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LETTER TO THE EDITOR

Is the Ability to Integrate Parts into Wholes Affected in Autism Spectrum Disorder?

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Abstract There is considerable debate about whether people with autism spectrum disorder (ASD) are biased toward local information and whether this disrupts their ability to integrate two complex shapes elements into a single figure. Moreover, few have examined the relationship between integration ability and ASD symptom severity. Adolescent/adult males with ASD and age and IQ-matched controls were compared on their performance of a simple silhouette-to-shape matching task and a higher-order shape-integration task. Relative to basic silhouette-to-shape matching, ASD participants were disproportionately slower than controls on shape-integration. Moreover, this relative slowing correlated with increased symptom severity in ASD participants. These findings support the notion that integrating local information is disproportionately more challenging in ASD; this weakness may play a role in ASD symptomatology.

Keywords Integration of shapes · Local detail · Sociality · Visual processing

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Introduction

In the seminal work "Autism: Explaining the Enigma" (1989), Frith described the natural tendency towards coherence and that "without this type of high-level cohesion, pieces of information would just remain pieces" (p. 98). Frith (2003) later elaborated that "in the normal cognitive system there is a built-in propensity to form coherence over as wide a range of stimuli as possible, and to generalize over as wide a range of contexts as possible" (pp. 159–160). An example of central coherence is our effortless ability to utilize contextual cues to acquire the correct meaning of ambiguous words heard during speech (e.g. son/sun, meet/meat, sew/so, pear/pair; Happé 1999). Frith (1989, 2003) suggests this natural drive (central coherence) is weak in individuals with autism spectrum disorder (ASD). People with ASD, instead, excessively focus on parts, often in the process sacrificing integration of these parts into coherent wholes. The weak central coherence hypothesis suggests this imbalance in processing (towards parts over wholes) is demonstrated by superior ASD performance in tasks where gestalt processing is disadvantageous and/or focus on parts is advantageous. Frith was among the first to propose a theory that could account for both ASD deficits and atypical *strengths* (e.g. savant skills, better visual search, superior block design (BD) performance; superior embedded figures task performance (see Happé 1999, for a review).

Much of early ASD research neatly fit the main tenets of weak central coherence (Frith and Snowling 1983; Hermelin and O'Connor 1967; Kanner 1943; Shah and Frith 1983; Snowling and Frith 1986). A review of the literature today reveals much evidence of superior local processing, but less consistent evidence of the diminished integrative processing predicted by the weak central coherence hypothesis (Happé and Booth 2008; Happé and Frith 2006). Happé and Booth (2008) implored researchers to employ paradigms that better examine the ability of individuals with ASD to integrate parts into whole. The primary aim of the present study was to revisit the notion of weak integrative processing in people with ASD with a new task.

Visual Integration of Parts in ASD

There is evidence that individuals with ASD may have more difficulty with the requirement to actively integrate parts than merely matching parts. For example, Deruelle et al. (2006a) observed atypical configural processing in a group of children with ASD. In the configural task, participants were shown schematic faces (composed of simple geometric shapes) and asked to indicate which of the two faces on the bottom was the best match to the face on the top. One figure matched the *global configuration* of the schematic faces, but the local elements (geometric shapes) differed from the schematic face, whereas the other figure matched the local elements of the schematic face, but the global configuration differed (i.e. the inter-elemental distances differed). Only the ASD group showed a local bias (greater number of local level choices) on this configural task. Results showed that while more basic form processing was spared in these ASD individuals, configural processing (which requires integration of local elements into meaningful wholes) was more difficult for them than their controls. It has also been suggested that the formation of global constructs may be more time-consuming in ASD individuals (Shalev 2007). Several other groups have observed reduced spatial integration ability in people with ASD (Booth et al. 2003; Jolliffe and Baron-Cohen 2001; Nakano et al. 2010). Jolliffe and Baron-Cohen (2001) employed the Hooper Visual Organization Test which has line drawings of common objects cut into pieces and the task is to visually integrate the pieces and name the object. The ASD group named fewer objects correctly than matched controls. Nakano et al. (2010) employed an integration task where ASD adults and matched controls were shown a portion of an object through a slit; by the end of each trial the whole image was displayed, but only one segment at a time; thus, integration of the segments, across time, was required. Findings showed ASD individuals had poorer performance (slower and less accurate) than controls. These studies suggest that a reduced ability to integrate parts into a whole is a key feature of processing style in ASD.

