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BRIEF REPORT

Brief Report: Information Processing Speed is Intact in Autism but not Correlated with Measured Intelligence

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Abstract Speed of information processing, as measured by inspection time (IT), is a robust predictor of intellectual functioning. However, among individuals with autism and low IQ scores, IT has been reported to be discrepantly fast, and equal to that of high IQ typically developing children (Scheuffgen et al. in Dev Psychopathol 12: 83–90, 2000). The present investigation replicates and extends this study by examining IT and its relationship to IQ in a higher functioning (average range mean IQ) group of children with autism spectrum disorders (ASD) versus matched controls. Though IT was not significantly faster in the ASD group than in the matched control group, the relationship between IT and IQ was uniquely discrepant for the ASD group, partially corroborating and extending previous findings.

Keywords Autism · Asperger's syndrome · Processing speed · Inspection time · Intelligence · IQ

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Introduction

Since Kanner's (1943) original descriptions in which he described autism as associated with good "cognitive potential", islets of intact or even exceptional functioning have been noted to characterize autism and to distinguish it from other developmental disorders. Uneven cognitive skills have been repeatedly documented in autism (Happé and Frith 1996; Rumsey 1992). Prototypically, using Wechsler scales to assess IQ has resulted in peak performance on the block design task and lowest performance on the socially laden comprehension subtest, though these findings clearly are not diagnostic (Siegel et al. 1996). What underlies this atypical cognitive profile remains unknown, but it may reflect reduced neural connectivity, idiosyncratic relationships between cognitive modules, specific cognitive deficits, such as theory of mind difficulties, and/or poor social learning. Nevertheless, individuals with autism demonstrate the dissociability of subtest performance purportedly underlying a general IQ factor and at least one large factor analytic study demonstrates weaker than expected relationships among IQ subtests for children and adults with high functioning autism (Goldstein et al. 2008). Moreover, among developmental disorders, autism spectrum disorders (ASD) are particularly associated with savant skills (Heaton and Wallace 2004; Treffert and Wallace 2002) that are often far out of line with measured IQ. Some theorists have highlighted savant skills as indicative of the modularity of mind while others deem these skills irrelevant to intellectual functioning (e.g., because they are the products of extreme practice; Ericsson and Charness 1994). Individuals with ASD also demonstrate good performance on Raven's Progressive Matrices which, unlike for typically developing (TD) individuals, is out of line with their performance on Wechsler scales of intelligence (Dawson et al. 2007). Raven's Progressive Matrices is the prototypical measure of fluid intelligence, an area of purported difficulty for individuals with autism. The diminished social demands of this task (relative to most subtests of the Wechsler scales) and its nonverbal/visuospatial presentation format may aid in maximizing performance among individuals with ASD.

Anderson's theory of the minimal cognitive architecture at the heart of intelligence and cognitive development (Anderson 2001) posits that knowledge, as assessed by traditional IQ measures, is acquired via two main routes, thinking and dedicated processing systems known as modules. One significant constraint on thought is the speed of a basic processing mechanism, which in turn determines individual differences in general intelligence. Moreover, speed of processing constitutes the unchanging basis of these individual differences. The idea that a basic speed of processing mechanism contributes to or underlies aspects of intellectual functioning is not new and is in fact a major component of a number of theorists' views of general intelligence (e.g., Eysenck 1988; Jensen 1982; Nettelbeck 1987). Evidence to support the relationship between the speed of a basic processing mechanism and intellectual functioning exists mainly in the form of correlations between measures of general intelligence and inspection time (IT) (see Nettelbeck 1987 for a review). As defined by Anderson and Miller (1998), IT is "the stimulus exposure duration required by a subject to make a simple perceptual judgement, for example, the relative length of two lines". So, IT describes the minimum stimulus exposure at which a person consistently and accurately discriminates a stimulus feature. To measure IT, exposure time of the stimulus is varied in order to determine the minimum duration of display needed for accurate performance. Note that response time is not measured, thus IT avoids difficulties inherent to reaction time (RT) studies, such as motoric and "thinking time" confounds when responding. These are especially apparent when the participant is unsure how to respond, which may result in a speed/accuracy trade-off. Based on meta-analytic studies of TD adults and children, the correlation between IT and intelligence hovers around −.50 (Grudnik and Kranzler 2001; Kranzler and Jensen 1989; Nettelbeck 1987).

