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ORIGINAL PAPER

Cognitive Differences in Pictorial Reasoning Between High-Functioning Autism and Asperger's Syndrome

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Abstract We investigated linguistic and visuospatial processing during pictorial reasoning in high-functioning autism (HFA), Asperger's syndrome (ASP), and age and IQ-matched typically developing participants (CTRL), using three conditions designed to differentially engage linguistic mediation or visuospatial processing (visuospatial, V; semantic, S; visuospatial + semantic, V + S). The three groups did not differ in accuracy, but showed different response time profiles. ASP and CTRL participants were fastest on V + S, amenable to both linguistic and nonlinguistic mediation, whereas HFA participants were equally fast on V and V + S, where visuospatial strategies were available, and slowest on S. HFA participants appeared to favor visuospatial over linguistic mediation. The results support the use of linguistic versus visuospatial tasks for characterizing subtypes on the autism spectrum.

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Introduction

Reasoning skills entail encoding, relating, and transforming premise stimuli to produce a logical output (Holyoak and Morrison 2005). This processing framework is essential to making sense of one's experiences as well as interactions with other individuals. Research in the typical development of reasoning skills has shown a transition from perceptually-based thought processes to concept-oriented reasoning (Holyoak et al. 1984; Rattermann and Gentner 1998). This ability to transition from a perceptual- to a conceptual-based approach to reasoning relies on a number of factors, including increased domain knowledge, working memory capacity, and inhibitory control, as well as on the nature of instructions and the relational complexity of the task (Goswami et al. 1998; Richland et al. 2006; Waltz et al. 2000). Additionally, the presentation modality and nature of the stimuli also influence one's use of conceptual versus perceptual processes. While verbally presented stimuli, such as oral or written words, are likely to be processed linguistically, by default (Houde 2002), pictures may be processed and manipulated "as a referent" (i.e., visually) or as a representation of a referent (i.e., semantically) (Schwartz 1995). Furthermore, the intended use of pictures and the extent to which linguistic coding (i.e., use of labels or semantic knowledge) may facilitate task execution can also impact the cognitive processing of pictures (Casasanto 2003).

To the extent that individuals on the autism spectrum have been found to vary in their linguistic versus perceptual abilities (Behrmann et al. 2006; Tager-Flusberg and Joseph 2003), we proposed to investigate visual perception and conceptual processing in high-functioning autism (HFA) versus Asperger syndrome (ASP). We designed a reasoning task involving a variety of pictorial puzzles that differed in the extent to which they necessitated the use of language or visuospatial processes to solve them. If effective, such a task could provide insight into the relative contributions of language and visuospatial skills to phenotypic differences that may be related to specific subtypes across the spectrum. In the following, we define linguistic strategy as one that makes use of verbal (i.e., pertaining to receptive or productive speech), or semantic (i.e., conceptual) processes.

Research studies point to impaired or delayed language abilities in autism from a very early age (Luyster et al. 2008), evident in a variety of domains, including lexical and semantic processing (Harris et al. 2006; Kamio et al. 2007; Perkins et al. 2006; Rapin and Dunn, 2003). Individuals with autism typically appear to have difficulties taking advantage of semantic context cues and with language pragmatics, though semantic comprehension is relatively spared (Harris et al. 2006; Toichi and Kamio 2001). Studies have attempted to determine the reliability of semantic access in autism using different modalities. Kamio and Toichi (2000) used a word–word and picture–word semantic priming paradigm with five conditions: categorical (car-bus), noncategorical (gasoline-engine), emotional (tears-sad), somatosensory (ice-cold) and unrelated (clock-soup). The authors found that whereas all participants showed a main effect of semantic relatedness, children with autism performed better in picture–word than word–word conditions while typically developing participants (matched on chronological/mental age and verbal/performance IQ) did not. This was taken as evidence for superior pictorial access to semantics in autism. The implication of this study was that semantic information processing per se may not be impaired, but rather some of the language deficits observed in participants with autism could be modality-dependent, with a visual advantage in autism spectrum disorders (ASD). Superior performance with pictorial materials has indeed been the empirical basis for much of the intervention in autism.

