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A deficit in shifting attention present in high-functioning autism but not Asperger's disorder

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ABSTRACT The aim of this study was to examine executive functioning, in particular, attentional set-shifting deficits in high-functioning autism (n = 12) and Asperger's disorder (n = 12). A large or global digit composed of smaller or local digits was presented during each trial. The participants indicated the presence of 1s or 2s by pressing the appropriate button. These targets could appear globally or locally. Relative to IQ, sex and age matched controls, reaction time to global targets in individuals with autism was retarded when the previous target appeared locally. This deficiency in shifting from local to global processing, however, was not observed in individuals with Asperger's disorder. The theoretical and neurobiological significance of this dissociation in executive functioning in these clinically related disorders was explored.

KEYWORDS *Asperger's disorder; attention; executive dysfunction; high-functioning autism; visual-perceptual processing*

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Autism is a neurodevelopmental disorder associated with impaired social and communicative functioning, and restricted, stereotyped or repetitive motor and cognitive behaviours (American Psychiatric Association, 1994). Several neurobiological models have been proposed to account for autism. Many of these models implicate disruption of the fronto-striatal region producing deficits in executive functions (Ozonoff and Jensen, 1999) and disordered attention (Pascualvaca et al., 1998).

Executive functions include the ability to behave in a flexible manner, to organize and plan behavioural responses, and to inhibit responses (Ozonoff and Jensen, 1999). Many studies have found support for executive dysfunction in autism (e.g. Hughes and Russell, 1993; Ozonoff et al., 1994; Pennington and Ozonoff, 1996; Prior and Hoffman, 1990; Rumsey and Hamburger, 1988; Russell, 1997). Nonetheless executive dysfunction does not distinguish autism from other disorders. The concept of executive function is broad, and dysfunction in this area is a feature of many neurodevelopmental disorders, such as Tourette's disorder, attention deficit hyperactivity disorder, obsessive-compulsive disorder (Pennington and Ozonoff, 1996; Sheppard et al., 1999).

Ozonoff and Jensen (1999) addressed the issue of specificity of executive dysfunction in autism by directly comparing a group of neurodevelopmental disorders on a series of executive function tests (i.e. Wisconsin Card Sorting Task, the Tower of Hanoi, and the Stroop Color-Word Test). These authors revealed that poor planning and cognitive flexibility characterize autism, whereas inhibitory deficits characterize Tourette's disorder and attention deficit hyperactivity disorder. The reduced cognitive flexibility found in the autism group has also been demonstrated on the Go No-Go task where participants are required to shift attention between visual stimuli (Ozonoff et al., 1994).

Unique aspects of executive dysfunction in autism have been further delineated by studies that isolate specific attentional processes. Several studies have shown that children with autism are impaired in their ability to shift attention between stimuli once visual attention has been engaged, and also have difficulties in orienting visual-spatial attention (Courchesne et al., 1994a; 1994b; Townsend et al., 1996; Wainwright and Bryson, 1996). Pascualvaca et al. (1998) examined the ability of children with autism to focus, sustain and also shift attention. They discovered that individuals with autism could successfully maintain attention, but displayed difficulties in shifting attention only when it had been focused on the target for a period of time. Thus these authors also uncovered a problem in disengaging attention.

Dysfunctional attentional mechanisms have been proposed to account for a range of autistic symptomatology. For example, Courchesne et al. (1994a) argued that deficits in shifting attention may underpin many of the social symptoms of autism. Using a prospective study design, Berger et al. (1993) found that cognitive shifting ability strongly predicted level of social understanding in autism. Similarly, Casey et al. (1993) proposed that the increased prevalence of savant skills in the autism population was related to attentional anomalies.