In the only group study completed to date, IT amongst individuals with autism was compared to that of intellectually impaired IQ-matched controls and TD children of high-average IQ (Scheuffgen et al. 2000). Interestingly, IT in autism was much better than expected, based upon the group's measured IQ; IT in the autism group was equal to that in a TD group with IQ scores 25 points higher on average and significantly better than that of a group composed of individuals with intellectual impairment (II). Therefore, this possible underpinning of intelligence was intact (or better) amongst individuals with autism, indicating that some other aspect(s) of cognition (e.g., socially-mediated learning) contributing to IQ is responsible for the depressed aspects of the IQ profile frequently observed in autism.

The present investigation attempts to extend the research in this area by replicating the Scheuffgen et al. (2000) findings of discrepantly fast IT (relative to IQ) in ASD within a larger and higher functioning (i.e., mean IQ falling in the average range) sample of children and adolescents with ASD. It is hypothesized that: (1) individuals with ASD will display an IT better than predicted by their IQ, and (2) correlations between IT and IQ will be significant for the TD children and children with II, but not for the children with ASD.

Methods

Participants

The ASD group was composed of 23 school-age (9–18 years) children, five of whom also had mild II (i.e., estimated Full Scale IQ [FSIQ]: 50–69). See Table 1 for details on age, sex ratio, and estimated FSIQ. Exclusion criteria for the ASD group included any known co-morbid medical conditions, such as fragile X syndrome, other genetic disorder, or neurological disorder (e.g., Tourette's syndrome) that might affect cognitive functioning. Inclusion criteria were deliberately broad due to the frequent omission of low functioning children from research investigations and because including children with II both maximizes variance in IQ for correlations and allows representation of the full autism spectrum. An independent diagnosis of autism or Asperger disorder, based upon DSM-IV criteria (APA 1994), had been given in every case, by an experienced clinician, as recorded in clinical notes.

The matched control group was composed of 25 children (20 TD children and five children with mild II [estimated FSIQ: 50–69]) who were group matched to the ASD group based upon estimated FSIQ (comprised of the Vocabulary and Block Design subtests), age, and sex ratio (see Table 1 for details). Similar to the ASD group above, exclusion criteria for the children with II consisted of known genetic and neurological disorders and FSIQ < 50, as well as any history or documentation of autistic traits. Again, children with II were included to maximize variance in IQ while also allowing more direct comparison of results to Scheuffgen and colleagues' findings.

In order to examine how IQ may influence group differences in IT performance and relations between IT and IQ, both the ASD group and the matched control group were split into IQ subgroups: IQ < 100 (the "lower IQ"

Table 1 Characteristics of the autism spectrum disorder and matched control groups and IQ subgroups: mean (standard deviation)

	Autism spectrum disorder			Matched controls			Statistic[c]	p[c]
	All (n = 23)	Lower IQ (n = 12)	Higher IQ (n = 11)	All (n = 25)	Lower IQ (n = 11)	Higher IQ (n = 14)		
Age	14.22 (1.98)	14.93 (1.81)	13.45 (1.94)	13.81 (2.07)	14.23 (2.31)	13.48 (1.88)	$F(1,46) = 0.09$	.77
Sex (% male)	96	92	100	92	91	93	Fisher's Exact Test	1
Vocabulary[a]	9.74 (4.07)	6.58 (2.47)	13.18 (2.18)	10.20 (3.99)	6.73 (3.23)	12.93 (1.77)	$F(1,46) = 0.16$	.69
Block design[a]	9.00 (4.41)	6.08 (3.45)	12.18 (2.89)	9.12 (3.53)	7.18 (3.71)	10.64 (2.59)	$F(1,46) = 0.01$	.92
FSIQ estimate[b]	96.39 (22.18)	78.83 (12.79)	115.55 (11.37)	98.28 (19.65)	82.64 (18.03)	110.57 (9.65)	$F(1,46) = 0.10$	.76

[a] Scaled scores

[b] Standard scores

[c] Comparing Values from all autism spectrum disorder to values from all matched controls

group) and IQ $\geq$ 100 (the "higher IQ" group). See Table 1 for demographic details pertaining to the IQ subgroups.

