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ORIGINAL PAPER

The Broader Autism Phenotype and Visual Perception in Children

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Abstract

Atypical visual perception has increasingly been described in individuals with autism spectrum disorders (ASD) and linked to quantitative, autism-like features that are present in children and adults without ASD. We investigated whether individual differences in visual processing skills were related to quantitative measures of autism traits in a pediatric sample with a range of clinical features. Visual processing was comprehensively characterized using the test of visual perceptual skills (TVPS), a standardized test of visual perception with seven subtests that capture a range of visual processing abilities. The TVPS Figure Ground (TVPS-FG) subtest requires an individual to disembed a smaller figure from a larger scene. TVPS-FG subtest scores were positively correlated with children's autism features as measured by a parental report of the Broader Autism Phenotype Questionnaire (BAP-Q). The correlation with BAP-Q was specific to the TVPS-FG subtest, as the other TVPS subtest scores were not significantly related to the BAP-Q. This adds to the growing body of research documenting that atypical visual processing is associated with the autism phenotype and highlights the importance of capturing quantitative traits in heterogeneous developmental brain disorders.

Keywords Broader autism phenotype · Visual perception · TVPS · Global–local processing · Children

Introduction

Global and local information processing abilities have been extensively researched within autism spectrum disorders (ASD). More specifically, individuals with ASD appear to demonstrate a superior focus on local details as compared to their peers. This phenomena has been given several names, including a "perceptual advantage" or "islet of ability" (Dakin and Frith 2005; Happe 1999; see Simmons et al. 2009 for review) and has been demonstrated in both children (Kaldy et al. 2013, 2011; Koldewyn et al. 2013; Pellicano et al. 2006) and adults with ASD (Dakin and Frith 2005; Happe 1999; Jolliffe and Baron-Cohen 1997; Mottron et al. 2006; O'Riordan et al. 2001; Plaisted et al. 1998; Simmons et al. 2009). The majority of these experiments use perceptual tasks that require the prioritization of detailed (local) information from a contextual (global) whole (i.e. Embedded Figures, Block Design, visual search tasks). Individuals with ASD appear to display superior local performance or a local precedence (Scherf et al. 2008; Dakin and Frith 2005; Kaldy et al. 2013, 2011; Mottron et al. 2006; O'Riordan et al. 2001) that stands in contrast to a global precedence effect that is often observed in typically developing peers (Navon 1977, 1981). The absence of a global precedence effect in individuals with ASD is also referred to as a local bias.

However, individuals with ASD do not show enhanced perceptual performance and local precedence across *all* visual tasks (D'Souza et al. 2016; Guy et al. 2016). While some studies report poorer performance in individuals with ASD compared to typically developing peers on tasks requiring global processing, others have reported comparable task performance (see Happé and Booth 2008 for review). Additionally, there appears to be natural variability in global and local precedence across the general population (Dale and Arnell 2013; McKone et al. 2010; Scherf et al. 2009). Taken together, visual perception in ASD may not be simply characterized in terms of biased or enhanced local processing and diminished global processing. Rather, meaningful

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individual differences in global versus local precedence may reflect a distribution of visual processing biases or abilities.

The broader autism phenotype (BAP) originally referred to subclinical autism features that were commonly found in at least one parent of children with ASD. This term has been adopted to describe the continuous distribution of subclinical traits across the general population (Hoekstra et al. 2008). Various self and informant-report quantitative measures of the BAP have been developed (Hurley et al. 2007) and used across numerous studies to assess the presence of autism traits among typically developing individuals (Di Martino et al. 2009; Ingersoll 2010; Jobe and White 2007). Recent studies on the BAP across the general population have focused primarily on adults and relied on behavioral measures primarily designed to identify a broad spectrum of social, cognitive, and behavioral traits consistent with a clinical ASD diagnosis rather than describing BAP traits. The three most common measures used within research contexts are the autism spectrum quotient (AQ; Baron-Cohen et al. 2001), the Broader Autism Phenotype Questionnaire (BAP-Q; Hurley et al. 2007), and the Social Responsiveness Scales (SRS; Constantino et al. 2003; Frazier et al. 2013). Briefly, the AQ was designed to measure autism-like characteristics in the general population, the BAP-Q was designed to measure subclinical autism traits in the parents of individuals with autism, and the SRS was designed to measure the presence and severity of social impairment. Although the AQ is perhaps the most widely used in non-clinical samples of adults (Ruzich et al. 2015), research on the validity and consistency of autism trait self-report measures has suggested the AQ demonstrates weaker reliability and factor structure relative to the BAP-Q and SRS (Ingersoll et al. 2011). Additionally, the BAP-Q appears to show relative strengths in capturing the elevated yet subclinical traits related to the BAP (Ingersoll et al. 2011) while the SRS may be most useful in specifically clinical settings as a screening tool for ASD (Bölte et al. 2011), alongside other clinical measures such as the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000) or the Autism Diagnostic Interview (ADI-R; Lord et al. 1994; Rutter et al. 2003).

Existing work on visual perception across the BAP has primarily focused on adult performance on the Embedded Figures Test (EFT; Witkin 1971) in conjunction with the AQ (Baron-Cohen et al. 2001). Individuals who score high on the AQ generally exhibit superior performance on the EFT relative to individuals with low-AQ scores (Almeida et al. 2010; Brock et al. 2011; Cribb et al. 2016). The majority of the current research on *quantitative* autism features as it relates to visual perception has focused on adults and little work has been done to assess individual differences in visual perception associated with the broader autism phenotype in children. Happé et al. (2001) assessed visual processing skills across parents *and* siblings of children with ASD using an experimental battery of visual perceptual tasks. Fathers of children with ASD demonstrated local processing biases across tasks aimed at assessing part versus whole processing, including the EFT and Block Design task; however, they were unable to identify atypical visual perception in siblings.

We have previously demonstrated a linear relationship between quantitative measures of autism traits and performance on the Test of Visual Perceptual Skills-3rd Edition Figure Ground subtest (TVPS-FG; Sabatino DiCriscio and Troiani 2017), with adults scoring high on the BAP-Q demonstrating greater visual perceptual skill (Sabatino DiCriscio and Troiani 2017). This TVPS-FG subtest is based upon similar hierarchical visual processing principles as those in the EFT, but there are some potentially important differences. In the TVPS-FG, individuals are asked to identify a simple image nested within a more complex shape. The simple and complex shapes are different for each test item; thus, individuals are not being asked to repeatedly identify the same shape (or a finite set of shapes) across test items. In the children's version of the EFT, individuals are asked to find the same shape repeatedly (a triangle or "tent" then a "house") across the two blocks of the test (i.e. participants complete the 11 "tent" test items before moving on to the 14 "house" test items). Thus, one notable difference between the EFT and Figure Ground subtest of the TVPS-3 (TVPS-FG) is that in the EFT the same visual target shape (or finite set of target shapes) is used for every trial; whereas, in the TVPS, the target shapes and surrounding distractors are unique across all trials.