Individuals with autism have also been found to show normal to superior visuospatial abilities on tasks such as the Block Design subtest of the Weschler scales of intelligence or low-level visual discrimination (Caron et al. 2006; Dakin and Frith 2005; Edgin and Pennington 2005; de Jonge et al. 2007; Mottron and 2006). The pattern of performance on other high-level tasks is, however, less clear in part because of confounding influences of working memory and executive functions capacities, and in part because of the intrinsic linguistic load of most higher level tests, which may affect individuals along the spectrum to varying extents. Recent studies using Raven's Progressive Matrices have shown that, in a language-independent measure of fluid reasoning, participants with autism and Asperger syndrome performed as well as or better than a normally developing comparison group (Dawson et al. 2007; Hayashi et al. 2007). Despite controlling for some of the above mentioned confounds, cognitive difficulties in autism were most evident when the use of verbal strategies was required (Joseph et al. 2005b). It appears then that some individuals with autism may rely on visual rather than verbal codes and favor visuospatial strategies in reasoning (Koshino et al. 2005). In fact, differences in verbal and non-verbal IQ scores have been frequently reported in ASD (Klin et al. 1995; Koyama et al. 2007; Mayes and Calhoun 2003), and the direction and magnitude of these differences may be associated with autism subtypes (Tager-Flusberg and Joseph 2003). Thus, a systematic investigation of reasoning skills in the conceptual/semantic and visuospatial domains appears warranted for an improved understanding of the varying profiles in autistic cognition.

Both, Asperger syndrome (ASP) and autism are pervasive developmental disorders, characterized by severe and chronic limitations in social interactions, difficulties in language pragmatics and non-verbal communication, as well as restrictive and repetitive behaviors and interests. While diagnosis reliability depends on the tools and criteria used (Klin et al. 2005) individuals with autism exhibit specific communication impairments before age 3, in the form of delayed or lack of expressive language, whereas individuals with ASP appear to develop language normally in these early years (DSM-IV). Although not a DSM-IV diagnosis, high-functioning autism (HFA) is viewed as a subtype of autism with no overall cognitive impairment (i.e., IQ $\geq$ 70). Studies have documented epidemiologic, psychological, genetic, motor, and neurobehavioral differences between HFA and ASP (Rinehart et al. 2002; Tager-Flusberg and Joseph 2003; Thede and Coolidge 2007; Volkmar et al. 2004); however, we focus here on cognitive disparities, and, more specifically, on visuospatial and linguistic processing in these two groups.

Individuals with autism have been found to present with superior visuospatial processing abilities compared to typically-developing participants, as evidenced in the Block Design and Embedded Figures Tests; in contrast, age and full-scale IQ (FSIQ) matched ASP participants score higher than HFA participants on verbal IQ (VIQ), vocabulary, and comprehension subtests of the Wechsler Intelligence Scale (WISC) (Ghaziuddin and Mountain-Kimchi 2004; Koyama et al. 2007). Conversely, performance IQ (NVIQ) may be lower in ASP than in HFA (Klin et al. 1995). Macintosh and Dissanayake (2004) warn against the potential circularity in interpretation when selecting dependent variables that are co-dependent on diagnostic criteria. For instance, group differences on tasks that measure language ability should not be surprising when the groups are formed based on language development criteria. For this reason, the HFA and ASP groups where matched on full scale IQ, and the task we used was designed to reveal potential differences in processing strategies (i.e., visuospatial vs. linguistic) in reasoning by incorporating a "hybrid" condition, amenable to the use of both strategies in solving the pictorial problem. Any differences between the groups in their performance on this condition relative to the linguistic and/or visuospatial conditions could help improve our understanding of potentially different cognitive subtypes within autism spectrum disorders.

In the present study we manipulated both stimulus type (pictures that are easy to label, or geometric forms that are more difficult to label) and processing strategy (visuospatial or semantic/conceptual manipulation). Task difficulty was equated by matching the number of dimensions and operations required across three fill-in-the-blank pictorial problem solving conditions: semantic, where reasoning necessitated access to the conceptual referents of picture stimuli in order to draw associative relationships between them; visuospatial, where the stimuli presented were meaningless black and white geometric forms, and therefore less amenable to linguistic mediation, and where reasoning required visuospatial manipulations; and visuospatial + semantic, a hybrid condition involving visuospatial manipulations of picture stimuli similar to those used in the semantic condition, but where linguistic (i.e., semantic) codes, while available, were not required for solving the puzzle (see examples in Fig. 1). Happe and Frith (2006) have emphasized the superiority of open-ended tasks in investigating processing biases in autism. The visuospatial + semantic condition was therefore critical, as it allowed the use of both linguistic and visuospatial strategies by providing an open-ended problem-solving paradigm to investigate any processing biases in autistic cognition.

