. (1998a)	8 ASD CA 9, VMA 7, Block Design MA 11 8 TD CA 8, VMA 7, Block Design MA 7	Visual search task (feature vs. conjunctive conditions; 5, 15 or 25 item displays)	ASD = TD on feature search ASD faster than TD on conjunctive search condition, and less slowed by increasing display size
Plaisted *et al*. (1998b)	8 ASD CA 29, BD scale score 13 10 TD CA and BD matched	Perceptual learning task	No perceptual learning effect in ASD ASD > TD discrimination of novel stimuli
Jolliffe and Baron-Cohen (2001)	17 HFA CA 31, FIQ 105 17 Asperger CA 28, FIQ 107 17 TD CA and FIQ matched	Object Integration test Scenic test	ASD < TD integrating objects to make coherent scene ASD < TD spotting incongruent objects and identifying scene
Jolliffe and Baron-Cohen (2001)	17 HFA CA 31, FIQ 105 17 AS CA 28, FIQ 107 17 TD CA and FIQ matched	Modified Hooper Visual Organisation test	HFA < Asperger < TD integrating fragments to identify whole object (ns at identifying object from single part)

Klinger and Dawson (2001)	12 ASD CA 14, VIQ 57, VMA 7 12 DS CA 14, VIQ/MA matched 12 TD CA 7, VMA matched	Rule-based category learning Prototype task	All groups extract rules to learn new category (no group effect) Only TD group develop a prototype (TD > ASD = DS)
O'Riordan *et al.* (2001)	12 ASD CA 8, Ravens score 26 12 TD CA 8, Ravens score 26	Visual search task (feature vs. conjunctive conditions; 5, 15, 25 item)	ASD = TD on feature search ASD faster than TD on conjunctive search condition, and less slowed by increasing display size
Gepner and Mestre (2002)	3 autism CA 9, PEP MA 2–4 3 AS CA 7, FIQ 85–115 9 TD CA 8	Postural reactivity to fast visual motion	Autism group more posturally stable than TD, AS children Autism group hyporeactive to visual motion vs. TD group AS children less posturally stable, at least as reactive to visual motion as TD
Lopez and Leekam (2003)	15 HFA CA 14, FIQ 87 16 TD CA 14, FIQ 99	Visual priming (scene – object) Memory for un/related pictures	No group difference, both groups primed by context No significant group difference in benefit from related pictures
Mann and Walker (2003)	13 ASD CA 10, Ravens score 26, BPVS score 59 15 MH CA, Ravens & BPVS score matched 15 TD CA 5, Ravens & BPVS score matched	RT to judge which line of a crosshair longest, presenting long and small crosshairs	No group difference by crosshair size for first stimulus ASD less accurate and slower judging large crosshair after a small crosshair (vs. large after large) No group differences judging small crosshair after large (vs. small after small)
Plaisted *et al.* (2003)[a]	9 HFA CA 10, Ravens score 30 9 TD CA and Ravens matched 12 HFA CA 9, Ravens score 30 12 TD CA and Ravens matched	Biconditional configuration discrimination Feature vs. configuration patterning	HFA > TD on feature task (% correct) HFA = TD on biconditional task Feature > biconditional for HFA only HFA feature > configuration trials (% correct) TD configuration > feature trials
Brosnan *et al.* (2004)	25 ASD CA 11, VMA 5 25 MH CA 10, VMA 5	Grouping, odd one out and impossibility judgement tasks testing similarity, proximity, closure	ASD < MH in use of gestalt principles for the perceptual judgment tasks (not in a drawing task)
Auditory		*Pitch and music*	
Heaton *et al.* (1998)	10 ASD CA 9, MA 8 10 TD CA 8 (MA matched)	Memory for exact pitches	ASD > TD number pitches correctly recalled
Mottron *et al.* (2000)	13 ASD CA 17, PIQ 107 13 TD CA and PIQ matched	Same-different judgement of melodies (local or globally altered)	ASD > TD at detection of change in non-transposed, contour-preserved melodies, reflecting local bias but not global deficit
Bonnel *et al.* (2003)	12 HFA CA 18, FIQ 108 12 TD CA and IQ matched	Discrimination and categorisation of pure tones	ASD > TD at both tasks
Foxton *et al.* (2003)	13 ASD CA 18, FIQ 88 15 TD CA and IQ matched	Match pitch direction changes between 2 and 5-note auditory sequences, local or globally altered (same/different judgment)	TD more impaired than ASD by alterations to local features (pitch and timing), interpreted as interference overall gestalt. Absence of interference from auditory coherent whole in ASD.