The primary objective of the current study was to replicate and extend our previous findings from a heterogeneous sample of adults to a clinically heterogeneous pediatric population. We assessed children on all subtests of the Test of Visual Perceptual Skills-3rd Edition (TVPS-3). The TVPS-3 is a validated measure of visual perceptual abilities across several dimensions. Test items within each subtest are organized according to difficulty and require a simple verbal response. Thus, the TVPS is appropriate for research in pediatric populations with a range of abilities, including those with neurodevelopmental disorders (Wan et al. 2015). In addition to the TVPS-3, we ascertained two quantitative measures of autism features, the SRS and BAP-Q. Although the BAP-Q has not been previously used in children, we collected a parent-report version of this metric on children based on our previous finding of a link between TVPS-FG and BAP-Q in adults. In addition, we obtained parental report on the SRS-2, a scale that is more commonly used to assess autism traits in children. We predicted that in a clinically heterogeneous sample of children, BAP-Q scores would be a significant predictor of visual perceptual skill. We also predicted that TVPS-FG subtest scores, specifically, would be directly related to BAP-Q scores, with higher TVPS-FG scores correlating with a greater number of autism traits. We did not predict a relationship between autism traits and TVPS subtest scores outside of the TVPS-FG subtest.

Methods

Participants and General Procedure

Participants (n = 54; mean age = 8.75 ± 2.69; 27 males) included individuals 5–16 years of age sample demographics can be found in Table 1. We used a broad recruitment strategy in order to obtain a wide range of autism traits. This included identifying participants based on patient referral to our neurodevelopmental pediatric clinic in Lewisburg, Pennsylvania, as well as from health system wide advertisement and the surrounding community. Participants recruited from our clinic were obtained via enrollment in our clinic's research protocol, which enables access to relevant electronic health record variables as well as re-contact of patients for additional research. Our clinic treats children with a very wide range of functioning, including children who would be unable to complete an IQ test. Therefore, we initially screened health records to identify potential participants with an estimated IQ of ~60 or higher and/or the absence of any description of the child being "non-verbal" (i.e. not being able to provide simple responses, use at least two word phrases, understand simple commands). On the day of research testing, all participants completed a cognitive assessment to document IQ (WASI-II: Wechsler abbreviated scale of intelligence, 2nd edition; Wechsler 2011). If an IQ test was ascertained as part of their clinic appointment that day (n = 2), we used the clinically ascertained IQ score. All participants assented to protocols approved by the institutional review board (IRB) at the authors' home institution. Seventeen of our participants had autism symptoms that reached the critical threshold for an ASD diagnosis, conferred by our clinic's team of ASD experts, including neurodevelopmental pediatricians and clinical psychologists. Demographic information can be found in Table 1.

Behavioral Measures and Scoring

Test of Visual Perceptual Skills-3rd Edition (TVPS-3)

The TVPS-3 is an assessment of visual perceptual strengths and weaknesses validated for individuals 4.0 years of age and older. The test uses black and white line drawings as stimuli for each of the seven subtests. Each item is administered in a multiple-choice format. The seven subtests are administered in succession, in the order outlined below, per standardized instructions.

Table 1 Means (SDs) of demographic and BAP-Q data

	Males (n = 27)	Females (n = 27)	Total sample (n = 54)	t (*p*)[a]
Age	8.26 (2.52)	9.29 (2.81)	8.75 (2.69) Min: 5 Max: 16	1.48, p = 0.144
FSIQ	102.08 (18.19) Min: 50 Max: 137	102.11 (13.84) Min: 55 Max: 122	102.10 (15.90)[b] Min: 50 Max: 137	0.01, p = 0.99
BAP-Q				
Total average	3.29 (1.03)	2.84 (0.83)	3.08 (0.96)	− 1.83, p = 0.072
Aloof	3.21 (1.06)	2.67 (1.02)	2.95 (0.99)	− 2.09, *p = 0.041[a]
Pragmatic language	3.15 (1.06)	2.73 (0.72)	2.95 (0.93)	− 1.74, p = 0.087
Rigidity	3.58 (1.23)	2.96 (0.75)	3.29 (1.07)	− 2.27, *p = 0.027[a]
SRS-2				
Total	56.97 (13.34)	58.33 (13.81)	57.61(13.47)	0.38, p = 0.71
SCI	56.59 (13.40)	57.23 (12.40)	56.89 (12.82)	0.18, p = 0.85
Social awareness	56.80 (12.69)	58.33 (11.32)	57.53 (11.98)	0.48, p = 0.63
Social cognition	55.93 (11.87)	56.38 (12.05)	56.14 (11.85)	0.82, p = 0.89
Social comm	55.97 (12.23)	57.38 (12.63)	56.63 (12.32)	0.75, p = 0.67
Social motivation	55.50 (14.05)	54.31 (11.70)	54.95 (12.91)	0.17, p = 0.73
RBRI	55.45 (12.15)	56.11 (12.12)	55.77 (12.03)	0.7, p = 0.84

[a]T scores indicate results from group comparisons across age, full scale IQ (FSIQ), and BAP-Q scores between males and females. Significant differences between males and females (p < 0.05) are indicated (*) in the right column

[b]n = 5 participants completed the WPPSI (Wechsler Preschool and Primary Scales of Intelligence-4th Edition; Wechsler 2012) due to a chronological age below the age range for the WASI-II

The subtests are as follows:

(1) *Visual discrimination (VD)* the participant is shown an image or design at the top of the page and is asked to identify the matching design among four available choices on the page.
(2) *Visual memory (VM)* the participant is shown a single design on one page for 5 s. The page is turned and the participant is prompted to identify the same design from among four available choices displayed on the subsequent page.
(3) *Spatial relationships (SR)* the participant is shown a series of designs or images on a page and then is asked to identify the one that is different from the rest. They are told that it may "differ in a detail or in the rotation of all or part of the design".
(4) *Form constancy (FC)* the participant is asked to identify one design among other images displayed on the page. They are instructed that the image can be "larger, smaller, or rotated".
(5) *Sequential memory (SM)* the participant is shown a sequence of shapes or simple images on one page for 5 s. The page turned and the participant is prompted to choose the matching sequence from among four available choices displayed on the following page. The number of shapes within each sequence gradually increases throughout the test.
(6) *Visual Figure-Ground (FG)* the participant is asked to find a simple image or a design nested within one of four more complex shapes. See Fig. 1 for sample item.
(7) *Visual closure (VC)*: the participant is shown a completed shape or design at the top of the page and is asked to match it with one of four incomplete patterns shown on the page.