Mottron and Belleville (1993) have suggested that global processing anomalies observed in autism may be related to a problem with shifting attention away from the local details of a Gestalt. Indeed it is well established that individuals with autism clinically appear to be overfocused on 'parts of objects' (DSM-IV, p. 73). Using a hierarchical 'selective attention' paradigm, Rinehart et al. (in press) found that incongruent local information disrupts global processing for individuals with autism and Asperger's disorder, and that this was not true for normal healthy controls (although see Mottron et al., 1999; Ozonoff et al., 1994; Plaisted et al., 1999 for contradictory findings). It was suggested that this style of processing is underpinned by an inhibitory deficit: for example, these disorder groups fail to inhibit local detail from intruding on global perception. A similar inhibitory problem was suggested by Plaisted et al. (1999) on the basis of their hierarchical processing study where participants were shown a series of hierarchical configurations which were either compatible, neutral or incompatible, and asked to identify whether a large A was present or not present within a particular hierarchical configuration. Participants were not informed about whether the target stimulus (i.e. A) was to appear 'locally' or 'globally' (cf. Rinehart et al., in press). These authors found that individuals with autism made more errors when responding at the global level when the stimuli at the local level were incongruent (e.g. a global/large A made up of local/small Hs). Thus, two quite separate experimental paradigms – for example, a 'selective attention' task (Rinehart et al., in press) and a 'divided attention' task (Plaisted et al., 1999) – have shown that individuals with autism have a bias towards processing locally, as evidenced by disrupted global processing when the local level is incompatible.

In addition to an inhibitory deficit, Plaisted et al. (1999) suggested that the local interference pattern observed in individuals with autism may also arise from an attention shifting deficit coupled with an innate propensity to focus attention at a local level. The relationship between this visual-perceptual anomaly and attentional deficits in autism can, in part, be established by examining whether individuals with autism have a particular difficulty in shifting attention between 'parts' and 'wholes'. Unfortunately, Plaisted et al.'s paradigm did not lend itself to a direct measure of attentional set-shifting between hierarchical levels.

The aim of this study was therefore to examine whether individuals with high-functioning autism and Asperger's disorder are slower at shifting attention between hierarchical stimuli, relative to age, sex and IQ matched non-clinical controls. On the premise that these groups may have difficulty shifting attention from a detail of the object to the whole object, we more specifically predicted that both groups would be slower at shifting attention from a local stimulus to a global stimulus. In this experiment, participants were required to maintain or shift attention across consecutive trials depending on whether the target remained at the same hierarchical level.

Table 1 **Sex, age and full scale IQ range for the high-functioning autism group**

Participants	*Sex*	*Age*	*FIQ range (IQ midpoint)*	
1	M	8.0	AV	(99.5)
2	M	11.3	LAV	(84.5)
3	M	11.0	LAV	(84.5)
4	F	6.8	AV	(99.5)
5	M	9.6	AV	(99.5)
6	M	6.4	AV	(99.5)
7	M	7.7	BORD	(74.5)
8	M	8.4	HAV	(114.5)
9	M	15.2	LAV	(84.5)
10	M	15.3	AV	(99.5)
11	M	10.8	LAV	(84.5)
12	M	8.1	AV	(99.5)
Mean		9.9		93.7
SD		3.0		11.0

FIQ, full scale IQ; BORD, borderline; LAV, low average; AV, average; HAV, high average.

Method

Participants

Twelve individuals with high-functioning autism (HFA) (11 males and 1 female), as well as 12 control participants matched on age, sex and full scale IQ, participated in the study. In addition, 12 individuals with Asperger's disorder (AD) (10 males and 2 females) and another 12 controls who were matched according to age, sex and full scale IQ were recruited. One-way analysis of variance (ANOVA) uncovered no significant age difference between the HFA and control group ($F(1, 22) = 0.001$, $p = 0.98$) (HFA, mean age 9.9 years; controls, mean age 9.9 years). There was also no significant age difference between the AD and matched control group ($F(1, 22) = 0.003$, $p = 0.96$) (AD, mean age 12.5 years; controls, mean age 12.5 years) (see Tables 1 and 2 for participant details).

Participants were referred from five different pervasive developmental disorder specialist assessment services. The participants with high-functioning autism fulfilled DSM-IV criteria for autistic disorder. The participants in the Asperger's disorder group satisfied DSM-IV criteria for Asperger's disorder. Four experienced clinicians were involved in diagnosis. Diagnostic information was gathered using the Autism Diagnostic Interview–Revised (Lord et al., 1994), structured parent interview, direct child observations, and information from other sources such as teachers and therapists. Inter-rater reliability, calculated on a sample of 107 cases of

Table 2 **Sex, age and full scale IQ range for the Asperger's disorder group**

Participants	*Sex*	*Age*	*FIQ range (IQ midpoint)*	
1	M	11.2	HAV	(114.5)
2	M	7.4	SUP	(124.5)
3	M	11.4	AV	(99.5)
4	M	10.3	SUP	(124.5)
5	M	20.2	HAV	(114.5)
6	M	10.3	LAV	(84.5)
7	M	17.5	BORD	(74.5)
8	M	13.3	VSUP	(134.5)
9	F	6.8	LAV	(84.5)
10	M	15.1	BORD	(74.5)
11	M	13.1	LAV	(84.5)
12	F	14.0	HAV	(114.5)
Mean		12.5		102.8
SD		3.8		21.8

FIQ, full scale IQ; BORD, borderline; LAV, low average; AV, average; HAV, high average; SUP, superior; VSUP, very superior.

autism and Asperger's disorder, generated a Cohen kappa of 0.95 for autism and 0.94 for Asperger's disorder, thereby indicating encouraging agreement.