Table I. Continued

Reference	Participants (group means)	Tasks	Main findings
Heaton (2003)	14 HFA CA 11, Ravens 108, VIQ 92 28 TD CA & Ravens/VIQ match	Pitch memory and labelling Disembedding un/labelled tones from chords	HFA > TD at pitch memory and labelling HFA > TD on disembedding tone from chord only when pre-exposed to labelled individual tones
Plaisted *et al*. (2003)[a]	8 HFA/AS CA 13–28, m18	Auditory filtering task	Width of auditory filters abnormally broad in ASD vs. published TD data
Verbal		*Homograph reading*	
Frith and Snowling (1983)	8 autism CA 9–17, RA 8–10 yrs 10 TD CA 9–10, RA matched 10 Dyslexia CA 10–12, reading age matched	Homograph reading Stroop Gap tests (supply or choose word to fill gap in read story)	Autism read fewer homographs correctly vs. TD and Dyslexia All groups showed expected Stroop interference Autism made more errors on both Gap tests than TD or Dyslexia groups
Snowling and Frith (1986)	16 autism CA 17, RA 10, VMA 6/10 15 TD CA 10, RA 9, VMA 6/10 9 MH CA 15, RA 9, VMA 5/9	Homograph reading with prior training Gap tests (choose word to fill gap in read story; spot anomalous word)	Higher ability ASD not different from TD or MH on number of correctly pronounced homographs or on Gap tests; low ability ASD and MH groups < TD
Happé (1994)	16 ASD CA 17, VIQ 80(divided by ToM performance) 13 TD CA 8	Homograph reading	ASD, regardless of ToM, fail to use preceding sentence context compared with TD; context x group interaction
Jolliffe and Baron-Cohen (1999)	17 HFA CA 31, FIQ 105 17 AS CA 28, FIQ 107 17 TD CA and FIQ matched	Homograph reading Bridging inference task Ambiguous sentences test	ASD < TD accurate rare pronunciations (before or after context) HFA < Asperger < TD at choosing bridging coherent sentence HFA < Asperger < TD at recognising rare context-dependent sentence meanings
Lopez and Leekam (2003)	15 HFA CA 14, FIQ 87 16 TD CA 14, FIQ 99	Homograph reading Semantic priming task Memory for un/related words	HFA < TD using context to determine rare pronunciation. No group difference, both groups primed by context word No group difference overall; for subset of (animal) words ASD benefit less than TD from related (vs. unrelated) word lists
		Various	
Beversdorf *et al*. (1998)	10 HFA CA 31, FIQ 110 13 T CA 31, FIQ 117	Recall tests; word lists varying in semantic/syntactic order; stories with sentences in/not in logical order (also emotion and theory of mind conditions)	No group differences in recall of coherent vs. incoherent word lists or stories. (Recall facilitated by emotional content in T > HFA)
Beversdorf *et al*. (2000)	8 HFA CA 32, FIQ 111 16 T CA 31, FIQ 113	False memory test	HFA > T discriminating false memory items from true items (suggesting less integration/use of context)

Jolliffe and Baron-Cohen (2000)	17 HFA CA 31, FIQ 105 17 AS CA 28, FIQ 107 17 TD CA and FIQ matched	Global integration test (arrange sentences for coherent story) Global inferences test	ASD < TD arranging sentences coherently (ns in condition using temporal cues) ASD < TD making context-appropriate inferences in short stories
Norbury & Bishop (2002)	10 HFA CA 9, Ravens 108, VIQ 91 16 SLI CA 9, Ravens 99, VIQ 83 24 PLI CA 9, Ravens 105, VIQ 89 18 TD CA 9, Ravens 111, VIQ 107	Story comprehension and inference task	No group differences in story comprehension Poorer inference (relative to literal) question performance in HFA

Note: In order to group studies by task/domain, some papers appear more than once. Studies from a single publication share a superscript letter.

Key: AS = Asperger Syndrome; ASD = autism spectrum disorders; BPVS = British Picture Vocabulary Scale; CA = chronological age (in years unless otherwise specified); (C) EFT= (Children's) Embedded Figures Test; DAS = Differential Ability Scales; DS = Down Syndrome; HFA = high functioning autism; MH = mentally handicapped; NVIQ = nonverbal IQ; ns = statistically non-significant; RA = reading age; SLI = specific language impairment; T = typical; TD = typically developing; ToM = theory of mind; VMA = verbal mental age.

2001), and reduced benefit from canonical pattern in dot counting (Jarrold & Russell, 1997).

A rapidly expanding body of work examines face processing in ASD. Faces are one class of stimulus that can be processed featurally or configurally, but may be so special in terms of evolutionary significance and developmental expertise that findings from face studies cannot be generalised to other stimulus classes (see, e.g. Suzuki & Cavanagh, 1995). A full review of face processing in ASD is beyond the scope of the present paper. However, a number of findings suggest abnormally feature-based face processing in ASD (e.g. Deruelle, Rondan, Gepner, & Tardif, 2004; Hobson, Ousten, & Lee, 1988), although there are also mixed (e.g. Teunisse & de Gelder, 2003) and contrary findings (e.g. Rouse, Donnelly, Hadwin, & Brown, 2004).

Conflicting Findings

As well as fairly consistent findings from relatively robust tasks that appear to be good probes of weak coherence, e.g., Block Design, Embedded Figures Test (EFT) and homograph reading, there have been inconsistent and negative findings. The early finding of more accurate (context-independent) judgement of visual illusions (Happé, 1996), for example, has not been replicated in later studies by Ropar and Mitchell (1999, 2001), using computerised and paper-and-pencil tasks—although the original finding of lack of benefit from 3-D disembedding has not been explored in subsequent studies. Scott, Brosnan, and Wheelwright (submitted for publication) suggest a possible explanation for conflicting findings in terms of test-question wording; in their study participants with ASD made the typical misjudgements when asked, for example, whether two lines of an illusion "looked the same length", but were more accurate than controls when asked whether the two lines "were the same length".