TVPS raw scores across each subtest were converted to scaled scores using the TVPS administration and scoring manual. Scaled scores for the TVPS are transformed scores in which the distribution of raw scores have been fitted to a normal distribution with mean of 10 and standard deviation of 3. Scaled scores range from a minimum of 0 to a maximum of 19, depending upon the subtest and age of the participant. A scaled score of 0 is possible in the event that a raw score of 1 or 2 is obtained. Group average TVPS scores can be found in Table 2.

Broader Autism Phenotype Questionnaire

The Broader Autism Phenotype-Questionnaire (BAP-Q) (Hurley et al. 2007), is a self- or informant-report measure designed to assess subclinical, quantitative traits across core domains commonly used in characterizing the BAP (i.e. social aloof, rigidity and pragmatic language). Informants (parents in this study) are asked to rate how frequently each statement applies to their child across a 6-point Likert scale ranging from very rarely to

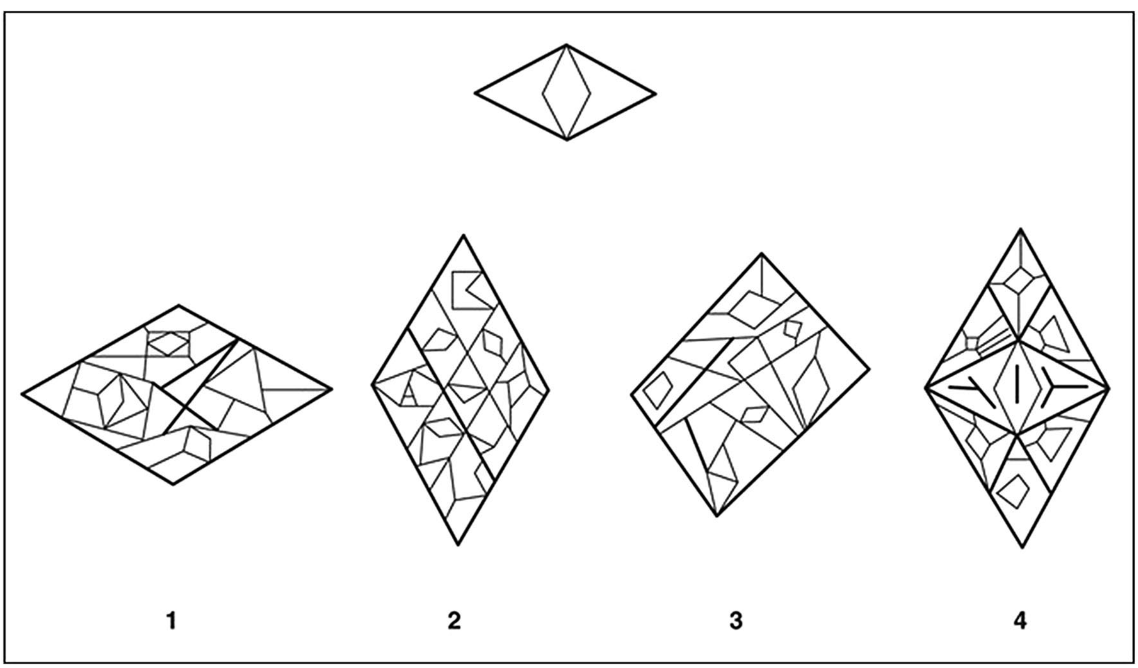

Fig. 1 Example item from the Figure-Ground subtest of the TVPS-3. Participants are asked to find a simple image or a design (top) nested within one of four more complex shapes (bottom). Correct answer in the above example: 4. Reproduced with permission from (Martin 2006)

Table 2 TVPS Scores [minimum, maximum, mean (SD)] for the entire sample (N = 54)

	Min	Max	Mean (St. dev)
TVPS-3 subtests (Scaled Scores)			
Visual discrimination	0	18	8.57 (3.63)
Visual memory	0	19	10.07 (4.16)
Spatial relations	2	19	11.30 (4.40)
Form constancy	0	18	8.09 (4.91)
Sequential memory	0	19	9.5 (4.21)
Figure-Ground	2	19	10.17 (4.17)
Visual closure	0	17	8.30 (4.43)

very often. Scores are averaged within each of the three subscales. Subscale scores are then averaged to produce an overall total score, which can be used as a summary metric reflecting overall autism trait load across the three subscales. The BAP-Q was originally derived from clinical assessment of parents with children diagnosed with ASD (Piven et al. 1994, 1997). In a validation study using direct clinical assessment (Hurley et al. 2007), clinical cutoff scores were reported. Average total scores for 16 subjects in our sample exceeded clinical diagnostic cutoffs (≥ 3.30) (Hurley et al. 2007). Group average BAP-Q scores for the current sample can be found in Table 1. To our knowledge, the BAP-Q has not been previously used in children. However, based on our previous finding of a link between TVPS-FG and BAP-Q, we obtained parental report on both this measure and the SRS-2, a scale that is more commonly used to assess autism traits in children (see below).

Social Responsiveness Scale-2nd Edition (SRS-2)

The Social Responsiveness Scale-2nd Editions (SRS-2) (Constantino et al. 2003; Frazier et al. 2013), is a parent-report measure assessing the presence and severity of symptoms of social impairment associated with ASD. SRS-2 Total T-scores can be used to assess symptom severity based upon a provided range: (1) ≤ 59 T-score: within normal limits/not clinically significant; (2) 60–65 T-score: mild range; (3) 66–75 T-score: moderate range; (4) ≥ 76 T-score: severe range. Average total t-scores for 17 subjects in our sample exceeded clinical cutoffs for moderate to severe autism symptoms. In addition to a total score reflecting overall impairments and social communication impairments (SCI), the SRS-2 generates scores across five subscales (Social Cognition, Social Motivation, Social Awareness, Social Communication, and Restricted Interests and Repetitive Behaviors).

Analysis

Scores from behavioral measures were primarily used to assess relationships between measures of visual perceptual skill and autism traits. Our main analyses focused on (1) identifying which measure of autism features (BAP-Q and/or SRS) significantly predicted performance on the TVPS-FG subtest and (2) investigating the relationship between individual differences in TVPS-FG performance and autism features. Our behavioral measures as well as age and FSIQ were entered into a stepwise linear regression to identify which of our autism measures significantly predicted TVPS-FG performance. We followed up this stepwise linear regression with a partial correlation, controlling for age and FSIQ, between TVPS-FG scores and measures of autism traits.

