J Autism Dev Disord (2010) 40:762–773
DOI 10.1007/s10803-009-0923-0

ORIGINAL PAPER

'Autistic' Local Processing Bias also Found in Children Gifted in Realistic Drawing

Jennifer E. Drake · Amanda Redash · Katelyn Coleman · Jennifer Haimson · Ellen Winner

Published online: 5 January 2010

Abstract We investigated whether typically-developing children with a gift for drawing realistically show the local processing bias seen in individuals with autism spectrum disorder (ASD). Twenty-seven 6–12 year-olds made an observational drawing (scored for level of realism) and completed three local processing tasks, and parents completed the Childhood Asperger Syndrome Test (CAST). Drawing score predicted local processing performance on all tasks independently of verbal IQ, age, and years of art lessons. Drawing score also predicted more frequent repetitive behaviors as assessed by the CAST. Thus, skill in realistic drawing is associated with a strong local processing bias and a tendency towards repetitive behaviors, showing that traits found in individuals with ASD irrespective of artistic talent are also found in typically developing children with artistic talent.

Keywords Autism · Perceptual cohesiveness · Giftedness · Drawing

Introduction

It is well-documented that individuals differ in their ability to draw realistically (Mottron et al. 1999), and these differences can be seen in very early childhood, prior to any kind of instruction in drawing (Golomb 1992; Milbrath 1998; Winner 1996). Striking realistic drawing talent has also been reported in some individuals with "savant syndrome," those individuals with autism who exhibit a disproportionate ability in one domain—music, mental calculation, realistic drawing (Rimland and Fein 1988; Ropar and Mitchell 2002; Sacks 1995; Selfe 1977; Sheppard et al. 2007).

Superior ability in drawing, even though not at the savant level, has also been reported in individuals with autism spectrum disorder (ASD; Vital et al. 2009). Whether the incidence of realistic drawing skill is higher in individuals with ASD than in the general population is a question that warrants investigation. Based on a sample of over 6,000 8-year-olds, Vital et al. (2009) found that 6% of those with ASD have drawing/art talent, but no study has examined the incidence of realistic drawing skill in non-autistic children. However, we looked at 43 drawings by typically developing children collected as part of another study and found not one drawing that could be considered skilled in realism. Clearly a larger sample is needed for any definitive conclusion, but these preliminary findings suggest that the rate of realistic drawing skill is higher in individuals with ASD than in typical populations.

Some researchers have argued that ASD realistic drawing skill is made possible by a diminished influence of conceptual knowledge (Ropar and Mitchell 2002; Sheppard et al. 2007). Others have argued that superior abilities in realistic drawing in both non-savant autistic individuals and autistic savants are made possible by strength, not weakness: individuals with ASD have been reported to excel in processing information at the local level—that is, in analyzing a visual pattern into its components—or at least to focus on local aspects of a scene before taking in the "whole" (Plaisted et al. 1999). Kuschner et al. (2009)

J. E. Drake (✉) · A. Redash · K. Coleman · J. Haimson · E. Winner
Department of Psychology, Boston College, Chestnut Hill, MA 02467, USA
e-mail: drakejc@bc.edu

E. Winner
Project Zero, Harvard Graduate School of Education, Cambridge, MA, USA

report findings suggesting that individuals with ASD treat global elements and details of a complex design (the Rey Osterrieth Complex Figure) as equivalent parts of the picture. Such a focus on detail could help to account for the precision of detail in ASD drawings (Mottron et al. 2006).

In addition, it should be noted that a focus on local components can exist side by side, and even be facilitated by, a diminished conceptual knowledge of what is being drawn. Artists have long known that techniques such as closing one eye, looking through a view finder or Durer's grid, or copying a picture upside down all result in greater realism. These techniques allow the artist to copy something without sensing what is being copied; thus the artist's global schema for the object is not triggered, and the artist can instead zero in on the local features of the scene to be drawn (e.g., Edwards 1989; Nicolaides 1990). In this study we investigate the strength of the association of local processing with drawing talent in typically developing children with the goal of determining whether this processing style in ASD is the extreme end of a continuously distributed trait.

Evidence that the tendency to analyze a pattern into its parts is associated with realistic drawing skill in savants comes from a report of the strategy used by E.C., a strategy referred to as "construction by local progression" (Mottron and Belleville 1993, p. 29). E.C. did not draw the global shape of a figure first but instead began his drawings with a detail, adding contiguous elements, and often using an even more extreme local strategy—moving onto an adjacent part before completing a part already begun. Each new line was in spatial contiguity with the preceding one—as if he were drawing shapes like tracing a pattern, rather than using lines primarily to reveal the representational meaning of what he was drawing. A similar focus on detail over global form was reported by Mottron et al. (1999) who presented autistic and non-autistic individuals (not selected for artistic talent or artistic training) with objects and non-objects to be copied. Overall accuracy was at ceiling and both groups produced an equal number of global and local features. However, in comparison to the non-autistic group, the ASD group produced more local features early on in the drawing sequence and more global features later on, and this held for both non-objects (where local features might be expected to have as much salience as global ones) and objects (where global features might be expected to have more salience than local features since knowledge of the object's identity should trigger a schema for that object). In addition, time taken to draw was unaffected by the impossibility of the objects drawn for the autistic group but not for the non-autistic group.