The Navon hierarchical figures (e.g. an H composed of small Ss; Navon, 1977) have also produced inconsistent results, with some researchers (e.g. Mottron, Burack, Stauder, & Robaey, 1999) finding the normal global advantage in groups with ASD, or the lack of such an advantage in typically developing comparison groups. This task is known to be sensitive to small variations in methodology; Navon (2003), in a recent review of the hierarchical figure literature, has questioned the use of directed (i.e. selective) attention methodologies, and figures in which one of the elements is strictly foveal. A study by Plaisted, Swettenham, and Rees (1999) showed local advantage and interference from local to global stimuli in a condition where participants with ASD were required to divide attention between local and global levels, but not in a selective attention task in which participants were instructed to pay attention to, for example, the global level. Reduced or absent global advantage may only be evident, then, when participants with ASD are not directed to attend to global information.

These findings underscore the importance of open-ended tasks in capturing what appears to be a processing bias towards features rather than a processing deficit for wholes. A similar finding is seen with verbal semantic materials, where alerting children with ASD to the special status of homographs (Snowling & Frith, 1986) removed the otherwise robustly found ASD-specific failure to disambiguate pronunciation/meaning on the basis of preceding sentence context (Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999; Lopez & Leekam, 2003). Lopez, Donnelly, Hadwin, and Leekam (2004) demonstrated the same effect for face processing; participants with ASD showed configural processing of faces in attentionally cued, but not in non-cued, conditions.

Other negative findings may help to demarcate the boundaries of weak coherence. People with autism *do* appear to integrate the properties of a single object (e.g. colour and form in a visual search task; Plaisted *et al.*, 1998a, b; but see Plaisted, Saksida, Alcantara, & Weisblatt, 2003), and to process the meaning of individual words (in Stroop tasks; Eskes, Bryson, & McCormick, 1990; Frith & Snowling, 1983) and objects (in memory tasks; Ameli, Courchesne, Lincoln, Kaufman, & Grillon, 1988; Pring & Hermelin, 1993). It seems to be in connecting words or objects that coherence is weak, although Lopez and Leekam (2003) showed that straightforward priming from a word or scene (or perhaps local elements of the scene) does occur in autism.

Local vs. Global Coherence?

Clearly, people with autism can connect information of certain sorts, for example in putting together the elements of their daily routine (disruption to which may be so distressing), accumulating connected facts within a narrow domain (e.g. calendrical calculating), or placing visual elements in coherent relation to one another when drawing. These examples may reflect alternatives to truly configural global processing, such as item-to-item processing (chaining), or intra-domain coherence. Chaining may be seen in, for example, picture sequencing tests such as the Wechsler scales Picture Arrangement subtest, where a coherent story must be made by arranging pictures shown on separate cards. This would appear to require central coherence. However, many such stories can be completed by chaining, i.e. linking one picture to the next, without having to take into account more than the adjacent picture/episode—that is only "local" and not "global", or central, coherence is needed. This sort of local coherence may also be sufficient to set up schemas of an event, routine, or route.

The second type of local coherence involves connecting information within a narrow domain, such as connecting facts about the calendar to develop a "coherent" representation supporting calendrical calculation. As Heavey (1999, 2003) has speculated, this system can be built up from small local parts. Calendrical calculation may not require more coherence than, say, grammatical processing—also notably intact in many people with autism—which emerges from a closed modular system (see below for related issues on Baron-Cohen's systemizing theory).

In reviewing the research on coherence, it is notable that many tasks assume or even create an inherent trade-off between processing at the local and global levels. For example, in the Navon task, there is competition and interference between local and global levels. In the EFT, successful performance is taken as both a measure of how salient the part is, and how (relatively) weak the camouflaging gestalt is, for the participant. In the Sentence Completion test, a local completion ('The sea tastes of salt and...', "pepper") may reflect either strength of local associates or lack of available global completions. This aspect of task design may obscure the possibility that local and global processing in other situations may not necessarily act in competition. At least in terms of individual or clinical group differences, a person/group characterised by good featural or detail-focused processing need not, necessarily, be poor at global processing. In principle, in a two by two matrix, all four quadrants might be filled; some people showing good local and good global processing, some poor processing of both levels, and some good at either local or global only. This raises the question of whether individual differences may reflect, in part, the ability to shift between modes of processing, itself perhaps an ability falling under the umbrella term "executive function" (see below).

Universality and Specificity

An important recent trend is to look beyond group effects to report the proportion of a participant group that shows the reported pattern of difficulties/abilities. Where such data are reported (e.g. Jarrold & Russell, 1997; Scheuffgen, 1998), the findings suggest that weak coherence may be characteristic of only a subset of the ASD population. This is, perhaps, not surprising for at least two reasons. First, such findings are typical for tests of any account of autism, such as the theory of mind and executive dysfunction accounts. They likely reflect the enormous heterogeneity within the group we currently designate, on behavioural criteria, as having ASD. Second, any test is an indirect probe of the underlying cognitive functions of interest, and there are typically many ways both to pass and to fail a test. The test–retest reliability and other psychometric properties of the experimental tasks used are also, typically, unknown. Despite this, individual analyses are important, as they may eventually shed light on cognitively meaningful subgroups, which might differ in their aetiology, behavioural features, prognosis, or response to intervention.