Before completing our primary analyses pertaining to our hypotheses, we determined whether there were relationships between our demographic variables (i.e. age and FSIQ) and behavioral measures described above that may impact interpretation. Age was not found to be related to BAP-Q scores (p's > 0.37, NS), SRS T-scores (p's > 0.09, NS), nor TVPS scores (p's > 0.10, NS) with the exception of Visual Discrimination subscale ($r = 0.33$, $p < 0.02$). FSIQ was found to be related to BAP-Q Total score and all subscale scores (p's < 0.002) as well as TVPS Overall scores ($r = 0.60$, $p < 0.0001$) and all TVPS subtest scores (p's < 0.02) with the exception of the TVPS-FG subtest ($r = 0.23$, $p > 0.09$, NS). FSIQ was also found to be related to SRS Total T-score ($r = 0.44$, $p < 0.001$) as well as all subscale scores (p's < 0.03) with the exception of the Social Awareness and Restricted and Repetitive Behavior subscales (p's > 0.13, NS). Finally, a partial correlation, controlling for age and FSIQ, was run to determine the concurrent validity between SRS and BAP-Q Total scores in this sample. SRS raw scores were used because t-score conversions account for gender and age. The BAP-Q does not include a t-score conversion and therefore a more comparable analysis would be between raw SRS scores and BAP-Q scores. There was a significant, positive relationship between SRS Total raw and BAP-Q Total average ($r = 0.338$, $p = 0.014$). Additional results from the partial correlation among BAP-Q and SRS scores can be found in Table 3.

Results

Individual Differences in Quantitative Autism Features as Predictors of Visual Perceptual Skill

Our primary hypothesis was that a linear relationship exists between autism traits and the TVPS-FG subtest scores, specifically. This hypothesis was based on our previous results linking the TVPS-FG to autism traits measured using the

Table 3 Correlation matrix includes BAP-Q and SRS raw scores (controlling for age and FSIQ)

	R value (p value)										
	BAP-Q				SRS						
	Total	Aloof	Pragmatic language	Rigidity	Total	SCI	Social awareness	Social cognition	Social comm	Social motivation	RRB
BAP-Q											
Total	1.00 –										
Aloof	0.752** (< 0.0001)	1.00 –									
Pragmatic language	0.811** (< 0.0001)	0.590** (< 0.0001)	1.00 –								
Rigidity	0.852** (< 0.0001)	0.649** (< 0.0001)	0.692** (< 0.0001)	1.00 –							
SRS											
Total	0.338* (0.014)	0.192 (0.173)	0.306* (0.027)	0.405** (0.003)	1.00 –						
SCI	0.343* (0.013)	0.190 (0.176)	0.315* (0.023)	0.386** (0.005)	0.993** (< 0.0001)	1.00 –					
Social awareness	0.302* (0.029)	0.223 (0.112)	0.339* (0.014)	0.322* (0.020)	0.868** (< 0.0001)	0.878** (< 0.0001)	1.00 –				
Social cognition	0.300* (0.031)	0.130 (0.357)	0.270 (0.053)	0.308* (0.026)	0.928** (< 0.0001)	0.937** (< 0.0001)	0.772** (< 0.0001)	1.00 –			
Social comm	0.337* (0.015)	0.194 (0.169)	0.331* (0.017)	0.377** (0.006)	0.973** (< 0.0001)	0.982** (< 0.0001)	0.848** (< 0.0001)	0.911** (< 0.0001)	1.00 –		
Social motivation	0.326* (0.018)	0.171 (0.226)	0.226 (0.108)	0.415** (0.002)	0.894** (< 0.0001)	0.893** (< 0.0001)	0.712** (< 0.0001)	0.762** (< 0.0001)	0.831** (< 0.0001)	1.00 –	
RRB	0.279* (0.045)	0.173 (0.220)	0.239 (0.088)	0.425** (0.002)	0.903** (< 0.0001)	0.845** (< 0.0001)	0.724** (< 0.0001)	0.778** (< 0.0001)	0.822** (< 0.0001)	0.791** (< 0.0001)	1.00 –

Single asterisk indicates correlation is significant at the 0.05 level (two-tailed); double asterisk indicates correlation is significant at the 0.01 level (two-tailed)

BAP-Q (Sabatino DiCriscio and Troiani 2017). Due to the degree of correlation between FSIQ and our autism trait metrics, we also included FSIQ in the model to account for any relationship driven by IQ differences.

A stepwise linear regression was run to predict TVPS-FG scores from the two separate measures of autism traits (BAP-Q Total average and SRS Total average scores) as well as age and FSIQ. Our hypothesis was that a linear relationship exists between TVPS-FG and autism traits. A regression equation including FSIQ as well as BAP-Q was significant, (F(2,49) = 5.63, p = 0.006, $R^2 = 0.18$, Adj $R^2 = 0.15$). Both FSIQ and BAP-Q Total average were significant predictors of TVPS-FG (p's < 0.03), while neither SRS Total T-score or age were found to be a significant predictor (p's > 0.71, NS) (See Table 4 for results). Thus, TVPS-FG scores can be predicted by broader autism traits (as measured by the BAP-Q) above and beyond the predictive value of FSIQ (see Table 4).

BAP-Q × TVPS Relationship

Given results from the linear regression, we examined whether there is a relationship between quantitative measures of autism traits using the BAP-Q and individual differences in visual perceptual skills using the TVPS-3. Analyses outlined above demonstrated that age was not a significant predictor of TVPS-FG and was not related to TVPS, BAP-Q, or SRS scores; however, given the broad age-range of our sample, we included both age and FSIQ as covariates.

Table 4 Linear regression analysis to predict TVPS-FG scores

Predictor	*β*	t	p value	*CI*
FSIQ	0.118	3.301	0.002	0.046–0.19
BAP-Q total average	1.53	2.265	0.028	0.173–2.896

β Beta weight, *t* critical t value, *CI* 95% confidence interval

Analyses without age as a covariate yielded similar results. Consistent with our hypothesis, a partial correlation of BAP-Q and Figure-Ground scaled scores controlling for age and IQ revealed a significant relationship between TVPS-FG and BAP-Q Total average score (r = 0.45, p = 0.002) (see Fig. 2; Panel A). Thus, participants with more autism traits were more accurate on the TVPS-FG subtest. We then examined the relationship between performance on the TVPS-FG subscale and BAP-Q Rigidity, Pragmatic Language, and Aloof Subscales. TVPS-FG was significantly related to the BAP-Q Rigidity subscale score (r = 0.46, p = 0.001) and the BAP-Q Pragmatic Language subscale score (r = 0.42, p = 0.003) (see Fig. 2; Panels B and C); however, TVPS-FG was not found to be related to the BAP-Q Aloof subscale score (r = 0.25, p > 0.08, NS). There was no other significant relationship with the other six TVPS subtest scores with BAP-Q scores (p's > 0.08, NS); thus, the relationship between quantitative measures of autism traits and visual perceptual skill appears to be specific to the TVPS-FG subtest.