It was hypothesized that given the apparent differences in their linguistic versus visuospatial processing abilities, performance of the ASP, HFA, and the typically developing (CTRL) groups would differ as a function of the degree to which these processes may be involved in the three pictorial reasoning conditions: we predicted that HFA participants would perform superiorly to typically developing children and ASP participants on the visuospatial condition, but would perform more poorly than both these groups on the semantic condition, reflecting their relative superiority in visuospatial skills but poorer language skills. Thus, in the V + S condition, we predicted that the HFA group would favor visuospatial mediation, whereas the ASP group would, as predicted by their lack of language delay in development, resemble the typically developing comparison participants, using both visuospatial and linguistic processes.

Materials and Methods

Participants

Participants consisted of three groups of adolescents and adults, matched in age and FSIQ ($N = 21$/group): high-functioning autism (HFA, 3 females, mean age = 18.95, SD = 5.45, range 12–29); Asperger syndrome (ASP; no females, mean age = 19.33, SD = 4.92, range 12–30); and a typically developing comparison group (CTRL, 4 females, mean age = 18.43, SD = 4.75, range 12–30). Participants had no history of gross neurological or psychological damage, and scored in the normal range on FSIQ (75–126), as measured by the Wechsler intelligence scales (WISC-III or WAIS-III, Wechsler 1991, 1997). None of the groups differed significantly from each other on age ($p > 0.55$) and IQ (Verbal IQ, $p > 0.07$;

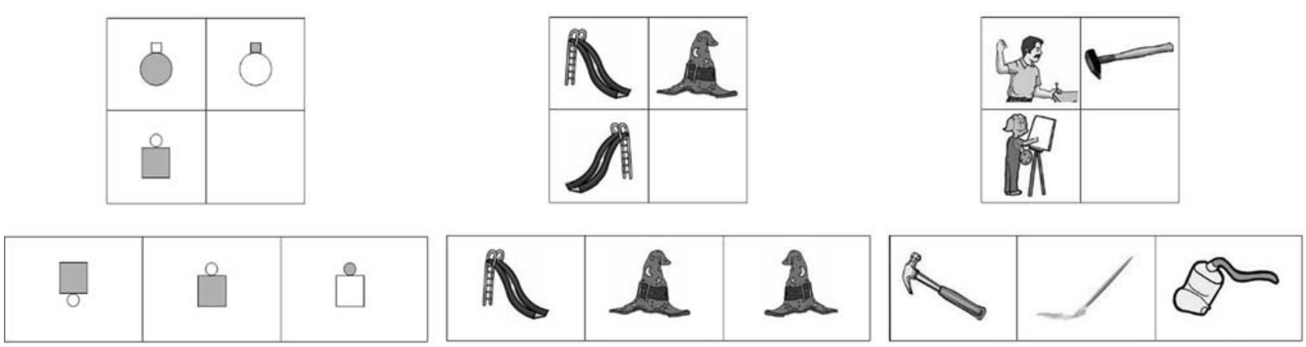

Fig. 1 Examples of stimuli from the three pictorial reasoning conditions. *Left* visuospatial, perceptual reasoning from nonlinguistic pictures; *middle* visuospatial + semantic, visuospatial reasoning using pictures with verbal labels; *right* semantic, semantic reasoning from linguistic pictures

Performance IQ, $p > 0.15$ and full-scale IQ, $p > 0.32$). All participants had normal hearing and normal or corrected-to-normal vision, with no evidence of color blindness. Individuals on the autism spectrum were identified on the basis of the ADI-R (Lord et al. 1994) and ADOS-G (Lord et al. 2000), and met DSM-IV criteria for autism or Asperger syndrome. Specifically, whereas both these groups scored above the ADI cut-off for autism, participants with Asperger syndrome were without significant history of early language delay (e.g. absence of one-word at 24 months or two-word phrases at 36 months), echolalia, pronoun reversal, or stereotypical language (no occurrence of out-of-context repetitive sentences). In contrast, individuals with HFA manifested delayed and/or atypical spoken language development based on the above criteria. Participants were also screened for comorbid neurodevelopmental conditions based on their medical record. In addition the first-degree relatives of participants in the comparison group were without neurological or major psychiatric disorders as well, based on a screening questionnaire. Participants were also administered Raven's Progressive Matrices (RPM, Raven et al. 1998). Wechsler IQ scores were unavailable for one ASP participant, and RPM scores were unavailable for three comparison participants and one HFA (Table 1).