Participants were included only if their performance and verbal IQ were above 70. In addition, participants were excluded if they had previously experienced the following conditions: comorbid medical (e.g. tuberous sclerosis), hearing or visual, neurological (e.g. epilepsy), psychiatric (e.g. Tourette's, attention deficit hyperactivity disorder) or genetic (e.g. fragile X disorder), other than the primary diagnosis of HFA or AD. None of the families that were approached refused to participate or subsequently abandoned the study. The cognitive functioning of the HFA and AD groups was established from previous cognitive assessment undertaken at the time of diagnosis. If 3 or more years had lapsed since diagnosis, the cognitive function of participants was reassessed using an age-appropriate Wechsler intelligence test. It was only possible to report IQ range because some of the participating assessment services do not provide specific IQ scores. For the purposes of statistical comparison, the mid range of each IQ range was utilized; for example, a full scale IQ in the average range (90–109) was recorded as 99.5.

Intellectual functioning in control participants was established using a short form of the Wechsler Intelligence Scales (either WPPSI–R, WISC–III–R, or WAIS–R), consisting of two verbal (information and vocabulary) and two performance subtests (picture completion and block design). This particular short form loads highly on verbal comprehension and visual-perceptual organization skills, and is a reliable estimate of full scale IQ scores (Sattler, 1992). Control participants were matched to clinical participants on the basis of full scale IQ. One-way ANOVAs confirmed no significant difference in IQ between the HFA and their matched controls ($F(1, 22) = 2.71$, $p = 0.11$) or between the AD and their matched controls ($F(1, 22) = 0.01$, $p = 0.96$).

Normal behavioural functioning was screened in both control groups using the parent form of the Child Behaviour Checklist (CBCL) (Achenbach, 1991). None of the control participants were reported to have levels of clinically significant behavioural problems.

Stimuli

On each trial, a hierarchical stimulus was presented on a computer monitor. The hierarchical stimulus was a large or global number composed of smaller or local numbers. In particular, the global 1s and 2s were always composed of local 3s and 4s, whereas the global 3s and 4s were always composed of local 1s and 2s. Global stimuli were 45 mm in height, ranged from 13–28 mm in width, and subtended a visual angle of 5.1×1.5–3.2 degrees. Local stimuli were 4×2.5–3 mm and subtended a visual angle of 0.5×0.1–0.3 degrees. All stimuli were white and presented on a black background (see Figure 1).

Procedure

The participants in this study had previously participated in Rinehart et al.'s (in press) selective attention hierarchical processing experiment. Participants sat directly in front of a Toshiba Notebook (440 CDT Satellite Pro; active screen) at a standard distance of 50 cm from the screen. Both arms were extended so that the index finger of each hand rested over one of the two microswitch buttons positioned at 30 cm either side of the midline. Participants fixated on a central dot while a 500 ms warning tone was presented. The hierarchical stimulus was then presented at this location. Participants pressed the left button when either the global or the local component was a 1; and pressed the right button when either the global or the local component was a 2. Participants were instructed to respond as quickly and accurately as possible.

The design yielded four configuration types. First, the 'global–global' (GG) type denotes a consecutive pair of stimuli in which the target appeared at the global level in both cases. Likewise, the 'local–local' (LL) type refers to a consecutive pair of stimuli in which the target was presented at the local