Although the SRS Total T-score was not found to be a significant predictor of TVPS-FG scores, we also explored the relationship between TVPS and SRS subscale scores, controlling for age and FSIQ. We also identified a significant relationship between the Social Awareness subscale of the SRS and TVPS-FG (r = 0.45, p = 0.002), TVPS-VC (r = 0.34, p = 0.02), and TVPS-VD approached significance (r = 0.29, p = 0.05). Neither the overall SRS Total T-score, the SCI T-score (p's > 0.06), nor other SRS subscale scores were found to be related to any of the other TVPS subtest scores (p's > 0.10).

While the focus of this study was to assess quantitative traits of autism and individual differences in visual perception, there can be confusion over whether the term "BAP" also includes individuals with ASD diagnoses, per se. Thus, we also confirmed that our main effect was not an artificial

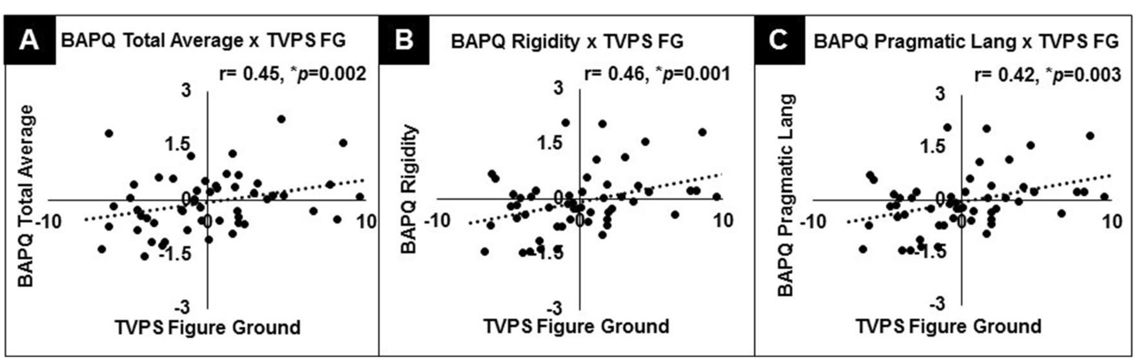

Fig. 2 Results of a partial correlation indicating a significant relationship between (**a**) BAP-Q Total Average scores and TVPS-FG subtest scores (r = 0.45, p = 0.002); **b** BAP-Q Rigidity subscale sores and TVPS-FG subtest scores (r = 0.46, p = 0.001); and **c** BAP-Q Pragmatic Language and TVPS-FG subtest scores (r = 0.42, p = 0.003). Scatterplots illustrate plotted residuals of BAP-Q and TVPS-FG scores

correlation driven by two distinct groups of patients (ASD vs non-ASD). BAP-Q Total average score was not found to be significantly related to TVPS-FG in either group (p's > 0.05); however, TVPS-FG scores in children without an ASD diagnosis were found to be related to BAP-Q Pragmatic Language ($r=0.34$, $p=0.04$) and BAP-Q Rigidity ($r=0.36$, $p=0.03$). See supplement for figures that illustrate the reported relationships separately for each group.

Discussion

In the current study, we assessed broader autism traits in a pediatric sample with a range of clinical features and visual perception measured via the TVPS, a standardized and comprehensive assessment of visual perceptual ability. In our pediatric cohort, we found BAP-Q scores to be a significant predictor of visual perceptual abilities. Specifically, we found a relationship between the Figure Ground subtest of the TVPS and quantitative measures of autism traits assessed via the BAP-Q. No other subtest of the TVPS was found to be related to BAP-Q scores; thus, the link between perceptual ability and autism traits appears to be specific to the TVPS-FG subtest. Results with the SRS Social Awareness subscale are largely consistent with BAP-Q results.

Results presented here are distinct from previous research in several ways. First, we quantitatively assess autism features and demonstrate a significant relationship between BAP-Q scores and visual perceptual skills. This indicates that visual perceptual abilities can be assessed along a continuum and certain perceptual skills scale with the presence of quantitative differences in autism traits. Second, we assessed a broad array of visual perceptual abilities using the TVPS, rather than a singular task that targets an isolated perceptual skill. Previous work in this domain has primarily utilized the EFT, a task that requires individuals to disembed local elements (i.e. a target shape) from a larger design or picture. We made use of the full battery of TVPS subtests in order to comprehensively assess visual perceptual function across several dimensions. Finally, we demonstrate a relationship between broader autism traits and visual perception that is specific to the TVPS-FG subtest in a heterogeneous pediatric sample. Most of the research to date linking domains of perceptual skill and autism traits has been in adults. This is especially true regarding the quantitative assessment of subclinical autism features associated with the broader autism phenotype. Thus, the results presented here make an important contribution to a growing body of literature regarding the dimensional assessment of autism features and other clinically relevant behavioral phenotypes.

In this study, we used a well validated perceptual battery that taps into perceptual processing across a range of visual-perceptual skills. Through this dimensional assessment of perceptual skills across each of all seven subtests of the TVPS, we demonstrated that individual differences within a specific visual perceptual ability are linked with the presence of autism features in children. The Figure-Ground subtest, which is thought to tap into the ability to extract local information from a contextual whole (i.e. local precedence), was the only subtest found to be related to BAP-Q scores. Previous studies assessing whether local precedence is more prominent in individuals with ASD have yielded mixed results (see Van der Hallen et al. 2015 for review). While several have reported a local processing advantage (Behrmann et al. 2006; Rinehart et al. 2000; Wang et al. 2007) or an enhanced ability to detect local targets in patients with ASD relative to typical peers, others found no differences between ASD and typical development (Ozonoff et al. 1994; Plaisted et al. 1999). Study population ascertainment biases and methodological differences in task administration (i.e. paradigm instructions, differences in presented stimuli) may be factors that drive these discrepant findings. In addition, the majority of these studies employ one or two tasks, rather than a complete visual perception assessment battery. Visual perception represents a composite skill of a hierarchy of subskills (basic, low-level skills and more advanced, high-level skills), all of which interact with one another to integrate visual information (Ritter and Ysseldyke 1976; Warren 1993). Thus, a battery of perceptual tasks such as those within the TVPS that assess a broad array of perceptual skills may be better suited to isolate the precise underlying visual perceptual skill that is associated with ASD traits.