The specificity of weak coherence is also of interest; do other clinical groups share this cognitive style? Four different clinical groups provide some empirical evidence of local processing bias; schizophrenia, Williams Syndrome, depression, and right hemisphere damage. Schizophrenia has been proposed to be characterised by featural vs. configural processing (e.g. Chen, Nakayama, Levy, Matthysse, & Holzman, 2003; John & Hemsley, 1992), and non-clinical groups high in schizotypy show reduced use of context resulting in superior performance on certain tasks (Uhlhaas, Silverstein, Phillips, & Lovell, 2004). People with Williams Syndrome have been described as showing unusually featural processing (e.g. copying components from hierarchical letters; Bellugi, Lichtenberger, Jones, Lai, & George, 2000), although processing style for faces, other visuo-spatial material, and verbal material should probably be considered separately in this group, who show visuo-spatial deficits alongside a strong preference for faces. Individuals with depression/anxiety may show an imbalance in global/local processing, with negative mood related to more detail-focused or analytic processing in clinical groups (e.g. Derryberry & Tucker, 1994; Hesse & Spies, 1996), and following mood induction in non-clinical samples (e.g. Gasper & Clore, 2002). Whether negative mood plays a part in coherence findings in ASD is unclear; anxiety and depression are common in higher ability ASD. Individuals with acquired right hemisphere damage show deficits on visuo-spatial constructional tasks, maintaining details but missing global configuration (Robertson & Lamb, 1991). Discourse also becomes fragmented in such patients, with difficulties integrating verbal information and extracting gist (Benowitz, Moya, & Levine, 1990). Developmental right hemisphere damage also seems to disrupt configural processing, as reflected, for example, in piecemeal drawing styles (Stiles-Davis, Janowsky, Engel, & Nass, 1988). It is important to bear in mind, however, that similar behaviour may not necessarily indicate similar underlying cognitive processes. Until these different clinical groups have been compared, alongside ASD, on the same coherence tasks, it remains unclear whether they truly share the same underlying cognitive style.

In the first direct comparison of clinical groups, Booth, Charlton, Hughes, and Happé (2003) tested boys with ASD or with Attention Deficit/Hyperactivity disorder (ADHD) on weak coherence and executive function tasks (see also below). They found that the ASD but not the ADHD participants showed detail-focused drawing styles. The same groups could also be distinguished on verbal tests of coherence (Happé & Booth, in preparation); despite their inhibition problems, the ADHD group did not make the sorts of local sentence completions found to be characteristic of children with ASD (e.g. 'You can go hunting with a knife and...', "fork").

Weak Coherence as a Normal Individual Difference

The notion of weak coherence as a processing bias, rather than deficit, lends itself to a continuum approach, in which weak coherence is seen as one end of a normal distribution of cognitive style, and people with ASD, and perhaps their relatives, are placed at the extreme end of this continuum. The opposite cognitive style, strong coherence, might be characterised as a tendency to process gist and global form at the expense of attention and memory for detail and surface form. Thus, while the person with weak coherence may be poor at seeing the bigger picture, the person with strong coherence may be a terrible proof reader. It is important, in this working hypothesis, to recall that these styles represent only biases; the person with strong coherence can, by an effort of will, turn their attention to details such as remembering unconnected facts for an exam, just as the person with weak coherence can, if really required to, extract the gist of a long speech.

Is there empirical evidence for the postulated individual differences in coherence in the general population? There is some evidence of normal individual differences in local–global processing from infancy (Stoecker, Colombo, Frick, & Allen, 1998), childhood (Chynn, Garrod, Demick, & DeVos, 1991), and adulthood (Marendaz, 1985). Sex differences have been reported on tasks thought to tap local–global processing (Kramer, Ellenberg, Leonard, & Share, 1996), although type (local/global) and domain (visuo-spatial/verbal) of processing are often confounded. Thus the typical (small) male superiority on visuo-spatial tasks may have contributed to apparent male bias for local processing, as seen for instance on the EFT. Tests benefiting from featural processing in auditory and verbal domains are needed to build up a fuller picture.

The Embedded Figures Test (EFT) originated as a test of "field independence", and the notion of individual differences in coherence recalls this postulated cognitive style (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962; Witkin & Goodenough, 1981). Field independence (FI) refers to a cognitive style characterised by the tendency to see objects in one's field of vision as discrete units, distinct from the field as a whole. The designs in the EFT take advantage of gestalt principles to create wholes that are difficult to break into component parts. Field independence is therefore defined by good EFT performance—as also seen in ASD. It might be a mistake, however, to equate FI with weak central coherence; while FI people are conceptualised as succeeding on EFT because of their ability to see, but resist, the gestalt, people with weak coherence are postulated to be good at this test precisely because they do not spontaneously attend to the gestalt, instead seeing the figure first in terms of its parts. Whether the suggested distinction between FI and weak coherence holds up is a matter for empirical inquiry. However, it is possible to derive distinct predictions for FI and weak central coherence. For example, when people with weak coherence make errors on the Wechsler Block Design subtest, these should be of a type that preserve design details and violate configuration. When FI people make errors on the BD, however, they (like field dependent people) would be expected to make errors reflecting a relative failure to resist the gestalt—i.e. errors that preserve the configuration but violate the details (e.g. Kramer, Kaplan, Blusewicz, & Preston, 1991). In other words, global processing remains the default for FI people according to Witkin's theory, while local processing is proposed to be the default for individuals with weak coherence.