Evidence for a local processing bias in individuals with ASD also comes from their reported performance on a variety of perceptual tasks requiring finding parts within wholes (often called hierarchical local–global tasks). Individuals with autism perceive such hierarchical stimuli without the global bias characterizing the typical population (for a review, see Wang et al. (2007): embedded figures are more rapidly detected (Edgin and Pennington 2005; Jolliffe and Baron Cohen 1997; Mottron et al. 2003; Shah and Frith 1983) and globally impossible figures are copied more quickly (Mottron et al. 1999).

Among those visuo-spatial superiorities in individuals with ASD, the most replicated is related to performance on the block design. According to the threshold chosen and the type of population identification, between 22 and 90% of autistic individuals with normal intelligence excel on the Block Design subtest of the WISC-III (Caron et al. 2006; Pellicano et al. 2006; Siegel et al. 1996), a task that requires matching blocks to each part of a design. Autistic superiority disappears when the figures to be copied are segmented (Shah and Frith 1993), although a ceiling effect may be implicated (Plaisted 2001). Thus autistic superiority on the Block Design Task may be at least partially due to superior mental segmentation, or 'locally oriented processing.'

Caron et al. (2006) studied individuals with ASD who showed relatively high performance on the Block Design Task, and compared them to individuals with ASD without a Block Design peak. They also included two groups of non-autistic individuals, ones with and without a relative Block Design peak. The participants were given a modified Block Design Task whose items varied in perceptual cohesiveness. In the items with minimal perceptual cohesiveness, the boundary between red and white always co-occurred with the edge separating two blocks, making it easy to see each block as a unit. Minimally cohesive items are easily solvable using a local strategy, matching each square to a block, and do not require the ability to analyze a whole into its parts since the parts clearly emerge from the figure to be reproduced. In the items with maximal perceptual cohesiveness, the boundary between red and white never co-occurred with the edge separating two blocks, making it difficult to see the contribution of each block as a unit. Maximally cohesive items require analysis of a whole into its parts (blocks) by spontaneous mental segmentation since the edges do not provide natural segmentation information. Those intermediate in perceptual cohesiveness had an intermediate number of same colored adjacencies. Results showed that for both ASD groups—those with a peak and those without—construction time on the unsegmented designs was delayed less by the increasing coherence of the items than it was for their respective control groups (typical individuals with and without a Block Design peak). The superior performance of the ASD participants was erased on the segmented version which allowed everyone to use a local strategy. The authors concluded that a local processing strategy revealed by the diminished detrimental influence of perceptual coherence on the unsegmented Block Design is specific to autism.

The possibility that ASD represents the extreme end of several possibly independent, sub-threshold, transmissible, and continuously distributed quantitative traits has received recent empirical support, although researchers disagree on whether what is involved is a unique variable (Constantino and Todd 2003) or several variables (Mandy and Skuse 2008). There is stronger support for the latter position since socio-communicative traits and visuo-spatial abilities are under separable genetic influences in the typical, sub-threshold and broader autistic phenotype population (Happé and Ronald 2008). Within this framework, a local processing bias may prove to be another of these autistic traits. Such a conclusion is consistent with findings that autistic personality traits are associated with absolute pitch (Brown et al. 2003), superior performance on the Block Design Task (Stewart et al. 2009) and the Embedded Figures Test (Grinter et al. 2009), and with the finding of superior performance by parents of autistic children on the Embedded Figures Test in comparison to parents of schizophrenic and typical children (Bölte and Poustka 2006). Therefore, typically developing children may exhibit autistic symptoms such as repetitive behaviors that might lead to a detail focus and hence hyper-realism in drawing.

Support for this suggestion comes from a study by Pring et al. (1995) showing that the local processing is not exclusive to individuals with ASD. Two tasks requiring mental segmentation—a picture puzzle task in which one must put together parts to complete a whole and the Block Design Task—were administered to two groups with artistic talent (autistic savants, gifted child artists) and two control groups (adults with ASD and children without ASD and not selected for artistic talent). Both art talented groups were faster at picture completion than the nontalented groups; and the non-autistic controls were faster than the autistics controls. On the Block Design Task, there was a difference between the talented and nontalented groups: the talented groups were faster than the nontalented groups. However, the autistic controls were significantly faster at completing the block design than the normal controls. The finding that both art talented groups outperformed the control groups on the puzzle task shows that the kind of local processing skill that speed on this task requires is not specific to ASD diagnosis.