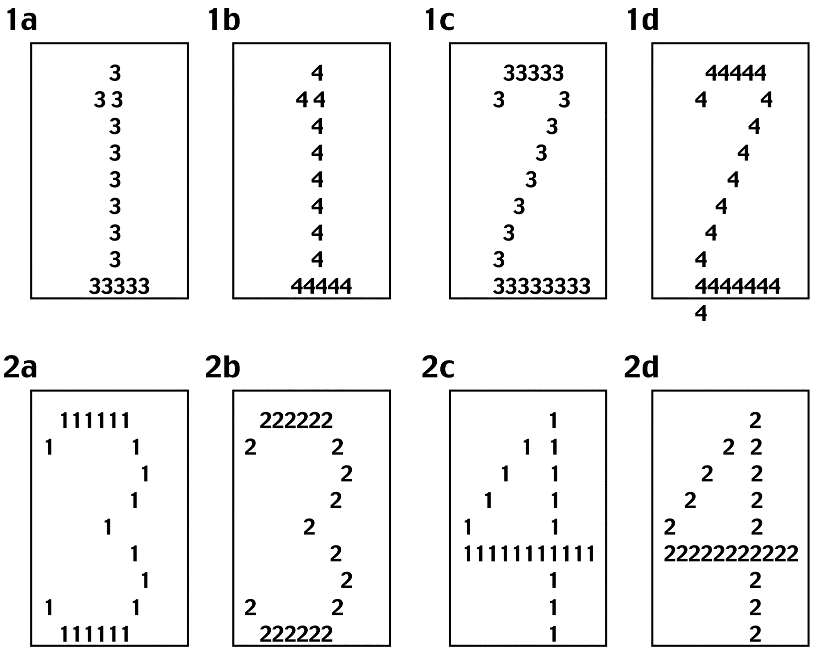

Figure 1 **Stimuli used for local–global shifting. The first four stimuli 1a–d represent the 'global' configurations, and the other four stimuli 2a–d the 'local' configurations**

level in both cases. The GL and LG configurations are defined analogously (see Figure 1).

Each participant completed a set of 12 practice trials with feedback about accuracy and reaction time (RT), and then completed a total of 132 experimental trials in four separate blocks of 33 trials without feedback. After completion of two sets of 33 trials, each participant was allowed a 5 minute break before completing the other half of the experiment.

Separate analyses were undertaken for RT and error rate. Likewise, the configuration types that involve maintenance of hierarchy (i.e. GG and LL) were subjected to separate analyses from configuration types that involve shifts in hierarchy (i.e. GL or LG). Finally, the two clinical groups, who were compared to their respective controls, were analysed separately.

Results

High functioning autism (HFA)

The initial series of analyses compared the individuals with HFA with their non-clinical counterparts. A two-way ANOVA was undertaken in which

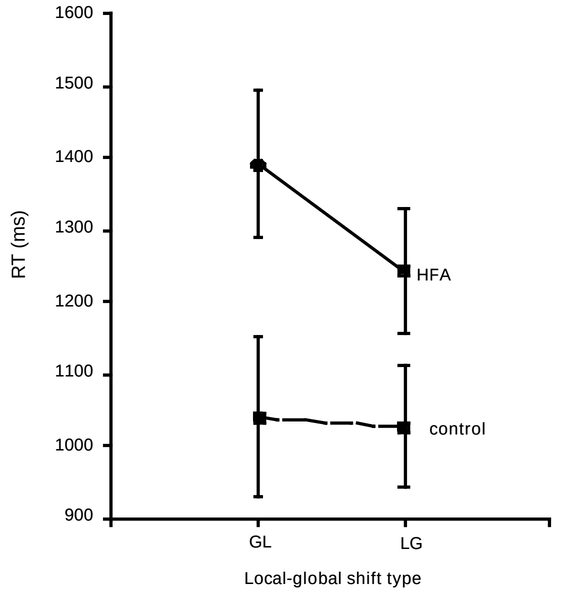

Figure 2 **Local–global shifting: mean RT (ms) for LG (shifting from a local to a global configuration) and GL (shifting from a global to local configuration) sequences for the high-functioning autism (HFA) and control groups (SE bars shown)**

response type (i.e. GG or LL response) was manipulated within subjects and group (HFA versus controls) was manipulated between subjects. There was no effect of group ($F(1, 22) = 2.98$, $p = 0.10$) or configuration type ($F(1, 22) = 0.12$, $p = 0.74$) and no group by configuration type interaction ($F(1, 22) = 0.02$, $p = 0.90$). Thus, the HFA group responded at the same speed as controls when presented with stimuli which maintained hierarchical level (i.e. GG or LL); also both groups showed no advantage when a global response was preceded by a global response compared with when a local response was preceded by a local response.