Stimuli

The experimental paradigm consisted of a pictorial problem solving task. Participants were presented plates in the form of a matrix of items (individual items ©2009 Jupiter Images Corporation) related by visuospatial or semantic relationships. Subjects were instructed to select the most appropriate item from among three choices to fill a blank in the matrix, as fast and accurately as possible. The layout of the problem "plates" was a grid of 2 × 2 to 3 × 3 images with an empty cell, to be filled using one of three choices given below the grid. The experiment consisted of three conditions, visuospatial, semantic, and visuospatial + semantic, differing in the involvement of linguistic skills needed to solve the plates. In the nonlinguistic, visuospatial condition, reasoning was based on visuospatial transformations of geometric patterns similar to those in the standard Test of Nonverbal Intelligence (Brown 1997). In the semantic condition, clipart drawings readily identifiable and easy to label were used in problems where selection of the correct answer necessitated the ability to draw thematic or associative relationships between the presented items. In this condition, a successful strategy would require linguistic mediation that is, extracting meaning from individual clipart pictures, recognizing semantic relationships between them, and inferring a logical solution consistent with these relationships. In the

Table 1 Group performance and standardized test scores

	Age	FSIQ	NVIQ	VIQ	RPM	Mean RT V	Mean RT S	Mean RT V + S	% Correct V	% Correct S	% Correct V + S
Control											
Mean	18.43	103.7	100.6	106.4	108.36	4,724.5	4,800.1	4,536.4	87.5	86.5	88.4
SD	4.75	8.3	11.2	9.2	11.70	844.7	761.9	773.8	3.7	6.2	4.4
Asperger syndrome											
Mean	19.33	102.0	96.1	108.0	113.39	4,930.5	5,039.9	4,569.8	85.7	84.5	85.8
SD	4.92	10.4	12.7	10.3	10.22	865.1	904.1	776.4	9.6	6.5	9.1
High functioning autism											
Mean	18.95	100.4	101.2	99.6	113.86	4,502.6	5,088.8	4,386.5	87.4	83.3	87.5
SD	5.45	12.6	9.6	16.9	17.65	932.3	1,084.7	884.4	9.2	10.9	7.5

FSIQ Wechsler full-scale IQ, *NVIQ* Wechsler nonverbal IQ, *VIQ* Wechsler verbal IQ, *RPM* Raven's Progressive Matrices, *RT* response time, *V* visuospatial condition, *S* semantic condition, *V + S* visuospatial + semantic condition visuospatial + semantic condition, pictorial stimuli, similar to those in the semantic case, were to be manipulated visuospatially, with similar reasoning patterns to the visuospatial condition. In this case, the semantic information carried by the pictures was not needed, but their labels were accessible for linguistic mediation, and potentially served a facilitative role. Example plates from each condition are shown in Fig. 1.

Plates were matched across the three conditions based on a framework inspired by Halford's theory of relational complexity (Halford et al. 1998). According to this theory, the complexity of a relation depends on the number of arguments to be considered simultaneously (e.g. two arguments a and b in the relation "bigger-than (a,b)") as each argument provides a degree of freedom. In addition, arguments (dimensions to be considered) are used as instances of first order relations (transformations or relationships between arguments), which may be embedded in hierarchical structures (operations on relations). Cognitive complexity is therefore dependent on the number of elements (or arguments) to be processed in parallel for a given task, and on the number of structural links between these elements. This was implemented here in terms of three custom-made factors, based on relational databases of semantic taxonomy (Chaffin and Herrmann 1984; Storey 1993; Winston et al. 1987) and visuospatial transformations (Brown 1997; Tversky 2005): (1) reasoning type or manipulation of interest (e.g. analogy, series completion, group formation, or addition/subtraction/intersection), (2) number of transformations or relationships (e.g. part–whole, sequential transformation, identity matching, spatial inclusion, etc.), and (3) number of dimensions manipulated (e.g. shape, orientation, size, or semantic category (animals, foods, sports,…). The first two factors were therefore representative of relational structure units, while the dimensions accounted for the number of elements to be considered. Conditions were equated in terms of structural units and elements required for each plate. This framework was thus operationalized in keeping with the relational complexity theory of reasoning, whereby task difficulty is gauged by the number of relations available and necessary for successful solving (Choet al. 2007; Halford 2005). Designing conditions that were thus matched for complexity was essential to avoid confounds in interpretation. The plate and paradigm were piloted on 20 adult comparison participants (not included in this study) to ensure difficulty matching across conditions.