Participants were recruited from schools for children with ASD and through contact with local schools for TD children and children with II. All participants were seen individually in a quiet place in a school, meeting, or clinic room. In order to control for possible reading comprehension differences/difficulties, instructions for the IT task were orally presented to each participant in addition to being presented visually.

Measures

Wechsler Intelligence Scales for Children-Third Edition, UK Version (WISC-III^{UK}: Golombok and Rust 1992)

The Wechsler scales are the most widely utilized and psychometrically sound measures of intelligence currently available. Short forms of the Wechsler scales, particularly those involving the two most robust subtests, Vocabulary and Block Design, have been shown to predict reliably an individual's FSIQ (Sattler 1992) and to load most highly onto the general intelligence factor (Cyr and Brooker 1984). Recent work suggests that short forms are also valid in predicting FSIQ, even when utilized with individuals on the autism spectrum (Minshew et al. 2005). A short form of the WISC-III^{UK} was administered to all participants. For both participant groups, two subtests, Vocabulary and Block Design, were utilized to extrapolate an estimated FSIQ.

Inspection Time

A "computer game" format was utilized to present the IT task in order to be appealing and child-friendly, similar to previous versions (e.g., Anderson 1988). The main stimulus was a "space invader" figure with two antennae of either the same or different lengths. This stimulus was presented horizontally centered, but at the bottom of the computer screen for varying durations controlled by a mask. Participants were instructed that the "space invader" figure would appear on the screen for only a very brief period of time before hiding behind a "bush" (i.e., a backward mask that remained on the screen until a response was made). The four permutations of antennae length (i.e., left antennae short-right short, left short-right long, left long-right short, or left long-right long) were randomly shown, with the participant asked to designate whether the antennae were of the same or different lengths through pressing the corresponding button. The key for "same" was on the left (the "z" key) and marked in blue while the key for "different" (the "/" key) was on the right and marked in red. Each correct response was followed by a beep, providing the participant with feedback. The participant then controlled presentation of the next stimulus by pressing the "space bar" when s/he was ready. The stimulus exposure duration was altered by varying the stimulus onset asynchrony (SOA) between the stimulus and the mask. A Parameter Estimation by Sequential Testing procedure (PEST; Taylor and Creelman 1967) was designed to estimate 70% accuracy of responding; the associated algorithm decides whether a given SOA results in accuracy greater or less than 70%; if so, the SOA is increased or decreased, as appropriate, by a given step size. This step size is halved for every change of direction in the performance staircase (increasing SOA to decreasing SOA or vice versa), and in this way the PEST procedure hones in on the SOA required for the desired level of accuracy. The initial exposure duration used by the PEST procedure was 568 ms (40 VDU screen frames), the initial step size was 114 ms (8 frames), and the final step size was 14.2 ms (1 frame), which is the shortest SOA possible. The SOAs of the last four turns or reversals in the performance staircase were used to calculate a participant's IT. A trial consisted of four blocks, each of 25 stimulus presentations. The participants were introduced to the task during a brief practice session with feedback. This task took approximately 15–20 min to complete. The main index of performance was IT, that is, mean exposure duration at which accuracy was 70%.

Results

Of the 26 ASD and the 26 matched control participants originally administered the IT task, one from each participant group had their data deemed invalid based on a variance score computed automatically in the IT program. The variance score indicates whether the IT score for each individual was being overly influenced by performance during early long exposures, which was the case for these two participants resulting in 25 matched control participants with valid IT data. Additionally, two of the ASD participants' data were lost through computer malfunction resulting in 23 participants with ASD who had completed and available IT data.

Group Differences

A one-way ANOVA was run in order to examine potential group differences in IT performance between children with ASD and matched controls. Children with ASD ($n = 23$; $M = 41.43 \pm 10.19$) demonstrated similar information processing efficiency to chronological age and IQ matched controls ($n = 25$; $M = 42.64 \pm 16.54$; $F(1,46) = 0.09$, $p = .77$, $d = 0.09$). After removing two outlying scores from the matched control group ($n = 23$; $M = 38.7 \pm 9.5$), results remained nonsignificant ($F(1,44) = 0.89$; $p = .35$; $d = 0.28$).