Secondly, RT data comparing response to shifting between hierarchical levels (i.e. an LG shift or a GL shift) were analysed using an analogous two-way ANOVA. Group ($F(1, 22) = 4.67$, $p = 0.04$) and configuration type ($F(1, 22) = 5.31$, $p = 0.03$) significantly affected RT. There was a trend towards a group by configuration type interaction: thus the HFA group were overall slower at shifting between hierarchical levels in comparison with controls ($F(1, 22) = 3.62$, $p = 0.07$) (see Figure 2). Although non-significant, this interaction of group by configuration type suggests that the HFA group were slower to shift from a local to a global configuration than the converse, unlike controls who did not differ between configurations (see Figure 2). This trend is consistent with the notion that individuals with HFA exhibit difficulties in shifting attention from a detail (i.e. local response) to a whole (i.e. global response). As a follow-up to this trend an analysis of the simple main effects was undertaken and confirmed that the HFA group were significantly slower when shifting from a local to a global configuration relative to controls ($F(1, 11) = 8.09$, $p = 0.02$); for the control group the simple main effect of configuration type did not attain significance ($F(1, 11) = 0.09$, $p = 0.77$).

Errors Mean errors were not influenced by group ($F(1, 22) = 0.35$, $p = 0.56$) or maintenance of hierarchical response level (i.e. GG, LL) ($F(1, 22) = 0.29$, $p = 0.60$). Also, these variables did not interact ($F(1, 22) = 0.01$, $p = 0.92$). Furthermore, there was no effect of group ($F(1, 22) = 1.76$, $p = 0.20$) or configuration type ($F(1, 22) = 0.47$, $p = 0.50$), or a group by configuration type interaction ($F(1, 22) = 0.77$, $p = 0.77$), for error data requiring a shift of hierarchical level.

Asperger's disorder (AD)

The second set of analyses was applied to the AD and control groups again using a two-way ANOVA in which response type (i.e. GG or LL response) was manipulated within subjects, and group (AD, controls) was manipulated between subjects. RT was unaffected by group ($F(1, 22) = 1.26$, $p = 0.27$) or by configuration type ($F(1, 22) = 1.01$, $p = 0.33$) and there was no group by configuration type interaction ($F(1, 22) = 0.21$, $p = 0.66$). Therefore, both the AD and control groups responded similarly when presented with stimuli that maintained hierarchical level (i.e. GG or LL), and both groups showed no advantage when responding to a global–global sequence over a local–local sequence.

Analysis of the RT for response shifting (i.e. LG, GL) also uncovered no effect of group ($F(1, 22) = 1.20$, $p = 0.29$) or configuration type ($F(1, 22) = 3.46$, $p = 0.08$). There was clearly no interaction between group and configuration type ($F(1, 22) = 0.48$, $p = 0.50$).

Errors A two-way analysis of error data revealed no effect of group ($F(1, 22) = 0.07$, $p = 0.79$) or configuration type ($F(1, 22) = 1.06$, $p = 0.32$) and no group by configuration type interaction ($F(1, 22) = 1.66$, $p = 0.21$) for stimuli requiring a maintenance of hierarchical level.

Error data for stimuli requiring a shift of hierarchical level was not affected by group ($F(1, 22) = 2.03$, $p = 0.17$); although there was a main effect of configuration type ($F(1, 22) = 4.65$, $p = 0.04$) there was no group by configuration type interaction ($F(1, 22) = 0.02$, $p = 0.90$). Therefore, both groups committed more errors when shifting from a global to a local configuration.

Discussion

In this experiment, we examined the effect of shifting between local and global processing sets or maintaining such sets. Individuals with autism were slower than controls at shifting processing set, especially in a local to global direction. Thus, there was an adverse impact upon global processing when it was immediately preceded by local processing; a shift in the opposite direction was less debilitating.

Overall, these results are consistent with theories that predict executive dysfunction, in particular attentional shifting and cognitive flexibility deficits (Courchesne et al., 1994a; 1994b; Damasio and Maurer, 1978; Maurer and Damasio, 1982; Ozonoff and Jensen, 1999; Pennington and Ozonoff, 1996; Prior and Hoffman, 1990; Rumsey and Hamburger, 1988). These results also add another dimension to these theories by suggesting an aspect of shifting that is particularly impaired: shifting from a detail to a whole. The idea that individuals with autism might fixate on detail also coalesces with clinical observations implicating a 'preoccupation with parts' (DSM-IV, p. 73). These findings are consistent with the prediction that individuals with autism may have a problem with inhibiting local information and also a problem with shifting attention away from such stimuli (Plaisted et al., 1999).