Two Novel Silhouette Tasks

In the traditional task, participants are shown the silhouette of drawings of common objects and asked to find matches. Similar tasks have been used by a number of groups to examine basic shape matching (Deruelle et al. 2006b, in children with William's syndrome; Mottron et al. 2003, in high-functioning children and adolescents with ASD). Relative to matched controls, both Mottron et al. (2003) and Deruelle et al. (2006a, b) observed no processing impairments in the relevant clinical group when employing these traditional silhouette tasks.

The traditional silhouette tasks had several limitations: (1) the tasks were too easy making them vulnerable to ceiling effects, (2) they used simple and familiar shapes or objects, that could be named; (3) Some required explicit naming. To avoid these problems, the present study (1) employed novel, and non-verbalizable geometric shapes, and (2) the tasks were designed to be sufficiently demanding to avoid ceiling effects. The present study utilized two types of novel silhouette tasks to better elucidate the profile of global processing in people with ASD. In the first silhouette task (the silhouette-to-shape matching task), participants must decide which of two solid black silhouettes match a white target shape presented above; only the outer contour of the target shape is relevant. In the second silhouette task (the shape-integration task) participants must visually combine the two white shapes, and then decide which of two solid black silhouettes (on the bottom) match the fusion of the two white target shapes (presented above). This second silhouette task requires an additional step than the first silhouette task; participants must not only process the basic silhouettes, they must also integrate these silhouettes into a single whole figure. We predicted the difference in performance of the silhouette-to-shape matching task and the shape-integration task would be greater in the ASD compared to the typical control (C) group, suggesting that integration of these two elements is more challenging in people with ASD.

In both silhouette tasks, a novel local-detail condition was included to examine if the addition of distracting task-irrelevant local detail within the target shapes disproportionately affected integrative processing in the ASD group.

Atypical Integrative Processing and ASD Social Symptom Severity

In the original formulation (Frith 1989) weak central coherence had a causal role in ASD social (and nonsocial) behavioral symptoms. Frith proposed that excessive focus on details paired with impaired ability to integrate information for high-level meaning greatly impacts social functioning in people with ASD (Frith 1989; Happé and Frith 2006). It is easy to see how difficulty processing context would greatly impact social skills, as social communication and interactions are filled with subtle cues and are heavily reliant on context integration (Penn et al. 2002; Russell-Smith et al. 2012).

Table 1 Participant characteristics

	ASD (n = 20) Mean (SE)	Control (n = 20) Mean (SE)
Age (years)	20.1 (.8)	19.6 (.3)
Kaufman Brief Intelligence Test (KBIT) scores		
Full IQ	105.3 (3.7)	101.6 (2.9)
Verbal IQ	100.5 (4.4)	100.1 (3.8)
Non-verbal IQ	108.4 (2.9)	102.2 (3.0)
Autism Diagnostic Observation Schedule (ADOS) scores		
Communication	3.6 (.3)	–
Social	8.3 (.6)	–
Repetitive behaviors	1.5 (.3)	–
Social Responsiveness Scale (SRS) Social Subscale scores		
Awareness	65.3 (3.0)	–
Cognition	73.8 (2.8)	–
Communication	74.1 (3.2)	–
Motivation	71.5 (2.7)	–
Mannerisms	77.5 (3.1)	–[a]

[a] ADOS and SRS only administered to ASD participants

Some have found a relationship between weak central coherence and ASD social cognitive impairments (Baron-Cohen and Hammer 1997; Jarrold et al. 2000; Russell-Smith et al. 2012); however, others have not (Burnette et al. 2005; Happé 1997; Morgan et al. 2003; Pellicano et al. 2006). These conflicting findings led Frith to downgrade her emphasis on the causal relationship between weak central coherence and social dysfunction in ASD (Happé and Frith 2006). Russell-Smith et al. (2012), however, assert these conflicting findings merely demonstrate that additional empirical evidence is needed to help clarify the association between atypical integrative processing in ASD and social behavioral impairments.

There is little evidence about the relationship between the ability to integrate parts into whole figures and ASD symptom severity. The current study investigated this association using the Social Responsiveness Scale (SRS). We predicted that a relative difficulty integrating shapes would correlate with ASD social symptom severity.