The goal of our study was to determine whether a local processing bias is associated with realistic drawing talent in typically developing children. Such a finding would suggest that a local processing bias contributes to artistic talent in those with and without ASD. Such a finding could therefore also suggest how and why savant skills occur so frequently among those with ASD and why artistic talent may occur more frequently among those with ASD than in a typical population. Of course, it is also possible that children not diagnosed with ASD who show realistic drawing skill have some autistic traits, and our study was also designed to test this hypothesis.

In summary, the study was designed to test the hypotheses that typically developing children with drawing realism skill (compared to those with no talent in drawing) show a local processing bias as evidenced by the following:

1. On the maximally cohesive Block Design Test items (which do not reveal their parts), less facilitation by presentation of the items in segmented rather than unsegmented version.
2. Superior performance on the Group Embedded Figures Test.
3. Copying of local before global features on the copying task.
4. Higher scores on the Childhood Asperger Syndrome Test.

Method

Participants

Participants were 27 children ranging in age from 6;9 to 12;0 years (mean age = 9;8 years) who were taking after-school art classes in the greater Boston area. There were 18 girls and 9 boys. None of the children had previously been diagnosed with ASD.

Materials and Procedure

Children were seen individually by one experimenter at the after-school art program, the child's home, or in our laboratory. The testing session lasted 2.0–3.0 hours and children were provided with snacks and breaks as needed. For all tasks, the child and the experimenter were seated next to each other at a table.

Socioeconomic Status

Socioeconomic status (SES) was assessed with the use of a written questionnaire given to parents asking about each parent's highest level of education. Following Norton et al. (2005), parents were classified into one of six categories: 1 = some high school; 2 = high school graduate or GED; 3 = some college, associates, or vocational degree; 4 = college graduate; 5 = master's degree; and 6 = doctoral degree. Children received an SES score based on the average parental score; for those with single parents, only one score was used.

Years of Art Lessons

Parents were asked to indicate on a questionnaire the number of years of art classes taken by their child in addition to the ordinary school curriculum.

Block Design

Caron et al.'s (2006) modified Block Design Task was administered. The items vary in perceptual cohesiveness (minimal, intermediate, and maximal) and number of blocks (4, 9, and 16). Greater cohesiveness increases task difficulty due to the lack of edge cues.

The task was presented first in traditional unsegmented form and then in segmented form with the units of the design separated from one another by 1/3 of the width of each unit, as in Shah and Frith (1993) (see Fig. 1 for an unsegmented and segmented version of the same item). The unsegmented version was always administered first in order to avoid a facilitation effect (as in Caron et al. 2006; Shah and Frith 1993).

Time limit differed by number of blocks to be used: 120, 180 and 240 s for 4, 9, and 16 blocks respectively. Participants received a point for each design correctly copied and construction times were recorded.

Group Embedded Figure Test

The Group Embedded Figure Test (GEFT) was administered (Witkin et al. 1971). In this task one must identify (by tracing) a smaller geometric shape embedded within a larger figure (Fig. 2).

The test consists of seven control items followed by 18 test items. Children were instructed to trace the shape

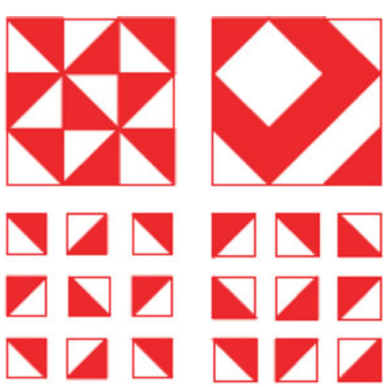

Fig. 1 Minimally (*left*) and maximally (*right*) cohesive block design in unsegmented and segmented versions

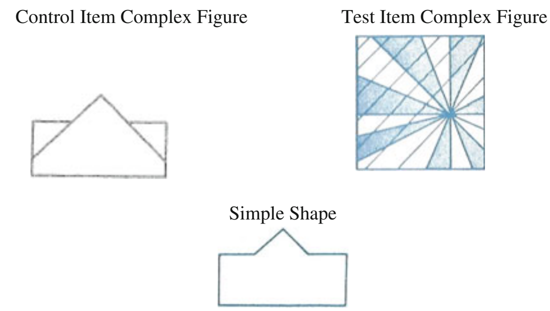

Fig. 2 Control item, complex figure, and simple shape from the Group Embedded Figure Test

completely and erase all mistakes. A point was given for each correctly traced item, with a maximum score of 18. We modified the timing administration of the GEFT. In adult samples, participants are given a set time to complete the items. In our sample, children were given unlimited time to complete each item. Response times were recorded from the time the item was presented until the child successfully traced the item or gave up. Since tracing ability may be related to drawing talent, the control items were included as a predictor in the GEFT analyses. As we report later, performance on the control items proved unrelated to tracing ability.