Individuals with Asperger's disorder did not exhibit a deficit in shifting attentional set. This finding challenges theories that suggest a causal link between attention shifting deficits and the social/emotional deficits observed in individuals with autism and Asperger's disorder (e.g. Berger et al., 1993; Courchesne et al., 1994a; 1994b). Nonetheless, this result of a *qualitative* difference between autism and Asperger's disorder supports recent studies (i.e. Ghaziuddin and Gerstein, 1996; Tonge et al., 1999; Ziatas et al., 1998) which suggest that these disorders may have unique neurobiological underpinnings. The dissociation of attentional shifting in autism and Asperger's disorder may suggest differential involvement of the dorsolateral prefrontal circuit in these disorders given its putative role in set shifting (Cummings, 1993).

Plaisted et al. (1999) raised the possibility that visual-perceptual anomalies may arise in autism as a result of a two-stage processing anomaly; for example, instead of processing at a global then local level (see Navon, 1977), individuals with autism begin by focusing at the local level, and additionally have problems shifting attention to the global level. This model may be used to explain why autism and Asperger's disorder groups showed *qualitative* differences on this 'divided attention' hierarchical processing task, but not in Rinehart et al.'s (in press) 'selective attention' hierarchical processing task. In Rinehart et al.'s task, *both* autism and Asperger's disorder groups exhibited an atypical local processing intrusion on global processing. It is possible that these findings pertained to Plaisted et al.'s first stage, for example, a local bias. In this study, only the autism group showed a problem with shifting attention between hierarchical stimuli. This finding may indicate that in addition to a local bias, individuals with autism, but not Asperger's disorder, exhibit a set-shifting deficiency. Essentially, it is being suggested that individuals with autism and Asperger's disorder share a core visual-perceptual anomaly (i.e. local bias), but that individuals with autism have an additional set-shifting anomaly which leads to greater functional impairment. This proposal is generally consistent with the clinical 'spectrum' notion which predicts that autism and Asperger's disorder exist on a continuum with Asperger's disorder showing milder 'autistic' features.

Both the Asperger's disorder and matched control group committed more errors when a global response preceded a local response. This finding did not arise in the autism and matched control group who were 2.6 years younger. This inconsistency could be imputed to a general developmental difference; the typical bias towards global, rather than local processing that appears in adults may have yet to emerge in the two younger groups (Navon, 1977).

Research examining the clinical presentation of young children with autism has found that the clinical features of autism change over time, for example, restricted and stereotyped behaviours have been reported to become more pronounced as children with autism develop (Howlin and Ashgarian, 1999). It is possible that the neurobehavioural characteristics of autism also change over time. Thus, although the autism and Asperger's disorder groups were not directly compared, constraints on recruitment resulting in a 2.6 year age difference between these groups could have had implications for the interpretation of these results. For example, it is conceivable that age and set-shifting ability may have interacted in some way which could explain some of the observed qualitative differences in the performance of these groups.

In conclusion, this study has found that individuals with autism were slower at shifting attention between hierarchical levels; this deficiency was particularly pronounced when *shifting attention from a local to a global level*. Individuals with Asperger's disorder exhibited normal set-shifting ability in this 'divided attention' hierarchical task. On the basis of these findings, it was suggested that individuals with autism may show greater executive functional deficiencies (i.e. set shifting) in comparison to individuals with Asperger's disorder. Ozonoff and Strayer (1997) point out that it is often difficult to determine which aspect of executive function is being measured during a cognitive task, for example, *inhibition* is implicit in most tasks which invoke cognitive *set shifting*. Set-shifting ability additionally requires the capacity to *disengage attention* and the ability to maintain the appropriate preparatory set in *working memory*. It is therefore possible that deficiencies in one or more of these areas (i.e. set shifting, inhibition, disengaging attention, working memory) could explain our results. The suggestion that individuals with autism have difficulty inhibiting local detail is somewhat at odds with Ozonoff and Jensen's (1999) conclusion that inhibitory function is intact in autism. The findings reported in this paper extend those of Plaisted et al.'s (1999) and support their proposal that perhaps weak central coherence is best conceptualized as a problem with filtering out, or shifting attention away from, local detail rather than a problem in the ability to draw details together into a global percept (Frith, 1989; Plaisted et al., 1999).

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