Methods

Participants

Twenty male adolescents and adults with ASD and 20 male control participants were recruited for this study. The project was approved by the Institutional Review Board at Boston University and informed consent was obtained from all participants. All ASD participants had previously been diagnosed by a clinician and met the DSM-IV-TR diagnostic criteria for autism/ASD (APA 2000). Clinical diagnoses of ASD were confirmed using the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999, 2000). All ASD participants received compensation for their participation. Control participants were undergraduates at Boston University and received course credit for their participation.

Independent samples *t* tests (two-tailed) confirmed that the groups were matched on age and full scale IQ as assessed by the Kaufman Brief Intelligence Test, second edition, KBIT-2 (Kaufman and Kaufman 2004). There were no significant group differences in age, $t(24.11) = -0.56$, $p = .58$, full scale IQ, $t(38) = -0.79$, $p = .43$, nonverbal IQ, $t(38) = -1.49$, $p = .14$, or verbal IQ, $t(38) = -0.07$, $p = .94$ (see Table 1 for participant characteristics).

Both tasks were piloted with 100 undergraduate Boston University students to (1) identify any flaws in task design or procedure, and (2) avoid floor or ceiling effects (the goal was an average accuracy of approximately 80 %).

Social Responsiveness Scale

The SRS is a 65-item questionnaire that was completed by the parents of the ASD participants. It provides a continuous measure of the severity of ASD behaviors, with an emphasis on impairments in social interaction and communication (Constantino and Gruber 2005; Constantino et al. 2007). The questionnaire has five subscales (social awareness, social cognition, social communication, social motivation, and autistic mannerisms; Constantino et al. 2003). Raw summary and Subscale scores are converted into standardized T-summary and Subscale scores (higher T scores suggest greater social impairment).

Apparatus

The tasks were presented using E-prime 1.2 software (Psychology Software Tools, Inc.) on a Pentium IV 3.2 GHz/2 GB PC with a 19 in. LCD display. Participants were seated approximately 60 cm from the computer screen. Test responses were collected via a two choice button box.

Silhouette Task 1 (ST1): Silhouette-to-Shape Matching Task

Stimuli

Twenty-eight unique white test target shapes and 14 unique white control shapes were designed and presented on a gray background. Silhouette shapes were created by blackening each target shape. For each white target shape a

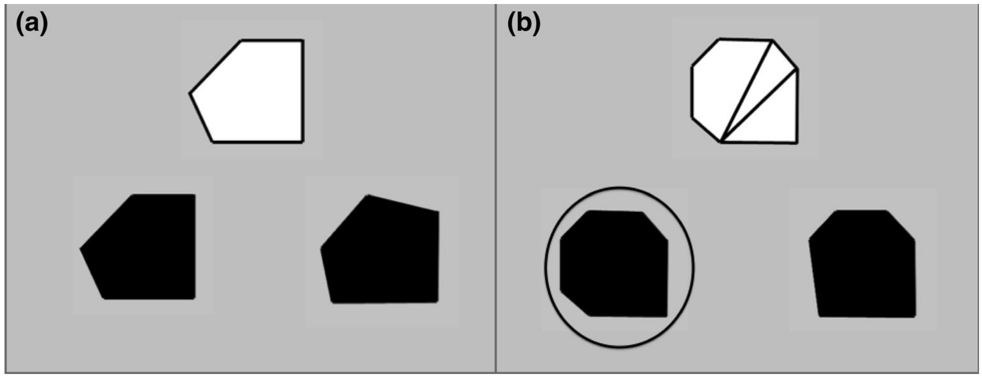

Fig. 1 Illustration of ST1: Silhouette-to-shape matching test trial. **a** A *white* target shape is presented at *top* of the screen, two *black* silhouettes are presented *below*. For both trials, the correct *silhouette shape* is the *black* silhouette on *left*. An example of the detail condition is shown in (**b**), *top white shape*