In our previous work (Sabatino DiCriscio and Troiani 2017), we reported a significant relationship between TVPS-FG and BAP-Q Aloof scores in a large cohort of adults. While we did identify a relationship between TVPS-FG and BAP-Q total scores in the current study, we did not replicate this specific result with the Aloof subscale in the current study. Thus, critical questions remain regarding how visual perceptual anomalies are related to broader autism traits and how developmental changes in both expression of autism traits and visual perception might influence this relationship. In typical development, perceptual processing is thought to shift from an over-emphasis on local details to a more mature, global bias gradually emerging in middle childhood or adolescence and well into early adulthood (Poirel et al. 2011, 2008). It remains unclear whether atypical visual development is linked broadly to a cumulative sum of ASD traits or specific subdomain of atypical behaviors in ASD. In the current context, we show a linear relationship between TVPS-FG scores and overall ASD traits as indicated by the BAP-Q Average Total score as well as the Pragmatic Language and Rigidity subscale scores. It has been suggested that deficits in pragmatic language arise from this enhanced perceptual and hyperfocused state that impede one's ability to gather meaning or integrate global information (Martin and McDonald 2003). It has also been suggested that enhanced perceptual skills, local processing biases, and hyperfocused states of attention are conceptually linked to the restricted and repetitive behavior (RRB) symptom domain, specifically circumscribed interests and resistance to disengagement (Landry and Bryson 2004; Sasson et al. 2011, 2008). Thus, hyperfocused states of attention and enhanced perceptual skills may simply be a manifestation of RRBs. It is worth highlighting important differences in the subjective content of the repetitive behavior items in the SRS-RRB and BAP-Q Rigidity subscales. SRS-RRB includes questions that focus on stereotypies and motor behaviors while the content of the BAP-Q Rigidity items aligns with higher-order RRBs such as insistence on sameness, circumscribed interests, and adherence to routines/schedules. Future work should continue to comprehensively assess visual perceptual skills and their link to specific subdomains of autism traits across children and adults.

To our knowledge, this is the first study to extend the use of the BAP-Q downward into a pediatric sample. In previous studies of autism traits in typical and atypical children, the SRS has been used to quantify symptom severity and distinguish children with ASD from typically developing peers but has also been used to characterize patterns of ASD behaviors across other neurodevelopmental conditions (Channell et al. 2015; Laje et al. 2010; Reiersen et al. 2007; Van Eeghen et al. 2013). However, the SRS has been noted as a behavioral measure that more accurately identifies clinically significant deficits or impairments central to ASD rather than peripheral and subclinical features of the BAP (Bölte et al. 2011; Ingersoll et al. 2011).While the BAP-Q was originally developed to assess autism symptoms in parents of children with ASD and has been used at length to quantify the presence of autism features in adult populations, the current study suggests that this measure may have a use as a measure of quantitative autism traits in children. Despite the original intention of the use of the BAP-Q as a behavioral measure for use in adults; upon further examination of BAP-Q items, there is nothing in the item wording or phrasing that would discount its use as a parent-report measure in children or self-report in adolescents. Findings presented here regarding the use of the BAP-Q in a pediatric cohort warrants further investigation in order to capture the range of variability in broader autism traits across development and characterize the overlap of typical and atypical developmental trajectories.

Future work should focus on understanding the developmental trajectory and mapping of autism traits and visual perceptual abilities. In the current study, we included two quantitative measures that both assess autism traits but are also considerably different. The SRS was designed to capture deficits in social behaviors that would indicate clinical significance above a designated threshold. The other measure, the BAP-Q, was created with the purpose of measuring subtleties in behavioral traits associated with subclinical ASD in adults. We did not replicate our previous finding of a relationship between TVPS scores and social impairment as measured by the BAP-Q Aloof subscale as in our previous study in adults (Sabatino DiCriscio and Troiani 2017), although we did show a relationship with the SRS Social Awareness T-scores and TVPS-FG. The absence of a relationship between the BAP-Q Aloof subscale and TVPS-FG in the current sample may be due to differences in how social skills manifest in children and adults or may be due to differences in the measurement of social abilities in the SRS and BAP-Q questions. For example, the SRS Social Awareness subscale includes questions focused on applied social skills (i.e. personal hygiene, appropriately ending conversation, walking between two people who are talking, awareness of others' thoughts or feelings, monitoring facial expressions). However, items from the BAP-Q Aloof subscale are focused on the rewarding or motivating aspect of social behavior or social interaction (i.e. "I like being around other people"; "I enjoy being in social situations"; "I look forward to…"; "I prefer…"). Thus, the nature of the relationship between enhanced visual perception and quantitative features of social impairment in children remains unclear. The BAP-Q Aloof items may measure the motivating and rewarding aspects of social interactions that become mature in later adolescence and adulthood, while not tapping into impairments in applied social skills that would be more obvious in pediatric populations. While there are cognitive measures, such as an IQ test, that can measure above and below average abilities at any age or developmental stage, this type of scale does not exist for social abilities and broader autism traits. Thus, in order to better understand the link between social information processing and visual perception across the lifespan, standardized quantitative measures that can be used across development to measure both above and below average abilities will need to be developed and validated.

In addition to identifying a relationship between SRS Social Awareness T-scores and the TVPS-FG, we also find that SRS Social Awareness scales with TVPS-VC scores in our sample (TVPS-VD approached significance). The TVPS-VD assesses an individual's ability to discriminate features of objects and the TVPS-VC assesses the ability to identify a whole, gestalt figure when only fragments are presented. Thus, similar to the TVPS-FG, The TVPS-VC and TVPS-VD subtests may require the focus of attention to local features within a complex image and skills that parallel Figure Ground processing. From this perspective, overlapping perceptual skills may be called upon for successful completion of these tasks. There may also be individual differences in the use of visual strategies for completing these TVPS subtests. For instance, some individuals may use a serial search strategy and compare each local feature from one image to the next that would impact task performance. Individual differences in these visual strategies in the extraction of local features may be linked with degree of social impairment. In order to more comprehensively describe the nature of these relationships with the SRS subscales and TVPS subscales, additional research with a much larger sample is necessary in order to confirm the specific link between precise domains of autism features and Figure-Ground processing.

This work represents critical first steps in documenting a relationship between precise visual perceptual skills and autism traits. However, there are several caveats that should be addressed in future studies. Our current results account for age and IQ; however, our current sample includes children from a wide age range. As mentioned previously, developmental changes in global–local processing have been described (Dukette and Stiles 2001; Poirel et al. 2011, 2008). In order to better quantify and dimensionally assess developmental differences across the hierarchy of visual perceptual skills, future iterations of this work should collect additional data across a larger cohort to identify potentially significant age-related changes across visual these perceptual functions. Our previous work in adults also reported important gender differences in task performance pertaining to trial-level RT to an adapted computerized version of the TVPS-FG items. The standardized administration of the TVPS does not include acquisition of RT data and thus this was not collected as a part of the in-person behavioral testing in the current study; however, future iterations of this work should include RT in addition to task accuracy to further elucidate the potential relationship between visual perception and broader autism traits as well as potential gender differences in visual perceptual skill. Despite these limitations, the current study underlines the importance of objective and dimensional assessment of quantitative traits across the BAP in children and their relationship to other behavioral traits such as cognitive abilities and/or perceptual skills.