Experimental Procedure

A total of 144 plates (3 conditions × 48 plates per condition) were presented in six self-paced consecutive runs on a PC desktop running the Presentation software (Neurobehavioral Systems 2008 CA, USA, n.d.). Within each run, the plates were presented using a pseudo-randomized event-related paradigm, with equiprobable conditions (i.e., 8 plates/condition) and correct button assignments. Participants were instructed to respond as fast and accurately as possible, using pre-assigned keys on a keyboard. Each plate presentation lasted between 1 and 12 s, as the plate disappeared upon subject response or timed out after 12 s. A fixation cross was shown between stimulus plates with a random ISI ranging from 1,500 to 3,500 ms. The maximal duration of each run was 5 min, and short breaks were offered between runs for subject comfort.

Behavioral Measures and Analysis

Behavioral statistics on response times (RT) and accuracy (percent correct responses) measures were carried out in SPSS v.15.0 (SPSS Inc., IL, USA, n.d.). Response times were measured between the appearance of a problem plate and the button press ending that trial, and registered by the Presentation software. Incorrect responses and trial outliers were discarded from all analyzes. Trial outliers were defined as any trial more than two standard deviations from the mean response time for that condition, and represented 5% of all trials in the comparison group, and 6% of all trials in both PDD groups. Repeated measures 3 × 3 ANOVAs were carried out for RT and accuracy separately, with condition as within-subject factor, group as between-subject factor, and using age as a covariate to control for developmental effects. Post-hoc *t*-tests were carried out appropriately with Bonferroni correction for multiple comparisons. Statistics were considered significant for $p < 0.05$.

In order to investigate potential differences in processing strategies, we conducted non-parametric correlation analyzes (Spearman's rho) between accuracy scores on the visuospatial + semantic condition and each group's performance on standardized tests of verbal ability (VIQ) and nonverbal ability (NVIQ), as well as general, language-independent fluid reasoning ability (RPM). The purpose was to delineate preferred strategies (visual or linguistic), if any, in the groups' performance on a dual-strategy condition (V + S).

Results

Participants in all three groups (HFA, ASP, CTRL) were able to perform the task, evident in their performance on the different conditions (Table 1).

Accuracy

Group (HFA, ASP, CTRL) × condition (V, S, V + S) ANOVA with accuracy, using age as a covariate, did not yield any significant main effects or interactions.

Response Times

Group (HFA, ASP, CTRL) × condition (V, S, V + S) ANOVA with response times, using age as a covariate, showed a significant group × condition interaction ($F = 4.338, p < 0.005$). Post-hoc paired comparisons did not yield any significant differences between the groups on any condition, but revealed significant within-group contrasts: in the ASP group: V > V + S ($p < 0.0001$) and S > V + S ($p < 0.0001$); similarly, in the CTRL group V > V + S ($p < 0.035$) and a trend for S > V + S ($p < 0.057$); in contrast, for the HFA group S > V + S ($p < 0.0001$) and S > V ($p < 0.0001$). Thus, the ASP and CTRL participants were fastest on the V + S condition, whereas the high-functioning autism group was slowest on the semantic condition (Fig. 2).

We performed condition-wise correlations between speed and accuracy for each group to examine potential speed-accuracy trade-offs. There was a trend for a significant correlation between RT and accuracy on the V + S condition in the ASP group only (rho = 0.41, $p = 0.063$), whereas all other correlations were non-significant ($p > 0.149$). This may indicate that in the V + S condition, the ASP group's performance showed some degree of speed-accuracy trade-off. In order to exclude overall speed differences as confounds to the RT differences between V and S, we performed additional t-tests between groups, using the difference between response times on V and S, adjusted for individual speed by dividing it by RT on the V condition, as our variable of interest. This analysis yielded no differences between ASP and CTRL, but there were significant differences between HFA and both ASP and CTRL ($p < 0.006$). The results confirmed that the RT difference between V and S was significantly greater in HFA than in CTRL or ASP, while accounting for potential overall speed differences.