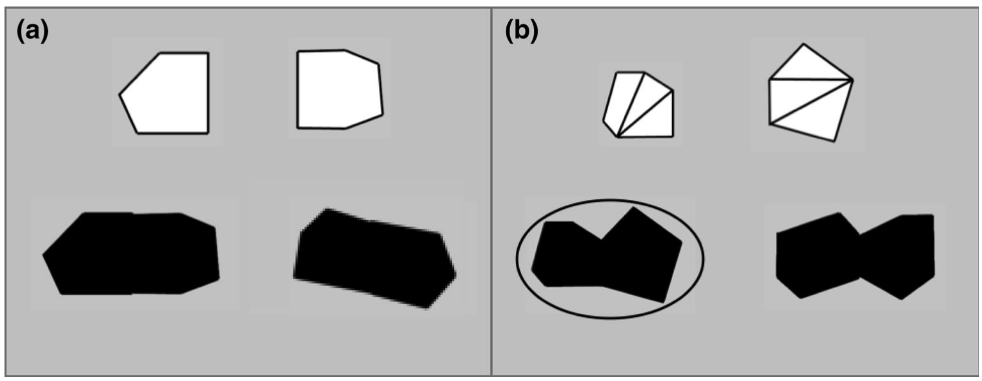

Fig. 2 Illustration of ST2: shape-integration test trial. Two *white* targets are presented at the *top* of the screen; two *black* silhouettes are presented *below*. For both trials, the correct integration of the two target shapes is the *black* silhouette on *left*. An example of the detail condition shown in (**b**), the *top white shapes*

counterpart was created that was identical, except two lines were used to segment it (see Fig. 1b, top shape), thus introducing potentially distracting local detail. Two black silhouettes were presented below a white target shape; one matched the target. The foil and the correct silhouette had approximately the same surface area and number of sides.

Design

The task was composed of three sections: practice, test, and control conditions. Practice was composed of two blocks, with eight trials each. Each target shape was presented twice in each block (once with segmentation lines, once without). Test sections followed the same format (two blocks-per-condition), except each consisted of 28 trials-per-block. Trials were presented in random order within each block.

Procedure

Participants were told they would see a target geometric shape, below which would be two blackened shapes which formed silhouettes. Participants were asked to decide, as quickly as possible while avoiding errors, which of the two silhouette shapes matched the target shape and indicate their choice via a two-button response key. Stimuli were presented for 1,500 ms, followed by a 1,000 ms fixation cross. If participants did not respond within 1,500 ms they were shown a new screen that prompted them for a response. Practice trials were administered with corrective feedback to help familiarize participants with the experimental demands.

Silhouette Task 2 (ST2): Shape-Integration Task

Stimuli

Twenty-eight unique test silhouette shapes were designed. Each silhouette figure was created by blackening and combining two smaller white geometric shapes. All shapes were presented on a gray background. For each white target shape a counterpart was created that was identical in every way, except two lines were used to segment the shape into three parts (see Fig. 2b, top shapes).

Procedure

Participants were told they would see two white shapes above be two black silhouettes. They were asked to choose, using the response key, which of the two blackened silhouettes at the bottom matched the *combination* of the two white target shapes at the top. They were told that the

Table 2 Means (standard errors) of ST1: silhouette-to-shape matching and ST2: shape-integration

	ST1: Silhouette-to-shape matching		ST2: Shape-integration	
	ASD group	Control group	ASD group	Control group
RT	1,195.57 (70.52)	1,276.44 (90.42)	1,657.78 (92.90)	1,510.86 (103.84)
Accuracy	88.7 (2.2)	86.0 (1.8)	79.5 (2.3)	81.2 (2.2)

fusion of the shapes did not require rotating either one of them.

Results

Since the order of presentation of ST1 and ST2 was counterbalanced across participants, we checked that task order had no significant effect on accuracy and speed, and then averaged the data across task order.

There were no significant differences in the mean accuracy (ST2–ST1) difference score between the ASD ($M = 9.2$, $SE = 1.9$) and the C ($M = 4.7$, $SE = 2.0$) groups. These results were not contaminated by a speed-accuracy trade-off since the correlation between ST2 and ST1 reaction time and ST1–ST2 accuracy ($r(19) = .05$; $p = .86$). Unless otherwise stated, results remained significant even when age and full scale IQ were included as covariates. RT data were analyzed for correct trials only. Partial eta-squared (η_p^2) was used as a measure of effect size. Alpha was set at .05. Mean RT and accuracy (for test trials) for each group are shown in Table 2. All data are shown without covariate adjustments (Fig. 3).