Similarly, there were no significant ASD-matched control differences in IT performance for the lower IQ ($F(1,21) = 0.53$, $p = .48$; $d = 0.30$) and higher IQ ($F(1,23) = 0.18$, $p = .68$; $d = 0.18$) subgroups. Nevertheless, a pattern emerged in which the participants with ASD in the lower IQ group ($n = 12$; $M = 43.25 \pm 12.96$) demonstrated a faster IT on average than the lower IQ matched controls ($n = 11$; $M = 48.55 \pm 21.37$) while participants with ASD in the higher IQ group ($n = 11$; $M = 39.45 \pm 5.94$) demonstrated IT speeds on average very similar to those obtained by the higher IQ matched controls ($n = 14$; $M = 38.00 \pm 10.04$).

Relationship of Age and IQ with IT

Pearson correlations were run to examine the relationship of IT with age and with IQ for each of the participant groups. There was no significant relationship between age and IT in either of the groups (ASD: $r = .01$, $p = .97$; matched controls: $r = .17$, $p = .41$). A significant negative correlation between IQ and IT was limited to matched controls ($r = -.59$, $p = .002$). Unique to the ASD group was the lack of relationship between IT and IQ ($r = -.08$, $p = .72$). Indeed, even with the small sample sizes reported here, the correlations between IQ and IT were significantly different for the ASD and matched control groups ($z_{r1r2} = 1.94$, $p = .05$) (see Fig. 1).

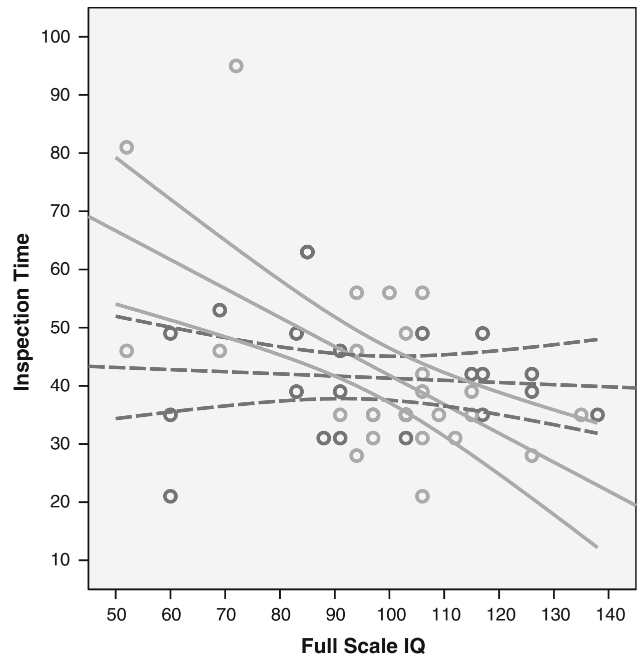

Fig. 1 The correlation between inspection time and overall IQ for children with autism spectrum disorders (*black*) and matched controls (*gray*)

In order to ensure that outliers did not exert undue influence on the relationship between IQ and IT in the matched control group, Spearman's rank correlations were also run. The results were consistent with the Pearson parametric correlation; IQ and IT were significantly associated with one another in the matched control group ($\rho = -.46$, $p = .02$), but not in the ASD group ($\rho = -.10$, $p = .66$).

Discussion

Failing to support our first hypothesis, information processing efficiency, as measured by IT, was comparable between children with ASD and matched controls, unlike findings from the one previous group study of IT in ASD (Scheuffgen et al. 2000), suggesting that IT may be a relative rather than absolute asset in the ASD cognitive profile. Scheuffgen et al. (2000) demonstrated that children with ASD outperformed children with II and scored comparably to age-matched TD children on the IT task. However, important differences arose when comparing characteristics of participants in the two studies. For example, the mean IQ of the ASD group (96) described here not only fell in the average range but also was one standard deviation higher than that for the autism group in the Scheuffgen et al. study (82). Splitting our sample into lower and higher IQ subgroups did not rectify this discrepancy in findings. However, splitting the sample into higher and lower IQ subgroups provided some indication that while IT among those matched controls and ASD children with IQs ≥ 100 was roughly equivalent, among children in these two groups with IQs < 100, ASD children demonstrated (nonsignificantly) faster ITs on average. It could be that, in comparison to Scheuffgen and colleagues' study, the smaller number of children with lower IQ in both the ASD and matched control groups in the present study, prevented us from detecting potentially significant group differences. However, it is worth noting that the IT scores obtained in the matched control group here are commensurate with those obtained in the TD group of the Scheuffgen et al. study. Accordingly, possible ceiling effects and/or restricted range in performance may have contributed to failed replication, so that the IT of ASD children was more likely to be discrepant from expectations in the context of II than in the matched control group. Perhaps poor processing efficiency (as shown by relatively slow IT) reflected a qualitative developmental difference between individuals with idiopathic II and individuals with both autism and II (Anderson 2001). It could be that II associated with autism does not compromise information processing speed whereas, based on the limited information currently available, other (sometimes unknown) causes of II do.