Copying Task

Children were given a pencil without an eraser and were asked to copy four drawings—two objects and two non-objects, figures from Mottron et al. (1999). Nonobjects were created by decomposing the objects features (i.e., lines, curves) and regrouping the features into a new two-dimensional design (see Fig. 3). Children were told to copy the pictures as quickly and accurately as possible and were given a maximum of 3 min to copy each stimulus. Drawings were videotaped and copying times recorded.

Using a scoring system developed by Mottron et al. (1999), we scored drawings for graphic hierarchization. Graphic hierarchization was assessed by calculating the mean proportion of local and global features copied during the first third set of features copied, followed by the second third, and by the last third. Thus, if a child successfully copied 36 out of 39 elements, the first third would contain 12 elements. We then calculated the number of local and global features among these 12 copied features. This enabled us to determine whether children with drawing talent drew local features before global ones, a tendency reported in autistic adults (Mottron et al. 1999). Reliability was performed on thirty-percent ($n = 8$) of the videotapes. Inter-rater reliability was high, $\Phi = .99$.

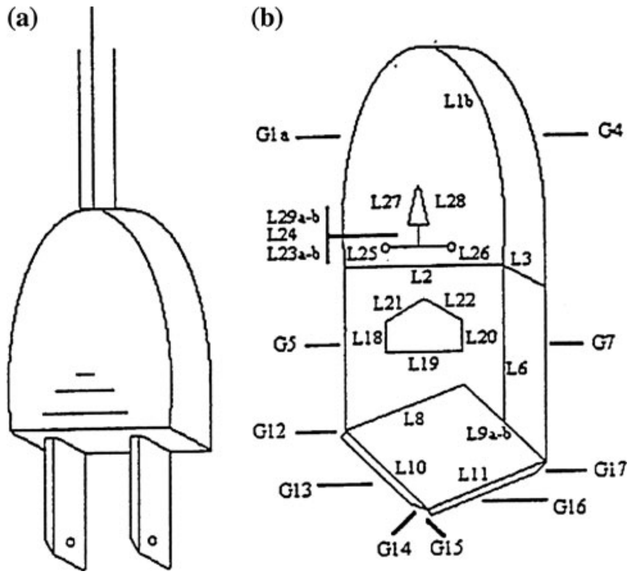

Fig. 3 Copying task stimuli and scoring procedure. Each line is identified by a number that corresponds to a local or global feature

Childhood Asperger Syndrome Test

Parents completed the Childhood Asperger Syndrome Test (CAST; Williams et al. 2005), a measure that assesses autistic personality traits in non-clinical settings. The CAST is a parent report measure that yields scores ranging from 1 to 31. A score above the cut-off of 15 represents the current consensus for a diagnosis of autism. Using DSM-IV criteria, items were divided into three scales: Social Impairments (SI), Communication Impairments (CI), and Restricted Repetitive Behaviors and Interests (RRBI; American Psychological Association 1994; Ronald et al. 2006). The SI scale consisted of 12 items, the CI scale consisted of 12 items, and the RRBI scale consisted of 7 items.

Observational Drawing

Children were given a 9″ × 11″ sheet of white paper and a sharpened pencil with an eraser and were asked to draw a still-life consisting of a corkscrew and six connected transparent cylinders, one of which contained a branch of dried leaves (see Fig. 4). These objects were chosen because they are difficult to draw: the leaves were irregular and organically shaped; a corkscrew is a complex object; and the way in which the cylinders connected and occluded one another was challenging. These objects were placed in precisely the same position for each child (the drawing paper was placed directly in front of the child; the objects were placed on a piece of same-sized white paper about two inches to the left of the child's sheet of drawing paper). Children were instructed simply to look at the "still life" and draw what they saw. They were told that they could draw for 15 min.

Drawings were rated by two experimenters who independently rated the drawings for the presence of elements characteristic of artistically gifted children's drawings (Milbrath 1998; Winner 1996): (1) use of line to indicate edge rather than use of line to stand for object: for the corkscrew this consisted of drawing the curlicue of the corkscrew with two lines and for the branch this consisted of drawing the stem with two lines; (2) detail: for the corkscrew this consisted of drawing square-shaped rather than rounded gears and for the branch this consisted of drawing at least one organically shaped leaf rather than a stereotyped circle for a leaf; (3) foreshortening: for the corkscrew this consisted of shortening the base and for the cylinders this consisted of drawing the tops of the cylinders as ellipses; and (4) occlusion: for the corkscrew this consisted of one demonstration of occlusion of one part of the corkscrew by another and for the cylinders this consisted of drawing the back row of cylinders behind the front row.