Task Performance and ASD Social Symptom Severity

In the ASD group, partial correlational analyses, controlling for age and IQ, were conducted to examine the relationship between the RT difference score and ASD social symptom severity, using the SRS Social Subscales (awareness, cognition, communication, motivation, and mannerisms, and the summary score). There was a significant positive correlation between the RT difference score and the SRS-Social Motivation Subscale, $r(16) = .51$, $p = .02$ (see Fig. 4); however, none of the other correlations reached statistical significance (see Table 3). As ASD social motivation impairment increased, the disruption in the shape-integration task (relative to the silhouette-to-shape matching task) increased.[1]

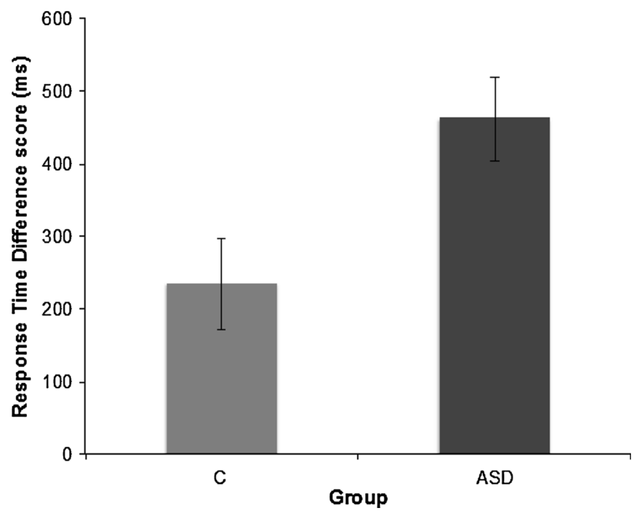

Fig. 3 Mean RT difference score (ST2–ST1) by group. *Error bars* represent standard errors of means

Effect of Local Detail

For each task (ST1 and ST2), a repeated measures analysis of variance was conducted with a between-subjects factor of group (ASD, C) and a within-subjects factor of condition (No Detail, Detail) using RT and accuracy measures, with age and IQ as covariates. On both tasks and for both measures there was a main effect of detail, but there was no effect of group or any group by detail interaction. For ST1, the presence of detail significantly slowed performance, $F(1, 38) = 16.29$, $p < .001$, $\eta_p^2 = .30$ (Detail $M = 1{,}269.17$, $SE = 60.31$; No Detail $M = 1{,}205.69$, $SE = 55.34$). For ST2, the presence of detail also significantly slowed performance, $F(1, 38) = 11.67$, $p = .002$, $\eta_p^2 = .23$ (Detail $M = 1{,}622.10$, $SE = 72.93$; No Detail

[1] Since the ASD sample size was 20, there was a risk concern that the findings might have been pulled by an outlier and/or the use of covariates. We tightened our cutpoint from 2.5 to 2.0 SD from the mean of the ST2–ST1 RT difference score. One participant's SD was 2.1; we labeled him a potential outlier. We retested the strength of the correlation between SRS Motivation Score and the ST2–ST1 RT difference score remained between .51 and 5.3 ($p < .05$) with or

Footnote 1 continued
without the potential outlier and/or the covariates. We used the comparison of two correlations with one variable in common from the same sample (Meng et al. 1992) to assure the reader that the ST2–ST1 RT difference score was in fact more strongly correlated with the Motivation subscale than either (a) the Overall SRS score ($z = -2.369$. $p = .01$); (b) the Mannerisms subscale, highlighted because it is a measure of non-social repetitive behavior ($z = -2.734$, $p = .01$); and (c) the Awareness Score, which was the next strongest correlation ($z = -2.00$, $p < .05$). Finally, in terms of the ST2–ST1 RT difference score, when all 20 ASD participants were included, the group effect was $F(1, 38) = 16.29$, $p < .001$. The group effect remained significant ($p < .05$) without the potential outlier and/or the covariates.