Weak Coherence and the Broader Autism Phenotype

Thinking about weak coherence as one end of a normal continuum in cognitive style suggests that this may be one aspect of the broader autism phenotype, and that tests of coherence might be useful for family studies of the genetic contribution to ASD. Happé, Briskman, and Frith (2001) studied the parents of boys with ASD using the EFT, Un/Segmented Block Design, visual illusions and sentence completion tests as coherence measures. They found that around half of the fathers and a third of the mothers showed consistent weak coherence, or detail-focus, across the test battery (often shown in superior performance). Self-report of "eye for detail" traits matched coherence test performance, while self-report of social difficulties or shyness did not (Briskman, Happé, & Frith, 2001). This suggests that the social and non-social aspects of the broader autism phenotype are independent. Among comparison groups (parents of boys with dyslexia, or with no disorder) significantly fewer participants showed consistent detail focus, on tests or self-report. These findings suggest that weak coherence can be found in well-adapted, healthy and intelligent adults—indeed, it may be this aspect of the broader autism phenotype that underlies the apparently higher prevalence of family members in engineering (Baron-Cohen *et al.*, 1997), and other professions where, putatively, attention to detail may be important. This aspect of the broader phenotype, unlike the social deficits, may have advantages for reproductive fitness, and its persistence in the gene pool is not hard to explain.

Weak Coherence in Relation to other Accounts of Autistic Signs and Symptoms

One of the changes in the working hypothesis of the weak coherence account has concerned the relationship between coherence and social deficits in autism (Frith & Happé, 1994). Frith's original conception (Frith, 1989) gave weak coherence a central and causal role, with problems integrating information for high level meaning underlying the deficits in social understanding, which Frith and her colleagues so influentially characterised as problems in "theory of mind" (Baron-Cohen, Leslie, & Frith, 1985). However, the fact that detail-focused processing can be found across the autism spectrum, regardless of level of theory of mind performance (Happé, 1997; Jolliffe & Baron-Cohen, 1997, 1999) suggests that these two aspects of the phenotype may be distinct (see Happé, 2000, 2001, for a full discussion of possible relationships). Indeed, evidence from recent behaviour genetic studies of autism-related characteristics in typically developing twins suggests somewhat distinct genetic contributions to the social vs. the non-social/restricted and repetitive behaviour domains (Ronald, Happé, & Plomin, in press). It currently appears most plausible to consider autism the result of anomalies affecting a number of core cognitive processes (Happé, 2003), including global–local processing (central coherence or one of the alternative conceptualisations discussed below), social cognition (e.g. theory of mind), and executive functions. In this framework, the weak coherence account does not attempt to explain all aspects of the autism phenotype, such as primary social abnormalities, although it seems plausible that detail focus might further interfere with already abnormal social functioning. For example, featural processing might disrupt recognition of facial emotion, and reduce context-sensitive interpretation of social behaviour or utterances.

Investigations of the relationship between central coherence and theory of mind have been somewhat mixed. Weak coherence seems to characterise people with autism regardless of their theory of mind ability in studies using perceptual (visual illusions; Happé, 1996), and semantic tasks (homograph reading; Happé, 1997). For example, Happé (1994) found that theory of mind task performance was related to performance on the Comprehension subtest of the Wechsler scales (commonly thought to require pragmatic and social skill), but not to performance on the Block Design subtest (a marker of weak coherence) in a large sample of individuals with ASD. Morgan, Maybery, and Durkin (2003) also found no relation between weak coherence (measured by EFT) and social skills (joint attention, pretend play), among preschoolers with ASD. However, Jarrold, Butler, Cottington, and Jimenez (2000) reported an inverse relation between performance on Baron-Cohen's "Eyes task" (tapping social cognition) and speed on the EFT in a sample of undergraduates; and in a group of children with autism and typically-developing children, false belief task performance was negatively correlated with EFT performance, with the correlation reaching significance once verbal mental age was partialled out. Pellicano, Maybery, and Durkin (in press), on the other hand, found no relation between performance on EFT, Block Design and two other tests aimed at assessing weak coherence (which loaded on two separate factors), and tests of theory of mind in a sample of typically developing 4- and 5-year-olds, with age and IQ partialled out.

Longitudinal studies would clearly be helpful in investigating possible causal relations. To date the only data of this type are from a study with adolescents and adults. Berger *et al.* (1993) found that cognitive shifting, but not a measure of disembedding, predicted social understanding in high-functioning people with autism (aged 16–25 years) at 2-year follow-up (see also Berger *et al.*, 2003).

Weak Coherence in Relation to other Deficit Accounts

A prominent account addressing the non-social aspects of ASD posits executive dysfunction at the root of the characteristic rigid and repetitive behaviour. Executive function is an umbrella term covering a range of higher-order cognitive abilities necessary for flexible and adaptive behaviour in the service of novel goals. As such, executive function might be seen to encompass the processing of information in context for global meaning, i.e. central coherence. Findings currently attributed to weak coherence might be explained by executive dysfunction: failure to process information globally might be argued to follow from problems in shifting between local and global levels, provided local processing is considered to be the default. Limitations of working memory might bias performance towards smaller fragments of information. Similarly, poor planning might result in piece-meal approaches to novel tasks.