Children received a point for each characteristic successfully drawn, for a total possible score of 8 (since there were four characteristics × two objects that we scored). So as not to penalize children who drew only the corkscrew or only the vase with leaves, we calculated the proportion of correct parts out of the total number of parts drawn. Inter-rater reliability between the two raters was calculated at $\Phi = .93$. The few disagreements were resolved by a third rater. Figure 4 shows the still-life model and a drawing by two 10-year-olds, one by a child with a perfect drawing score of 1.0 (left), one by a child with a low drawing score of 0.0 (right).

Kaufman Brief Intelligence Test-II

The verbal and nonverbal section of the Kaufman Brief Intelligence Test-II (Kaufman and Kaufman 2004) was administered. The verbal section consists of two parts, a vocabulary test in which pictures of objects must be named, and a definitions test in which a word with missing letters must be deciphered after hearing its definition. The nonverbal section consists of matrices to be completed by selecting the correct design or representation. Age-scaled scores were computed.

Results

Preliminary Analyses

Children had an average of 2.3 years of art lessons (range = 0–5; SD = 1.8 years). Parents' mean SES score

Fig. 4 Still-life model and drawings by two 10-year olds, one with a drawing score of 1.0 and (*left*) and one with a drawing score of 0.0 (*right*)

was 4.5 (range = 4.0–6.0; SD = .73). Mean verbal IQ was 115.8 (range = 94–146; SD = 12.3) and nonverbal IQ was 120.6 (range = 92–153; SD = 17.8). Verbal IQ, age, and years of art lessons were included as predictors in all subsequent analyses.

A preliminary analysis showed nonverbal IQ to be related to drawing talent ($r = .611$, $p < .001$). Such a finding is not surprising because spatial ability likely contributes to nonverbal IQ. In previous studies of local processing in individuals with autism, participants have been matched only on verbal IQ (Caron et al. 2006; Shah and Frith 1993). Nonverbal IQ was therefore not included here as a predictor because of its relation to drawing talent.

Analyses were conducted to determine whether children performed at ceiling for any of the item types on the Block Design and items on the Group Embedded Figure Test. A one sample t-test performed for the six conditions for the Block Design, segmentation (2) by item type (3), showed that mean scores were always significantly different from the highest possible score of 6 ($p < .003$). A one sample t-test performed on the accuracy on the Group Embedded Figure Test showed that the mean score was always significantly different from the highest possible score of 18 ($p < .001$). Table 1 presents the means and standard deviations for drawing score and the Block Design Task.

Block Design Task

In order to test the hypothesis that children with realistic drawing talent show a local processing bias on the Block Design Task, we conducted two kinds of regression analyses (Table 2). First, we calculated an unsegmented minus segmented difference score for each child across all items. A regression was performed with the segmentation difference score as the dependent variable and drawing score, verbal IQ, age, and years of art lessons as the independent variables. The model was significant,

Table 1 Means and standard deviations for drawing score and the block design task

	Mean	Standard deviation
Drawing score	0.6	0.34
Block design unsegmented		
Accuracy	13.2	5.1
Construction time	171.4	49.2
Block design segmented		
Accuracy	14.8	3.5
Construction time	95	28.5

Note: Construction Time is in seconds

$R^2 = .408$, $F = (2, 22) = 3.793$, $p = .017$, but contrary to hypothesis, the difference score was not predicted by drawing score ($p = .136$); instead the difference score was marginally predicted by age ($\beta = .356$, $p = .079$), but not by verbal IQ ($p = .213$), or years of art lessons ($p = .638$).

The segmentation difference score included items at all three levels of perceptual cohesiveness. Since items at the lowest level of perceptual cohesiveness should be unaffected by presentation in segmented version, we next created segmentation difference scores for each of the three level of cohesiveness, and performed a regression on each of these three scores. The key test is how participants perform on the maximally cohesive items in unsegmented vs. segmented form.

A regression on the maximally cohesive item segmentation difference score as the dependent variable, and drawing score, verbal IQ, age, and years of art lessons as the independent variables, approached significance, $R^2 = .300$, $F = (2, 22) = 2.354$, $p = .085$. More importantly, drawing score ($\beta = .456$, $p = .047$) significantly predicted the maximally cohesive difference score; neither age ($p = .683$), verbal IQ ($p = .235$), nor years of art lessons ($p = .476$) were predictive. Similar but somewhat weaker results were obtained for the intermediate cohesive item segmentation difference score: the model was significant, $R^2 = .365$, $F = (2, 22) = 3.167$, $p = .034$ and drawing score ($\beta = .386$, $p = .075$) but not age ($p = .112$), verbal IQ ($p = .459$), or years of art lessons ($p = .853$) marginally predicted the difference score. As expected, no effect of segmentation was found for the minimally cohesive item difference score: the model was significant, $R^2 = .379$, $F = (2, 22) = 3.352$, $p = .028$, but age ($\beta = .510$, $p = .017$) and not drawing score ($p = .311$), verbal IQ ($p = .077$), or years of art lessons ($p = .855$) predicted the difference score. The fact that drawing talent was associated with a smaller segmentation difference score on the maximally cohesive items demonstrates that drawing talent is associated with a local processing perceptual style.