Using the speed-adjusted RT difference between V and S as a dependent variable, we also conducted a complementary stepwise multiple regression analysis to examine the extent to which group membership predicted the discrepancy between the semantic and visuospatial response times above and beyond IQ measures or gender. This analysis used PIQ, VIQ, the difference between PIQ and VIQ, gender, and group membership as predictor variables. Of these, only group membership significantly contributed to the model ($R^2 = 0.117$, $F = 8.073$, $p < 0.006$), while other variables were not found to be significant predictors ($p > 0.619$).

Correlation Analysis

The comparison group (CTRL) showed no significant correlations between accuracy on the V + S condition and both verbal (rho = 0.12; $p = 0.61$), and nonverbal IQ (rho = −0.21; $p = 0.35$) scores. There was a trend for a correlation between accuracy on V + S and RPM score (rho = 0.42; $p = 0.07$). However, typically developing participants appeared not to show a strong bias for either in their use of linguistic or visuospatial processing when both strategies were available.

The ASP group showed significant correlations between accuracy on the V + S condition and both VIQ (rho = 0.482, $p < 0.031$) and RPM (rho = 0.493, $p < 0.023$), but not with NVIQ (rho = 0.37; $p = 0.11$). The ASP group thus showed a significant relationship between their performance in the V + S condition and

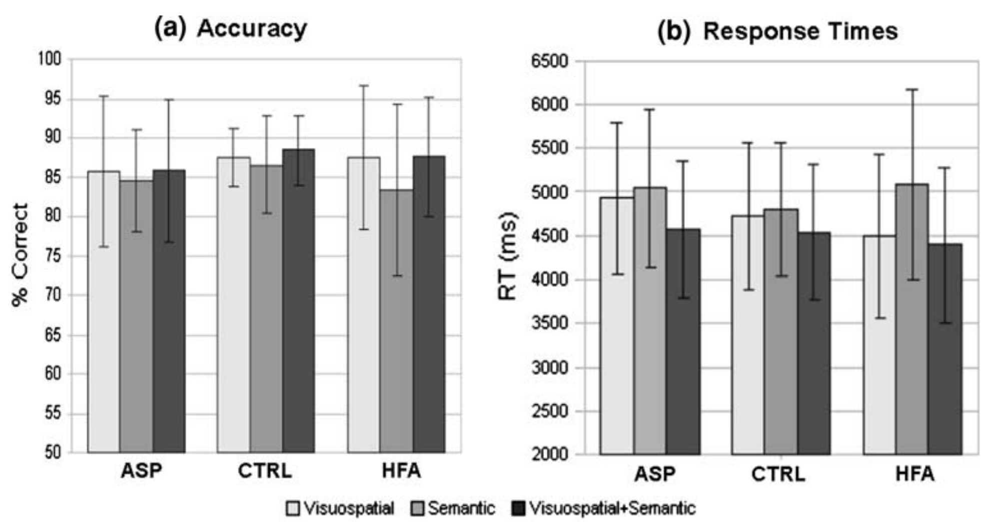

Fig. 2 **a** Accuracy on each condition for each group. **b** Response times on each condition for each group (*ASP* Asperger syndrome group, *CTRL* comparison group, *HFA* high-functioning Autism group, *Error bars* represent standard deviations of the mean)

their verbal skills as well as more general, language-independent fluid reasoning ability.

In contrast, we found that the HFA group had significant correlations between accuracy on the V + S condition and NVIQ (rho = 0.501, $p < 0.021$), but not with VIQ (rho = 0.19; $p = 0.41$) or RPM (rho = 0.36; $p = 0.12$). Therefore, in the HFA group, only the relationship between the dual-strategy condition V + S and nonverbal ability was significant.

Discussion

The present study demonstrated differences between the two ASD and comparison groups in processing efficiency and strategies in pictorial reasoning. Typically developing participants appeared to benefit from the availability of both visuospatial and linguistic processing routes, as they were fastest in the hybrid condition, V + S. Participants with high-functioning autism showed an increased processing efficiency in favor of visuospatial mediation when this strategy was available: they were faster on the V and V + S conditions than on the S condition. Asperger syndrome participants, while sharing a similar RT profile with the comparison group, appeared to have used verbal mediation in conjunction with a more general, language-independent fluid reasoning ability, at no cost to performance. Taken together, these results point to the existence of different cognitive profiles across the autistic spectrum.