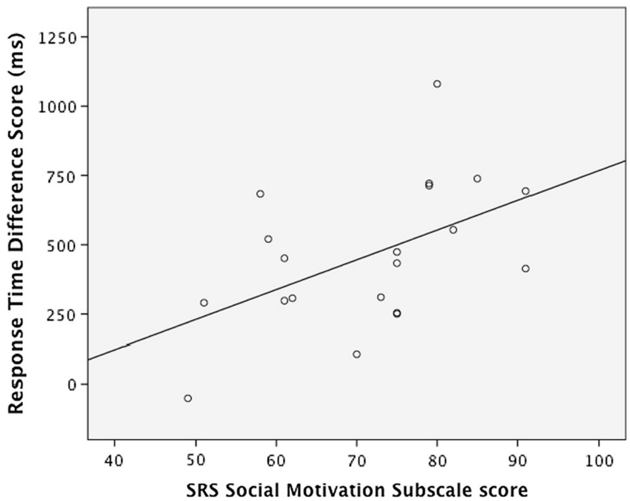

Fig. 4 Scatterplot of significant correlation between SRS-Social Motivation Subscale score and RT difference score (ST2–ST1)

$M = 1{,}550.19$, $SE = 68.38$). Accuracy was also significantly lower on trials with detail for ST1, $F(1, 38) = 33.95$, $p < .001$, $\eta_p^2 = .47$ (Detail $M = 83.7$, $SE = 1.8$; No Detail $M = 90.9$, $SE = 1.3$) and ST2, $F(1, 38) = 12.09$, $p = .001$, $\eta_p^2 = .24$ (Detail $M = 78.3$, $SE = 1.7$; No Detail $M = 82.4$, $SE = 1.8$).

Discussion

The goal of this study was to revisit the weak central coherence theory's claim of reduced integrative processing ability in people with ASD using novel, well-controlled tasks. Based on the assumption that shape-integration (ST2) would require higher-order integrative processing than the basic silhouette-to-shape matching task (ST1), it was predicted that (1) ASD performance would be disproportionately impaired on ST2, (2) this disruption would be related to social symptom severity, and (3) and that ASD performance would be more disrupted in the presence of added detail. We found strong support for the first hypothesis, and some evidence for the second; however, both groups were equally affected by the presence of added detail in the target stimulus. We take up each of these findings in the discussion.

Shape Integration is Disproportionately Slower in ASD than C

The most important finding in this study showed that when we compared the degree to which the higher-order shape-integration task slowed performance relative to the silhouette-to-shape matching task, the ASD group was slowed twice as much as the control group. Since there were no group differences in accuracy between these two tasks, the RT finding was not confounded by a speed-accuracy trade off. Compared to IQ and age-matched controls, ASD participants were disproportionately slower at integrating two independent elements into a single figure. This is the first study to first establish the level of basic silhouette-to-shape matching and then compare it to a higher-order shape-integration task.

The results from the present study also showed that processing which demanded greater integration was more effortful for individuals with ASD. Bertone et al. (2003, 2005) proposed that information requiring more complex neural integration would be more difficult for people with ASD. In a commentary, Shalev (2007) suggested that tasks that demand the formation of an integrated whole are more time-consuming for people with ASD; typicals are more efficient at processing these types of stimuli.

It is important to mention that our finding that shape-integration was worse in our ASD sample than in controls might seem at odds with the superiority of mental image generation repeatedly found within a specific high functioning ASD *subgroup*. This is a subgroup whose BD scores are disproportionately higher than their other IQ subtest scores (Souliéres et al. 2011).

The reasons for this discrepancy in findings may be twofold: there may be differences between our selection of participants or our tasks. In the Souliéres et al. (2011) paper, superiority in mental imagery was only found in one subgroup, but across ASD subgroups the BD score was a strong predictor of the individual's image generation and manipulation; in our ASD sample there was no significant correlation between the ASD/BD score and ST2–ST1 RT difference score ($p = .41$). In addition, in the Souliéres et al. study, participants were excluded from their control group who had BD superiority; no such exclusions were made in our study.

Table 3 Correlation coefficients within the ASD group between SRS Subscale scores and mean difference between RTs (RT) for ST2 and ST1. The degrees of freedom are 18

	SRS overall and Subscale scores					
	Overall	Aware	Cogn.	Comm.	Motiv.	Manner.
RT score (ST2–ST1)	r = .02 $p = .91$	r = .14 $p = .53$	r = .07 $p = .75$	r = .07 $p = .76$	**r = .51** **$p = .02$**	r = −.10 $p = .52$

Bold values indicate the significant correlation

In terms of tasks, mental rotation of irregular geometric figures (Souliéres et al. study; tasks 1 and 2) may only require veridical, isomorphic mapping to identify a match, whereas our task requires that the two shapes be fused together mentally (in their same orientation) and matched to a silhouette.