Difference scores were also computed for the construction times (Table 3). A series of regressions was performed with the difference score as the dependent variable and drawing score, verbal IQ, age, and years of art lessons as the independent variables. Verbal IQ ($\beta = -.451$, $p = .028$) predicted the segmentation difference score for the minimally cohesive items. None of the independent variables predicted the construction time difference scores for the intermediate or maximally cohesive item segmentation difference scores. Thus, the hypothesis was supported for accuracy but not construction time.

Group Embedded Figure Test

In order to test the hypothesis that children with realistic drawing talent excel on the group embedded figures test, a regression was run on the GEFT accuracy and reaction time scores for the test items, using as independent variables accuracy on the control items, drawing score, verbal IQ, age, and years of art lessons (Table 4).

Accuracy on the GEFT was predicted by drawing score ($\beta = .662$, $p < .001$) but not by performance on the control items ($p = .363$), verbal IQ ($p = .302$), age ($p = .575$), or years of art lessons ($p = .865$). No factors predicted reaction time performance on the GEFT, $R^2 = .268$, $F = (5, 20) = 1.465$, $p = .245$. Thus, the hypothesis was supported for accuracy but not reaction time.

Table 2 Regression coefficients for accuracy on the block design task

	Accuracy			
	Segmentation difference	Maximally cohesive difference	Intermediate cohesive difference	Minimally cohesive difference
Mean difference (SD)	−1.67 (3.13)	−1.37 (1.84)	.00 (1.0)	−.30 (1.23)
Predictors				
Drawing score	.309	.456*	.386^t	−.212
Age	.356^t	.087	.322	.510*
Years of art lessons	−.086	−.142	.035	−.034
Verbal IQ	.224	.232	−.136	.331
R^2	.408*	.300^t	.365*	.379*

Note: Segmentation Difference = Unsegmented correct—Segmented correct; Maximally Cohesive Difference = Maximally cohesive unsegmented correct—Maximally cohesive segmented correct; Intermediate Cohesive Difference = Intermediate cohesive unsegmented correct—Intermediate cohesive segmented correct; Minimally Cohesive Difference = Minimally cohesive unsegmented correct—Minimally cohesive segmented correct

^{t} $p < .10$; * $p < .05$

Table 3 Regression coefficients for construction time on the block design task

	Construction time			
	Segmentation difference	Maximally cohesive difference	Intermediate cohesive difference	Minimally cohesive difference
Mean difference (SD)	79.1 (39.0)	34.8 (26.8)	30.5 (19.6)	15.5 (14.9)
Predictors				
Drawing score	.075	.178	−.113	−.206
Age	−.093	.053	−.070	−.092
Years of art lessons	−.158	−.233	−.077	.050
Verbal IQ	−.262	−.049	−.177	−.451*
R^2	.118	.083	.075	.272

Note: Segmentation Difference = Unsegmented construction time—Segmented construction time; Maximally Cohesive Difference = Maximally cohesive unsegmented construction time—Maximally cohesive segmented construction time; Intermediate Cohesive Difference = Intermediate cohesive unsegmented construction time -Intermediate cohesive segmented construction time; Minimally Cohesive Difference = Minimally cohesive unsegmented construction time—Minimally cohesive segmented construction time

[t] $p < .10$; * $p < .05$

Table 4 Regression coefficients for accuracy and reaction time on the group embedded figure test

	Accuracy	Reaction time
Mean (SD)	9.5 (5.9)	24.5 (12.1)
Predictors		
Control items	.152	.537
Drawing score	.662***	−.183
Age	.088	−.249
Years of art lessons	.022	−.133
Verbal IQ	.132	−.178
R^2	.723***	.268

Note: Reaction time is in seconds

*** $p < .001$

Copying Task

In order to test the hypothesis that children with realistic drawing talent copy local features before global ones, as was found for autistic adults (Mottron et al. 1999), a series of regressions was performed. We looked at the order in which local and global features were copied, and divided each participant's copied features into thirds. We next computed the proportion of local to total and global to total features in the first and last third of the items copied for each participant. As before, drawing score, verbal IQ, age, and years of art lessons were included as independent variables (Table 5).

Drawing score predicted one thing only: mean proportion of local object features copied in the first third of features copied ($\beta = .467$, $p = .047$), and neither verbal IQ ($p = .820$), age ($p = .998$), or years of art lessons ($p = .573$) were predictive. Thus, children with greater realism skill drew more local than global features early on in the drawing process, but only when they knew what they were copying (that is, only with objects and not with non-objects). This finding is partially consistent with what Mottron et al. (1999) showed with adults with ASD: their participants showed this same bias towards copying local features early on but they did so equally when copying objects and non-objects.