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Author Contributions ASD and VT designed the research. ASD collected the data. ASD analyzed the data with guidance from VT. ASD and VT interpreted the data. ASD drafted the manuscript. ASD and VT critically revised the manuscript. All authors have read and approved the final version of the manuscript. All authors reviewed the manuscript.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2010). A new step towards understanding embedded figures test performance in the autism spectrum: The radial frequency search task. *Neuropsychologia, 48*(2), 374–381.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, malesand females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*(1), 5–17.

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., & Minshew, N. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia, 44*(1), 110–129.

Bölte, S., Westerwald, E., Holtmann, M., Freitag, C., & Poustka, F. (2011). Autistic traits and autism spectrum disorders: The clinical validity of two measures presuming a continuum of social communication skills. *Journal of Autism and Developmental Disorders, 41*(1), 66–72.

Brock, J., Xu, J. Y., & Brooks, K. R. (2011). Individual differences in visual search: Relationship to autistic traits, discrimination thresholds, and speed of processing. *Perception, 40*(6), 739–742. https://doi.org/10.1068/p6953.

Channell, M. M., Phillips, B. A., Loveall, S. J., Conners, F. A., Bussanich, P. M., & Klinger, L. G. (2015). Patterns of autism spectrum symptomatology in individuals with down syndrome without comorbid autism spectrum disorder. *Journal of Neurodevelopmental Disorders, 7*(1), 5.

Constantino, J. N., Davis, S. A., Todd, R. D., Schindler, M. K., Gross, M. M., Brophy, S. L., … Reich, W. (2003). Validation of a brief quantitative measure of autistic traits: Comparison of the social responsiveness scale with the autism diagnostic interview-revised. *Journal of Autism and Developmental Disorders, 33*(4), 427–433.

Cribb, S. J., Olaithe, M., Di Lorenzo, R., Dunlop, P. D., & Maybery, M. T. (2016). Embedded figures test performance in the broader autism phenotype: A meta-analysis. *Journal of Autism and Developmental Disorders, 46*(9), 2924–2939.

D'Souza, D., Booth, R., Connolly, M., Happé, F., & Karmiloff-Smith, A. (2016). Rethinking the concepts of "local or global processors": Evidence from Williams syndrome, down syndrome, and autism spectrum disorders. *Developmental Science, 19*(3), 452–468.

Dakin, S., & Frith, U. (2005). Vagaries of visual perception in autism. *Neuron, 48*(3), 497–507. https://doi.org/10.1016/j.neuron.2005.10.018.

Dale, G., & Arnell, K. M. (2013). Investigating the stability of and relationships among global/local processing measures. *Attention, Perception, & Psychophysics, 75*(3), 394–406. https://doi.org/10.3758/s13414-012-0416-7.

Di Martino, A. M. D., Shehzad, Z., Kelly, C., Roy, A. K., Gee, D. G., Uddin, L. Q., … Milham, M. P. (2009). Relationship between cingulo-insular functional connectivity and autistic traits in neurotypical adults. *American Journal of Psychiatry*. Retrieved from http://ajp.psychiatryonline.org/doi/abs/10.1176/appi.ajp.2009.08121894.

Dukette, D., & Stiles, J. (2001). The effects of stimulus density on children's analysis of hierarchical patterns. *Developmental Science, 4*(2), 233–251.

Frazier, T. W., Ratliff, K. R., Gruber, C., Zhang, Y., Law, P. A., & Constantino, J. N. (2013). Confirmatory factor analytic structure and measurement invariance of quantitative autistic traits measured by the Social Responsiveness Scale-2. *Autism*. https://doi.org/10.1177/1362361313500382.

Guy, J., Mottron, L., Berthiaume, C., & Bertone, A. (2016). A developmental perspective of global and local visual perception in autism spectrum disorder. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-016-2834-1

Happe, F. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Science, 3*(6), 216–222.

Happé, F., Briskman, J., & Frith, U. (2001). Exploring the cognitive phenotype of autism: Weak "Central Coherence" in parents and siblings of children with autism: I. Experimental tests. *Journal of Child Psychology and Psychiatry, 42*(3), 299–307. https://doi.org/10.1111/1469-7610.00723.

Happé, F. G., & Booth, R. D. (2008). The power of the positive: Revisiting weak coherence in autism spectrum disorders. *The Quarterly Journal of Experimental Psychology, 61*(1), 50–63.

Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor structure, reliability and criterion validity of the autism-spectrum quotient (AQ): A study in Dutch population and patient groups. *Journal of Autism and Developmental Disorders, 38*(8), 1555–1566. https://doi.org/10.1007/s10803-008-0538-x.

Hurley, R. S. E., Losh, M., Parlier, M., Reznick, J. S., & Piven, J. (2007). The broad autism phenotype questionnaire. *Journal of Autism and Developmental Disorders, 37*(9), 1679–1690. https://doi.org/10.1007/s10803-006-0299-3.

Ingersoll, B. (2010). Broader autism phenotype and nonverbal sensitivity: Evidence for an association in the general population. *Journal of Autism and Developmental Disorders, 40*(5), 590–598.

Ingersoll, B., Hopwood, C. J., Wainer, A., & Donnellan, M. B. (2011). A comparison of three self-report measures of the broader autism phenotype in a non-clinical sample. *Journal of Autism and Developmental Disorders, 41*(12), 1646–1657.

Jobe, L. E., & White, S. W. (2007). Loneliness, social relationships, and a broader autism phenotype in college students. *Personality and Individual Differences, 42*(8), 1479–1489.

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal on the Embedded Figures Test ? *Journal of Child Psychology and Psychiatry and Allied Disciplines, 38*(5), 527–534.

Kaldy, Z., Giserman, I., Carter, A. S., & Blaser, E. (2013). The Mechanisms underlying the ASD advantage in visual search. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-013-1957-x.

Kaldy, Z., Kraper, C., Carter, A. S., & Blaser, E. (2011). Toddlers with autism spectrum disorder are more successful at visual search than typically developing toddlers. *Developmental Science, 14*(5), 980–988. https://doi.org/10.1111/j.1467-7687.2011.01053.x.

Koldewyn, K., Jiang, Y. V., Weigelt, S., & Kanwisher, N. (2013). Global/local processing in autism: Not a disability, but a disinclination. *Journal of Autism and Developmental Disorders, 43*(10), 2329–2340.

Laje, G., Morse, R., Richter, W., Ball, J., & Smith, A. (2010). Autism spectrum features in Smith–Magenis syndrome. In *American journal of medical genetics part C: Seminars in medical genetics* (Vol. 154, pp. 456–462). Wiley Online Library. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/ajmg.c.30275/full.

Landry, R., & Bryson, S. E. (2004). Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry, 45*(6), 1115–1122. https://doi.org/10.1111/j.1469-7610.2004.00304.x.

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., … Rutter, M. (2000). The autism diagnostic observation schedule-generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3), 205–223.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*(5), 659–685.

Martin, N. (2006). *Test of visual perceptual skills, (TVPS-3)*. Flórida: PAR.