To date, there have been three investigations of the possible relation between coherence and executive functions. Teunisse, Cools, van Spaendonck, Aerts, and Berger (2001) found that weak coherence and poor shifting were more common among high-functioning adolescents with autism than among comparison typically-developing participants, but neither was universal. Performance on the two types of measure was unrelated and did not correlate with symptom severity or social ability. Pellicano *et al.* (in press) found a significant relationship between executive function tasks and some but not all tests aimed at assessing coherence in her study of 4- and 5-year-old typically developing children. However, the choice of tasks is likely to have confounded processing style and visuo-spatial ability. Booth *et al.* (2003) examined directly the possible role of one executive function, planning, on global/local processing in a drawing task. They compared boys with ASD and boys with ADHD, as well as a typically developing comparison group, all matched on age and IQ. A drawing task requiring planning ahead (to add a requested internal element), showed the predicted planning deficits in both clinical groups, while analysis of drawing style showed that piecemeal drawing, e.g., starting with features or drawing detail to detail, was characteristic of the ASD group only. Performance on the executive function and central coherence elements of the task did not correlate in the clinical groups, and Booth *et al.* conclude that weak coherence is not common to all groups with executive dysfunction, and that poor planning cannot explain detail-focus in autism. Notwithstanding this evidence that weak coherence findings are not a mere side-effect of executive dysfunction in planning or inhibition, there may be important theoretical shared ground between these two accounts. The executive function metaphor of the "chief executive", in top–down control of lower resources, certainly resonates with Frith's original notion of *central* coherence. Many aspects of autism seem well characterised as manifestations of reduced top–down modulation (Frith, 2003), and local or piecemeal processing might be postulated to be the default when control from above (the CE) is weakened or absent. In this sense, coherence might be seen as one aspect of executive function. However, coherence would be unlike most processes grouped under the executive function umbrella, in so far as the neural substrate for coherence is not hypothesised to be in the frontal lobes, and coherence is thought to be a property of low- as well as higher-level systems.

Alternative Accounts of Weak Coherence Findings

In recent years, there has been a renewal of interest in perceptual processes in autism, as reflected in a number of alternative theoretical accounts of the findings underpinning the weak coherence theory. Theories by Plaisted, by Mottron and by Baron-Cohen are notable amongst these. Plaisted (2000, 2001) has suggested that the mechanism underlying weak coherence effects may operate at the perceptual level, and specifically lie in enhanced discrimination and reduced generalization. Plaisted hypothesizes that people with autism process features held in common between objects relatively poorly, and process features unique to an object, i.e. those that discriminate items, relatively well. This is thought to underlie the pattern of superior visual search (Plaisted *et al.*, 1998a; O'Riordan *et al.*, 2001), superior discrimination learning of highly confusable patterns (Plaisted *et al.*, 1998b), and poor prototype extraction (Plaisted *et al.*, submitted for publication; see also Klinger & Dawson, 2001), demonstrated by Plaisted, O'Riordan, and colleagues in an elegant series of studies.

Mottron and colleagues also situate the mechanism for weak coherence effects at the level of perception. Their "enhanced perceptual functioning" (EPF) framework posits overdeveloped low-level perception and atypical relationships between low- and high-level processing (see Mottron & Burack, 2001). On this account, 'persons with autism may be over-dependent on specific aspects of perceptual functioning that are excessively developed and, as a consequence, more difficult to control and more disruptive to the development of other behaviours and abilities (p. 137)'. While this account, like weak coherence, has to do with atypicalities in the relations between lower and higher level processing, and addresses much of the same data, EPF predicts superiority on some tasks that weak coherence does not; 'autism is characterised by the enhancement of several functions that share the properties of low-level processing not necessarily associated with an imbalance between local and global processing (p. 139)'. An example might be the finding that participants with high-functioning autism were better than matched typical comparison participants on certain map tasks, as indicated by superior accuracy in graphic cued recall of a path and shorter learning times in a map learning task that may reflect superior detection and reproduction of simple visual elements (Caron, Mottron, Rainville, & Chouinard, 2004). It is hard to see how the weak coherence account could predict this finding.

By contrast, other data cited in support of EPF fit well with the weak coherence prediction of detail-focused processing bias and superior local processing; e.g. higher pitch sensitivity (Bonnel *et al.*, 2003), and parity between phonological and semantic cueing in verbal memory (Mottron, Morasse, & Bellville, 2001). Mottron and colleagues cite in favour of their EPF proposal, but also compatible with Plaisted *et al.*'s account, the finding that people with autism show enhanced local processing and intact global processing of musical stimuli (Heaton *et al.*, 1998; Mottron *et al.*, 2000; but see Foxton *et al.*, 2003).

While such findings may be at odds with the original description of weak coherence, they are in keeping with the suggestion that weak coherence is a cognitive style or bias—that is, that global processing is possible for people with autism, but that local processing is preferred in open-ended tasks.