Table 5 Regression coefficients for drawing sequence in the copying of objects and nonobjects

	Objects				Nonobjects			
	Local first third	Global first third	Local last third	Global last third	Local last third	Global last third	Local last third	Global last third
Mean percentage (SD)	.19 (.05)	.14 (.05)	.24 (.04)	.09 (.04)	.15 (.07)	.18 (.07)	.24 (.07)	.09 (.07)
Predictors								
Drawing score	.467*	−.363	−.330	.304	−.022	.044	−.217	.235
Age	.000	−.056	.014	−.015	.109	−.119	.064	−.071
Years of art lessons	.115	−.220	−.233	.223	.343	−.333	.004	.000
Verbal IQ	−.045	.022	.103	−.066	−.237	.213	.196	−.212
R^2	.264	.259	.205	.178	.138	.123	.072	.085

* $p < .05$

Sub-Threshold Autistic Traits

In order to test the hypothesis that higher levels of drawing realism skill should predict score on the repetitive behavior scale a series of correlations were run (Table 6). No child in our sample scored above the cutoff level of 15 for the diagnosis of autism.

Contrary to prediction, the overall CAST score was not associated with drawing score, $r = .049$, $p = .809$. However, one subscale of the CAST was associated with drawing score—the restricted repetitive behavior and interests subscale ($r = .440$, $p = .022$). The overall CAST score and three subscales were unrelated to accuracy on the GEFT, the difference score on the maximally cohesive Block Design items, and the sequence of local and global features copied in the copying task. Thus, we conclude that skill in drawing realism and not performance on the local processing tasks is related to the repetitive behavior scale.

Discussion

Artists seeking to draw realistically have often relied on aids that help them to overlook the global aspects of the scene they are trying to draw and instead to keep their eyes trained on the local components: aids such as Durer's grid (where the artist looks at the scene through a grid and draws what is seen in each section of the grid, part by part) or the trick of looking with one eye through a viewfinder are both ways of breaking up a three-dimensional scene into smaller parts and weakening the influence of the whole. Even without such aids, however, artists may be skilled in focusing on local components of a scene either because they have trained themselves to do so or because they have the same kind of atypical visual processing that has been reported in individuals with ASD. In this study we present evidence that children with drawing skill, as defined by a precocious ability to transfer a three-dimensional scene onto a flat surface without the use of any aids, exhibit the same kind of local processing bias seen in individuals with ASD. We cannot definitively answer the question of whether this processing was learned by practice in drawing, but our study does suggest that training was not implicated, since years of art lessons did not predict local processing on any of our measures.

We hypothesized that children gifted in drawing realism would exhibit a local processing bias like that seen in ASD, and we demonstrated this with the use of three separate measures. First, on a revised version of the Block Design Task developed by Caron et al. (2006), children with higher drawing skill were less helped (in comparison to those with lower drawing skill) by presentation of the maximally cohesive items in segmented form. Second, children with higher drawing skill performed better than those with lower drawing skill on an embedded figures test, and this finding was independent of their presumably greater copying skill. And third, when asked to copy drawings of objects, those with greater drawing skill drew more local features early on compared to those with lesser drawing skill. When copying drawings of non-objects, no association of drawing skill with temporal priority of local features was found. A non-object, however, has far less of a global form that needs to be overcome since one does not have any conceptual knowledge to impose upon that non-object. We suggest that non-object stimuli are similar to the segmented block design items: the parts are more clearly shown because of the diminished influence of the whole.

The association between drawing skill and performance on the block design was found only for the most difficult and unsegmented items—maximally cohesive items. It was

Table 6 Correlation matrix of autistic personality traits with drawing score and performance on the local processing tasks

	Overall CAST score	SI	CI	RRBI
Mean (SD)	4.59 (3.5)	1.04 (1.83)	1.67 (1.88)	1.89 (1.12)
Drawing score	0.049	0.018	−0.189	.440*
Maximally cohesive difference score	−0.03	0.141	−0.126	−0.114
Accuracy GEFT	0.129	0.173	−0.082	0.259
Copying task objects				
Local first third	0.253	0.265	0.115	0.164
Global first third	−0.233	−0.284	−0.088	−0.118
Local last third	−0.102	−0.172	0.1	−0.204
Global last third	0.137	0.182	−0.051	0.216
Copying task nonobjects				
Local first third	0.032	0.087	0.086	−0.185
Global first third	−0.02	−0.091	−0.067	0.197
Local last third	0.112	0.062	0.06	0.149
Global last third	−0.105	−0.065	−0.047	−0.14

* $p < .05$

on these items that presentation of the task in segmented form facilitated performance more for those without drawing skill. This finding contrasts with the overall effect of segmentation reported by Shah and Frith (1993). However, Shah and Frith (1993) did not compute the kind of difference score used here. Instead, they compared the construction time of autistic and non-autistic children separately for segmented and unsegmented items, finding that autistic children were faster only on the unsegmented designs. Furthermore, Shah and Frith (1993) did not include items of low perceptual cohesiveness, items that would not benefit from segmentation. Our results, therefore, are not in fact inconsistent with those of Shah and Frith since we found a diminished benefit of segmentation on the maximally cohesive items—just those items where segmentation could help.