Slower Integrative Processing is Associated with ASD Low SRS-Social Motivation Scores

We found among ASD participants, that the SRS-Social Motivation Subscale, which relates to differential difficulty with the participant's drive to participate in social situations, was significantly correlated with especial slowness on the shape-integration task compared to the silhouette-to-shape matching task. The social motivation theory of autism has garnered a great deal of interest (for a review, see Chevallier et al. 2012), and asserts that ASD can be viewed as an extreme form of impaired social motivation. "Social motivation models of ASD posit that early-onset impairments in social attention set in motion developmental processes that ultimately deprive the child of adequate social learning experiences and that the resulting imbalance in attending to social and non-social stimuli further disrupts social skill and social cognition development" (Chevallier et al. 2012, p. 4). Both the social motivation and weak central coherence theories place a great emphasis on *drive*. The weak central coherence theory asserts that people with ASD have a weakened *drive* to integrate elements. The social motivation theory asserts that people with ASD have a weakened *drive* to attend to social information. The observed correlation suggests there may be a relationship between ASD impairments and drive in both the social and cognitive domain. Perhaps ASD can be summed up as a disorder in drive, and misplaced attentional focus, both cognitively and socially.[2] More research in large heterogeneous samples of children and adults is needed before any conclusive claims can be made. Future work should place emphasis on concurrent investigation of impaired motivation in both social and cognitive domains in ASD children and adults.

Why Local Detail Did Not Disproportionately Disrupt ASD Individuals

Based on evidence of a local processing bias in individuals with ASD (for review, see Dakin and Frith 2005), we predicted that ASD participants would be disproportionately engaged and distracted by local detail which was irrelevant to the goal of the task. Results showed that while adding local distracting detail did disrupt performance for both ASD and control participants, contrary to predictions, ASD participants were not disproportionately affected. Rinehart et al. (2000) may have the best explanation for when detail will interfere with global processing. Rinehart et al. (2000) argue that incongruent local information disrupts the processing of global information in individuals, only when there is a high level of interference between the global and local levels. In their version of a Navon task, the participant was cued to attend to either the local or global version of the numbers "1" and "2", and to press one of two buttons accordingly. For example, a large global number "2" could be made up of small (local) "2" elements (congruent) or small local "1" elements (incongruent). Therefore, attending to the wrong level during the incongruent trials was guaranteed to be incorrect. Incongruent trials disrupted the ASD but not the control group.

Rinehart et al. (2000) then contrasted their findings with Mottron et al. (1999), who used the targets H and S, with interference generated by a third letter E. In this case, E was not one of the possible target responses (H or S). Mottron et al. (1999) found that the individuals with ASD could ignore these "distracting" as opposed to "interfering" local elements as well as their controls. On the basis of this reasoning, we conclude that in our experiment, the introduction of segmented lines within the target shapes may have been "distracting," but it did not interfere with the global integration of the two shapes into one compound shape in either group.

Conclusion

Is the ability to integrate parts into a single figure affected in people with ASD? In this study a basic silhouette-to-shape matching task and a more complex shape-integration task were created to address this issue. Our findings indicated that relative to their age and IQ-matched controls, individuals with ASD were worse at mentally integrating two complex shapes into a single figure, relative to their ability to decide which of two complex shapes matched, a silhouette of the shape. Our findings may be consistent with Frith's (1989) weak central coherence hypothesis, if our measure is a true measure of "central coherence". However, our measure of integration of shapes may not be analogous to the "central coherence" that is required for integration of words for the formation of gist.

An additional finding was that there is an association between one dimension of ASD social severity (social motivation) and the degree to which ASD performance is slowed by the shape integration as compared to the shape-

[2] One of the reviewers suggested an alternative interpretation of our data which we think is intriguing: "Individuals with ASD who find integration of information difficult may find they 'get things wrong' socially and so lose motivation to try".

matching task. This may suggest that impairments in social motivation may be a primary root for some cognitive abnormalities in ASD.

Our results indicate that we must continue to find additional ways to measure a wide variety of kinds of integrative behavior in ASD populations and explore their relationship to both social severity and the notion of central coherence. Further explication of atypicalities in integrative processing could inform neural accounts, abnormal developmental trajectories, and key genetic factors that underlie ASD.

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