Martin, I., & McDonald, S. (2003). Weak coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. *Brain and Language, 85*(3), 451–466.

McKone, E., Davies, A. A., Fernando, D., Aalders, R., Leung, H., Wickramariyaratne, T., & Platow, M. J. (2010). Asia has the global advantage: Race and visual attention. *Vision Research, 50*(16), 1540–1549.

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*(1), 27–43. https://doi.org/10.1007/s10803-005-0040-7.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9*(3), 353–383.

Navon, D. (1981). The forest revisited: More on global precedence. *Psychological Research Psychologische Forschung, 43*(1), 1–32.

O'Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance, 27*(3), 719.

Ozonoff, S., Strayer, D. L., McMahon, W. M., & Filloux, F. (1994). Executive function abilities in autism and Tourette syndrome: An information processing approach. *Journal of Child Psychology and Psychiatry, 35*(6), 1015–1032.

Pellicano, E., Maybery, M., Durkin, K., & Maley, A. (2006). Multiple cognitive capabilities/deficits in children with an autism spectrum disorder:"Weak" central coherence and its relationship to theory of mind and executive control. *Development and Psychopathology, 18*(1), 77–98.

Piven, J., Palmer, P., Jacobi, D., & Childress, D. (1997). Broader autism phenotype: Evidence from a family history study of multiple-incidence autism families. *American Journal of Psychiatry, 154*(2), 185.

Piven, J., Wzorek, M., Landa, R., Lainhart, J., Bolton, P., Chase, G. A., … et al. (1994). Personality characteristics of the parents of autistic individuals. *Psychological Medicine, 24*(3), 783–795.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry, 39*(5), 765–775. https://doi.org/10.1111/1469-7610.00375.

Plaisted, K., Swettenham, J., & Rees, L. (1999). Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 40*(5), 733–742.

Poirel, N., Mellet, E., Houdé, O., & Pineau, A. (2008). First came the trees, then the forest: Developmental changes during childhood in the processing of visual local-global patterns according to the meaningfulness of the stimuli. *Developmental Psychology, 44*(1), 245.

Poirel, N., Simon, G., Cassotti, M., Leroux, G., Perchey, G., Lanoë, C., … et al. (2011). The shift from local to global visual processing in 6-year-old children is associated with grey matter loss. PLoS ONE, 6(6), e20879.

Reiersen, A. M., Constantino, J. N., Volk, H. E., & Todd, R. D. (2007). Autistic traits in a population-based ADHD twin sample. *Journal of Child Psychology and Psychiatry, 48*(5), 464–472.

Rinehart, N. J., Bradshaw, J. L., Moss, S. A., Brereton, A. V., & Tonge, B. J. (2000). Atypical interference of local detail on global processing in high-functioning autism and Asperger's disorder. *The Journal of Child Psychology and Psychiatry and Allied Disciplines, 41*(6), 769–778.

Ritter, D. R., & Ysseldyke, J. E. (1976). Convergent and discriminant validation of the trait of visual Figure-Ground perception. *Journal of Learning Disabilities, 9*(5), 319–325.

Rutter, M., Le Couteur, A., Lord, C., & et al. (2003). *Autism diagnostic interview-revised* (Vol. 30, p. *29*). *Los Angeles, CA: Western Psychological Services*.

Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., & Baron-Cohen, S. (2015). Measuring autistic traits in the general population: A systematic review of the autism-spectrum quotient (AQ) in a nonclinical population sample of 6,900 typical adult males and females. *Molecular Autism, 6*, 2. https://doi.org/10.1186/2040-2392-6-2.

Sabatino DiCriscio, A., & Troiani, V. (2017). Brief report: Autism-like traits are associated with enhanced ability to disembed visual forms. *Journal of Autism and Developmental Disorders, 47*(5), 1568–1576. https://doi.org/10.1007/s10803-017-3053-0.

Sasson, N. J., Elison, J. T., Turner-Brown, L. M., Dichter, G. S., & Bodfish, J. W. (2011). Brief report: Circumscribed attention in young children with autism. *Journal of Autism and Developmental Disorders, 41*(2), 242–247. https://doi.org/10.1007/s10803-010-1038-3.

Sasson, N. J., Turner-Brown, L. M., Holtzclaw, T. N., Lam, K. S. L., & Bodfish, J. W. (2008). Children with autism demonstrate circumscribed attention during passive viewing of complex social and nonsocial picture arrays. *Autism Research: Official Journal of the International Society for Autism Research*. https://doi.org/10.1002/aur.4.

Scherf, K. S., Behrmann, M., Kimchi, R., & Luna, B. (2009). Emergence of global shape processing continues through adolescence. *Child Development, 80*(1), 162–177.

Scherf, S., Luna, B., Kimchi, R., Minshew, N., & Behrmann, M. (2008). Missing the big picture: Impaired development of global shape processing in autism. *Autism Research, 1*(2), 114–129.

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Research, 49*(22), 2705–2739. https://doi.org/10.1016/j.visres.2009.08.005.

Van der Hallen, R., Evers, K., Brewaeys, K., Van den Noortgate, W., & Wagemans, J. (2015). *Global processing takes time: A meta-analysis on local–global visual processing in ASD*. American Psychological Association. Retrieved from http://psycnet.apa.org/journals/bul/141/3/549/.

Van Eeghen, A. M., Pulsifer, M. B., Merker, V. L., Neumeyer, A. M., Van Eeghen, E. E., Thibert, R. L., … Thiele, E. A. (2013). Understanding relationships between autism, intelligence, and epilepsy: A cross-disorder approach. *Developmental Medicine & Child Neurology, 55*(2), 146–153.

Wan, Y.-T., Chiang, C.-S., Chen, S. C.-J., Wang, C.-C., & Wuang, Y.-P. (2015). Profiles of visual perceptual functions in down syndrome. *Research in Developmental Disabilities, 37*, 112–118.

Wang, L., Mottron, L., Peng, D., Berthiaume, C., & Dawson, M. (2007). Local bias and local-to-global interference without global deficit: A robust finding in autism under various conditions of attention, exposure time, and visual angle. *Cognitive Neuropsychology, 24*(5), 550–574.

Warren, M. (1993). A hierarchical model for evaluation and treatment of visual perceptual dysfunction in adult acquired brain injury, part 1. *American Journal of Occupational Therapy, 47*(1), 42–54.

Wechsler, D. (2012). *Technical and interpretative manual: WPPSI-IV*. NY: Pearson Inc.

Wechsler, D., Psychological Corporation. (2011). *WASI-II: Wechsler abbreviated scale of intelligence* (2nd ed.). San Antonio, TX: Psychological Corporation.

Witkin, H. A. (1971). *A manual for the embedded figures tests*. Palo Alto, CA: Consulting Psychologists Press.