The task used in this study was carefully designed to equate the three conditions on multiple dimensions, using a simplified relational complexity metric. The relatively high performance and absence of group difference in accuracy on these three conditions attest to their comparability. Difference in response times on these conditions, thus, provides insight into the relative processing efficiency of visuospatial or linguistic mediation in the three groups of participants. The visuospatial + semantic condition, which allows the use of both verbal and visuospatial strategies, served as a reference within each group, and offered the opportunity to examine strategy preferences in problem solving, as a function of clinical diagnosis. The comparison group's performance on this task (lack of correlation between performance on the dual-strategy condition and measures of verbal and nonverbal IQ, with faster solving of the V + S condition) reflects the absence of any strong strategy preference, and may suggest that the availability of both visuospatial and linguistic routes facilitates processing efficiency in this group. However, the trend for a correlation between accuracy on the V + S condition and score on the RPM, a measure of fluid reasoning ability, may in turn point to a relationship between performance and general cognitive ability in the CTRL group. Deviations from this pattern of efficiency may therefore be reflective of PDD diagnosis (Lincoln et al. 1995). The V + S condition was hence critical as it went beyond the assessment of linguistic or visuospatial abilities provided by the other conditions, to reveal potential cognitive preferences in processing strategies.

Whereas there was no significant difference between the groups on accuracy, the group × condition interaction was significant for reaction times. The semantic condition took significantly longer to solve than the visuospatial or visuospatial + semantic conditions in the HFA group but not in the ASP, or CTRL groups (though, note minor trend for S > V + S in the CTRL group). This suggests that linguistic processing may be less efficient than visuospatial processing of pictorial stimuli in HFA. A diagnosis of autism requires early language delay, and despite inconsistent prognoses of linguistic development, language difficulties may persist later in life. The most common difficulties pertain to the pragmatics of language, but lexical and semantic problems have also been documented (Harris et al. 2006; Kamio et al. 2007; Perkins et al. 2006; Rapin and Dunn 2003). Semantic access through pictorial stimuli has been found to be preserved in autism, as also evident in the lack of difference in accuracy between the ASD groups compared to the non-ASD group in the semantic condition in the present study (see also Kamio and Toichi 2000); however, the efficiency of the ability to use this information, as required in the S condition, was clearly more limited in the HFA group (Joseph et al. 2005a).

This suggests that the effects of early language delays in HFA may persist in later years, in the form of increased reliance on a visuospatial mediation strategy. While oral language deficits in autism have been reliably demonstrated, recent studies of intelligence in autism have shown spared or superior intelligence in tests devoid of language requirements (Dawson et al. 2007; Mottron et al. 2006; Plaisted et al. 1998). It is likely that deficits in language and good visuospatial abilities interact to provide a picture whereby the processing efficiency of HFA is increased by the availability of visuospatial mediation (V and V + S conditions), but reduced where conceptual/linguistic processing is necessary. Thus, when presented with a task where both visuospatial and verbal mediations were possible, the HFA group appeared to favor the use of visuospatial strategies. This was confirmed by the correlation between NVIQ and accuracy on the visuospatial + semantic condition in HFA but not CTRL participants, suggesting that nonverbal processes were primarily recruited for solving the V + S condition in autism. This clearly points to a strategy preference for visuospatial processing in HFA, while the lack of correlation in CTRL suggests an absence of bias in their approach of the hybrid condition.

Our finding is consistent with an elegant study by Joseph et al. (2005b), who examined differences in verbal and non-verbal working memory skills in autism. Using a self-ordered pointing task with pictures varying in the extent to which they were amenable to verbalization, they showed that the phonological loop and visuospatial sketchpad of working memory were intact in autism; however, the availability of verbalization improved performance for the comparison group but not in participants with autism. The authors argued that individuals with autism were unable to spontaneously generate strategies based on verbal mediation when these could help task performance. However, these results may result from a difficulty in converting visual and verbal modalities, or an effect of a prepotent perceptual preference, leading to the use of visuospatial strategies, even when verbal mediation could facilitate task performance. In the same study, individuals with autism showed improved performance relative to a typically developing comparison group on a non-verbal self-ordered pointing condition. The autism group also showed no difference in performance between verbal and non-verbal conditions, indicative of the use of similar strategies in both tasks. These results suggest that individuals with autism favor the use of visuospatial strategies.