Baron-Cohen (2002, 2003) has proposed an empathising-systemizing account of ASD, of which the suggested facility for systemizing is relevant to the weak coherence account. Systemizing refers to the drive to analyse and construct systems, essential to which, on Baron-Cohen's account, is an initial attention to exact detail. This attention is proposed to explain some of the coherence findings, such as superior EFT performance. Where the systemizing account makes distinct predictions from the coherence account, according to Baron-Cohen, Richler, Bisarya, Gurunathan, Wheelwright (2002), is in regard to the ability to master a new system, discovering the rules and regularities and relationships between underlying parameters. This ability to integrate information about the components of a system is seen as the antithesis of weak coherence. However, as discussed above, some systems (e.g. bus route numbering) may be fathomable through 'local' coherence, provided that simple if-then rules operate without context-dependent effects. Mastery of such systems would not be counter to the coherence account. Clearly the key data needed would identify which systems people with ASD do and do not master quickly from scratch. The data available on systemizing largely comprise self-ratings of abilities and preferences (e.g. Baron-Cohen *et al.*, 2002), and have yet to be validated against actual performance (but see Lawson, Baron-Cohen, & Wheelwright, 2004). However, the systemizing account draws attention to an important aspect of ASD not encompassed by the coherence account—the desire to collect and connect information within circumscribed narrow areas of interest.

Possible Mechanisms for Weak Coherence

A major limitation of the coherence account to date is the lack of specification of the mechanism, at both the cognitive and neural levels, that underlies detail-focused processing bias among people with ASD. The alternative accounts respond in part to this challenge. Important questions remain: should we think of a single, central mechanism integrating information from diverse modules/systems, for higher-level meaning/configuration? Or should coherence be thought of as a property of each subsystem, a setting for the relative precedence of global vs. local processing, repeated at different levels throughout the brain? Data are needed, in this respect, regarding individuals' performance on coherence tests across and within a number of domains.

Examining a possible attentional mechanism for some of the findings of detail-focused processing in visual tasks, Mann and Walker (2003) (see also Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001) found evidence of difficulty broadening the spread of visual attention; children with autism, in contrast to typically developing and intellectually impaired groups, were slower to respond to a large crosshair if it appeared after a small crosshair stimulus, but not vice versa. Mann and Walker (2003) suggest that difficulty in "zooming out" may account for some of the findings in the coherence literature (e.g. good EFT performance), without the need to postulate problems in integrating stimuli. However, Burack (1994) found performance in ASD indicative of an 'attentional lens...inefficient in contracting its focus'; the beneficial effect of a window directing attention in a forced-choice RT task was negated by the presence of distractor stimuli, whether near or far from the target.

Computational Models

Computer models may suggest possible cognitive and neural bases for weak coherence. Several parameters in such models can be altered to simulate detail focus and poor generalisation. Suggestions to date include excessive conjunctive coding, high inhibition relative to excitation, excessive inhibitory feedback, and an increase in number of key processing units. McClelland (2000) suggested that excessive conjunctive neural coding in at least some brain regions might limit generalisation of learning, due to "hyperspecificity" of representations. O'Loughlin and Thagard (2000), using their theory of coherence as constraint satisfaction, simulated weak coherence on the homograph task in a connectionist network with unusually high inhibition compared to excitation. Gustafsson (1997) suggested that excessive inhibitory feedback might result in narrow feature maps, and over-specificity of processing, and Cohen (1994) presented a computational model of ASD in which lack of generalisation results from an increase in units.

Neural Models

At the neural level, two types of mechanism have been proposed in relation to findings of local processing bias in ASD. The first type of mechanism posits a deficit in a specific pathway or region of the brain. The second type proposes diffuse changes in neuronal connectivity. Variants of each type of account are briefly reviewed below.

Spencer *et al.* (2000) proposed a specific pathway abnormality underlying ASD. They found raised coherent motion thresholds in ASD, and suggested these were due to abnormal processing in the dorsal stream/magnocellular pathway, thought to be specialised for low spatial frequency information. Milne *et al.* (2002) replicated this finding and made an explicit theoretical connection between weak central coherence and magnocellular pathway impairments. Milne (unpublished Ph.D. thesis) found a relationship between performance on EFT and motion coherence in a subgroup of individuals with ASD, and Pellicano, Gibson, Maybery, Durkin, and Badcock (2005) reported a significant correlation between these tests in a separate sample of children with ASD. Deruelle *et al.* (2004) provide indirect evidence in support of the magnocellular pathway account. They demonstrated better performance by participants with ASD using high- vs. low-spatial frequency stimuli (filtered pictures of faces). Pellicano *et al.* (2005) and Bertone *et al.* (2003) have refined the nature of the motion perception deficit in ASD. Children with ASD showed normal flicker contrast sensitivity, suggesting intact lower-level dorsal stream functioning, alongside raised global motion thresholds (Pellicano *et al.*, 2005). Bertone *et al.* (2003) report raised thresholds for second-order (texture-defined), but not first-order (luminance defined), motion in ASD. The authors interpret their findings as showing that processing of motion breaks down only at complex neural levels, where integrative functioning is necessary.