Nevertheless, despite the failed replication of group differences in IT as found in Scheuffgen et al., there was indication that the cognitive architecture of those with ASD is differently organized to those without ASD. The robust relationship between overall IQ and IT was replicated here for the group including both TD and II children; however, this strong correlation was not found in the ASD group. Together, the correlational findings substantiate Scheuffgen et al.'s study and further support their argument that one or more non-processing speed factors contribute to lower (or in the present study, variation in) traditionally measured IQ in ASD. Scheuffgen and colleagues proposed deficits in theory of mind as the key factor, since it may have particularly detrimental effects on opportunities for "social learning", used to convey knowledge. Similarly, language and communication deficits (as reflected in low Vocabulary scores reported in the Lower IQ group here) also will necessarily hinder verbally mediated learning opportunities, social or otherwise. Indeed, it may be that IT scores reflect good intellectual potential in ASD that is not expressed in typical IQ tests because of the social, communication, and/or linguistic demands of the task and the reliance of these tests on culturally transmitted knowledge and skills. Perhaps IT does in fact measure "potential" in ASD; instead of being expressed in IQ scores as is typically the case, it may be demonstrated in savant or savant-like skills often associated with autism (Heaton and Wallace 2004; Treffert and Wallace 2002). In support of this idea, Anderson et al. (1998) showed that the IT of a savant prime number calculator with autism was consistent with that of typical university undergraduates, but inconsistent with his own low IQ. Moreover, it may be that Wechsler IQ scales do not adequately assess intellectual potential in ASD to the same degree as other measures, such as Raven's Progressive Matrices (Dawson et al. 2007) perhaps capitalizing on diminished social demands and nonverbal assets.

Future research should investigate the potential source of discrepancy in IT-IQ relations between children with ASD and control participants. Assessing correlations between social cognitive (including theory of mind) task performance and IT in both groups may address the speculative links proposed by Scheuffgen et al. In addition to further assessment of IT among savants (e.g., Wallace, Happé and Giedd 2009) with different skills (e.g., artistic, musical, or calendrical), correlational studies between IT and the good 'eye for detail' often exhibited by individuals with ASD should be investigated. Perhaps the IT task taps into the purported enhanced perception in ASD, particularly the ability to discriminate easily between different stimuli (Plaisted et al. 1998). Correlational studies between visual search and IT performance may provide clues here.

General limitations within this study included methodological constraints. Time constraints prevented the use of gold-standard diagnostic instruments (e.g., the Autism Diagnostic Observation Schedule) to check the independently given clinical diagnoses in the ASD group. In addition, use of a validated ASD trait-based measure that could be administered to both the individuals with ASD and to controls would allow investigation of what aspects of the triad of impairment are associated parametrically with IT performance or IT-IQ discrepancy. Moreover, although the two-subtest short form used to estimate overall IQ from the Wechsler scales has proven highly predictive in both ASD and TD populations (Minshew et al. 2005), more comprehensive assessment of IQ, including a measure of matrix reasoning, could have been particularly informative.

In summary, the current study expanded upon previous work by demonstrating intact IT among relatively high functioning children with ASD as compared to matched controls. However, among children with ASD, IT scores were not found to be significantly associated with IQ, unlike the relationship found for the matched controls assessed here and for TD individuals as documented in many previous studies. Findings from this study, in conjunction with previous studies, point to atypical cognitive mechanisms underlying intellectual functioning in ASD.

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