The Asperger syndrome group performed similarly to typically developing participants. Both ASP and CTRL solved V + S more rapidly than V or S. Insofar as the V + S condition was designed to be solved visuospatially but with the possibility of verbal mediation, having both processing routes available therefore appeared to be facilitative for both ASP and CTRL groups. In addition, we found no significant difference between V and S in both ASP and CTRL groups, suggesting that both tasks were performed similarly. Thus, the ASP and typically developing comparison groups shared similar accuracy and response time profiles across the three conditions. Interestingly, the ASP group took slightly longer to solve the problem plates overall, though this difference between the groups was not significant. Their accuracy on the V + S condition was correlated with both RPM, a language-independent measure of fluid reasoning ability (also seen in the CTRL group as a trend, further supporting processing similarities between these two groups), as well as verbal ability (VIQ). Somewhat difficult to interpret, this result clearly warrants further investigation of the use of both linguistic mediation and general fluid reasoning abilities in ASP, especially as this seems to occur at no cost to performance (Ozonoff et al.1991).

In contrast to results in HFA, research with adults with ASP has shown that while not typical, their linguistic abilities are relatively spared (Koyama et al. 2007; Volkmar 2004). The ASP group did not show a significant difference between V and S, suggesting that conceptual processing was not less efficient than visuospatial processing. There have been questions raised about the validity of ASP as a mutually exclusive diagnosis from HFA, and about the criteria for adequately differentiating between the two phenotypes (Baron-Cohen and Klin 2006; Volkmar 2004). Although the ASP group did not differ in accuracy from the HFA group, the two groups presented different RT profiles: the HFA group took longest to solve the S problems, whereas the ASP group resembled the typically developing participants, without marked differences between visuospatial and conceptual processing. The relationship between visuospatial and linguistic abilities may therefore be a more powerful metric for differentiating between high-functioning autism and Asperger syndrome than an absolute measure of language abilities alone.

The present experiment suggests a difference in relative processing efficiency of visuospatial versus linguistic processes between the HFA and ASP groups. High functioning autism participants appear to favor a visuospatial strategy in pictorial reasoning, whereas Asperger syndrome individuals may recruit both verbal mediation and fluid reasoning resources.

This difference in processing patterns found in the performance of the ASP and HFA are in keeping with studies characterizing cognitive profiles in ASD. Koyama et al. (2007) found that whereas both groups (HFA and ASP) present similar patterns of relatively superior visuospatial ability versus lower social intelligence and language scores, this profile was less marked in ASP, who also showed superiority to HFA in Wechsler VIQ (esp. in Vocabulary and Comprehension subtests) and in communication scores using the Japanese CARS-TV autism rating scale. In the present study, no superiority in visuospatial skills was found in ASP over the typically developing comparison group. Instead, individuals with Asperger syndrome and the comparison group presented similar performance profiles, but the HFA group appeared to favor visuospatial processing in the face of linguistic processing difficulties. A potential limitation of the study is the possibility that early language difficulties, used here as a selection criterion, may have persisted in later years in HFA, thereby leading to a decreased development and use of verbal strategies and/or a preference for visuospatial strategies in this group, as found here. Whereas our groups were matched on FSIQ, there was a trend for a significant difference in verbal IQ between the HFA and ASP groups ($p = 0.07$) which may account for some of the differences between them. A multiple regression analysis, however, showed that verbal IQ was not a significant predictor for the difference between response times on the V and S conditions.

Conclusion

The protocol developed in this study may be a powerful paradigm for differentiating cognitive profiles characteristic of autistic phenotypes. Our findings suggest that high-functioning autism participants have more difficulties in pictorial reasoning involving semantic manipulations, and appear to rely in a larger extent on visuospatial strategies. This is in contrast with Asperger syndrome individuals who resembled the non-ASD comparison group in their performance profiles and were not significantly slower in conceptual-based pictorial reasoning. The current task may prove useful in studying the neurobiological bases of ASD in current efforts to establish genotypes and phenotypes along the spectrum. The dichotomy between visuospatial and linguistic profiles along the autism spectrum provides opportunities for using functional brain imaging to elucidate the neurobiological correlates of the different patterns of cognitive efficiency found in this study, along with structural imaging to help differentiate between possible phenotypes of the disorder.

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