While Spencer *et al.* and Milne *et al.* have proposed a specific pathway as the locus for weak coherence anomalies, a specific *region* implicated in global and integrative processing is the right hemisphere. Individuals with acquired right hemisphere damage show deficits integrating information for global form and meaning (see above). Functional imaging work, too, suggests a role for right hemisphere regions in configural processing. For example, Fink *et al.* (1997) found evidence of right lingual gyrus activation during attention to global aspects of a hierarchical figure, and left inferior occipital activation during local focus. Electrophysiological (ERP) studies, too, suggest right hemisphere activity during global (vs. local) tasks (e.g. Heinze, Hinrichs, Scholz, Burchert, & Mangun, 1998), although this is not observed under all circumstances (see, e.g. Volberg & Hubner, 2004, for discussion). Most recently, the technique of transcranial magnetic stimulation has been used to demonstrate the role of right posterior parietal lobe in the perception of global aspects of hierarchical figures, although interestingly this laterality appears to be true only for right-handers and is reversed in left-handed people (Mevorach, Humphreys, & Shalev, 2005). To date, however, there is little conclusive evidence of localised and specific structural damage in ASD. Some brain imaging studies of individuals with ASD have found right hemisphere abnormalities (e.g. McKelvey, Lambert, Mottron, & Shevell, 1995; Waiter *et al.*, 2005), but evidence of damage in (bilateral) limbic, frontal and cerebellar regions has also been reported and it is by no means clear which anomalies are specific and universal to ASD. The only functional imaging study of global–local processing in ASD to date, which used the EFT, did not find clear evidence for lateralised abnormalities (Ring *et al.*, 1999). Group comparisons indicated greater frontal and parietal activity in the typical group, and greater activation of occipital regions in the ASD group, but the lack of a well-matched control task in this study limits the conclusions that can be drawn.

Perhaps more intuitively appealing than localised neural accounts, are proposals that weak coherence is the result of reduced connectivity throughout the brain. A number of variations of this type of account have been proposed, including reduced connectivity due to lack of synchronisation of activation (Brock, Brown, Boucher, & Rippon, 2002), lack of connecting fibres (Just, Cherkassky, Keller, & Minshew, 2004), and failure of top–down modulation (Frith, 2004). Brock *et al.* (2002) have put forward perhaps the most thorough working hypothesis of this type in which they propose that brain specialisation in ASD develops without normal cross-talk between regions, and that weak coherence emerges due to lack of synchronisation of neural activity necessary to bind parts into wholes. They predict reduced synchronisation of high-frequency gamma band activity between local networks, and suggest ways in which their temporal binding deficit hypothesis might be tested using EEG techniques.

Also suggesting reduced connectivity, Just *et al.* (2004) reported results from functional imaging of volunteers with ASD during a sentence comprehension task. They found patterns of activation in the ASD vs. control group suggestive of increased low-level processing, and reduced functional connectivity. A similar finding was previously reported by Castelli, Frith, Happé, and Frith (2002). Just *et al.* propose an "underconnectivity" theory, in which symptoms of autism result from underfunctioning of integrative circuitry responsible for integration of information at the cognitive and neural levels. There is considerable evidence of abnormal brain connectivity in ASD (for review see Belmonte *et al.*, 2004), including recent findings of reduced white matter (e.g. Chung, Dalton, Alexander, & Davidson, 2004), and disrupted white matter tracts (Barnea-Goraly *et al.*, 2004), which might result from excessive brain growth at key periods (Courchesne, 2004), or, more speculatively, disruptions to developmental trajectories of serotonin synthesis (Chugani *et al.*, 1999).

Connectivity of lower brain regions can also be altered by top–down feedback (Friston & Buechel, 2000). Frith (2004) has suggested that a lack of top–down modulation, due to failure of early neural pruning of feedback connections, could be a cause of abnormal connectivity. Decreased functional connectivity, in this model, would result from misconnections due to unpruned synapses (see also Belmonte & Yurgelun-Todd, 2003). Such a suggestion fits well with proposed computational models in which reduced generalisation results from too many neural units, and with anatomical evidence of larger and heavier brains in ASD (perhaps due to failures of synaptic pruning and programmed cell death; for review see Courchesne, 2004). For example, Lee (2002) demonstrated top–down influences on the activity of early visual neurons using single cell recording techniques, and suggests that top–down interaction, through recurrent feedback connections, allows contextual information to influence early perceptual processing. If such feedback connections were abnormal in ASD, perceptual abnormalities might result due to lack of modulation by higher-level 'meaning' (e.g. expectation, context).

CONCLUSIONS

There is a strong and growing body of evidence that people with ASD are characterised by superior performance on tasks requiring detail-focused processing. Whether this superiority is achieved at the cost of normal global processing is less clear, and the weak coherence account has moved towards an emphasis on superiority in local processing rather than deficit in global processing. It has also become clear that people with ASD can process globally for meaning when explicitly required to do so, leading to the notion of a processing bias for local over global levels of information, best tapped by open-ended tasks. Whether this bias is specific to ASD, compared with other clinical groups, is as yet unclear—although there is some evidence that it may form part of the broader autism phenotype. Results to date suggest weak coherence is not reducible to executive dysfunction, and most studies suggest weak coherence is independent of deficits in social cognition. Many questions remain to be answered concerning the mechanism for weak coherence, at both the cognitive and neural levels. Growing evidence of disturbed neural connectivity in ASD holds promise for further understanding the brain basis of weak coherence. Among the remaining challenges is the need to establish relationships between weak coherence, or alternative accounts of detail-focused processing bias, and real-life abilities and difficulties. Finally, the notion of weak coherence has yet to be translated into educational approaches, which may, perhaps, prove the ultimate test of this theory's veracity and value.

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