Our finding that children gifted in drawing realism have a superior ability to mentally segment a complex design into its local features is consistent with research by Pring et al. (1995), showing that gifted artists focus on the local elements of a complex design. Thus, local processing is not exclusive to individuals with ASD. With a difference in the relevant variable (accuracy rather than speed), these findings also parallel Caron et al.'s (2006) finding that autistic individuals show a diminished facilitation effect of segmentation on the Block Design Task compared to non-autistic individuals. The non-autistic individuals in Caron et al.'s study were not selected for drawing giftedness. The present study shows that non-autistic children who are talented in drawing realism perform in the same way as do autistic individuals, revealing the same kind of visuo-spatial strength.

We found a similar result with the Group Embedded Figure Test. Drawing score predicted accuracy but not reaction time. While children had similar reaction times, it was those skilled in drawing who were able to detect a simple shape in a complex pattern with greater accuracy. Once again, this suggests that children gifted in observational drawing share a local processing bias with individuals with autism.

On the copying task, drawing score was related to more local features being copied in the first third of the task, but only for objects. This is in contrast to what has been found with adults with ASD: Mottron et al. (1999) reported that adults with ASD showed this same bias towards copying local features early on but they did so equally when copying objects and non-objects. Local features are likely to be more salient in drawings of non-objects than objects since the non-object has no categorical identity. The presumed increased salience of local features in non-object drawings may have erased any effect of drawing skill in our typically developing participants.

If typically developing children with precocious drawing skill show the same kind of atypical perceptual processing that has been reported in those with ASD, perhaps these children are not in fact typically developing, but have sub-clinical autistic traits. We investigated this by asking all parents to complete the CAST. There was no association with overall CAST score and drawing score. Thus, children with precocious realism skill and a local processing bias are not children undiagnosed with ASD. But when we looked more closely at the pattern of response on the CAST by looking separately at responses to questions about social impairments, communication impairments, and restricted and repetitive behaviors and interests, we discovered that drawing skill is related to restricted and repetitive behaviors and interests.

Surprisingly, however, the repetitive behavior scale was not associated with local processing bias on any of our measures. Thus, while we can conclude that drawing talent is associated with both local processing and repetitive behaviors, repetitive behaviors are not associated with (and thus cannot be causally implicated in) local processing. Repetitive behaviors appear to be a function of drawing skill in addition to being associated with autism, revealing that individuals gifted in drawing share traits with individuals diagnosed with autism. Finally, the lack of association between drawing giftedness and overall CAST score contrasts with findings that autistic personality traits in adults are associated with absolute pitch (Brown et al. 2003), superior performance on the Block Design Task (Stewart et al. 2009) and the Embedded Figures Test (Grinter et al. 2009). However, the finding that children gifted in drawing realism have more restricted and repetitive behaviors and interests is consistent with what has been found in those with ASD who also have special talents: Vital et al. (2009) showed that engaging in repetitive behavior was related to drawing talent.

Taken together, the results reported here and those reported by Vital et al. allow us to posit the following conclusions. First, the tendency to engage in repetitive behaviors, a tendency along a continuum that can be found in more extreme forms in individuals with ASD, is associated with drawing talent in typically developing children. Second, while local processing bias is associated with a diagnosis of ASD regardless of the presence or absence of drawing talent, this is not the case in typically developing individuals. Instead, in non-autistic populations, local processing bias is associated with drawing talent. Hence, our results show that typically developing children with drawing talent share an atypical perceptual processing tendency (local bias) with individuals diagnosed with ASD, and an atypical behavioral tendency (repetitive behaviors).

The present study provides the first evidence that both the local processing bias and the repetitive behavior tendencies reported in individuals with ASD, irrespective of drawing skill, are also a characteristic of typically developing children gifted at realistic observational drawing. Such children resemble autistic children in their perceptual talents (as shown by how they perform on our tasks and as shown by parents' reports of their repetitive behaviors) despite the gifted drawers not being autistic in any sense. These results were found independently of age, years of art lessons, and verbal IQ.

Our results cannot be used to adjudicate different views about autism since our participants were typically developing. However, we argue that our results suggest that the local processing bias found in ASD should be considered a strength rather than a deficit since we find the same tendency in typically developing children with drawing giftedness. We conclude that skill in realistic drawing is made possible by a strong local processing bias and is associated with repetitive behaviors. In these senses, individuals with ASD share important traits with non-ASD individuals who have artistic talent. We make no claims, however, about the brain basis of local processing style in ASD vs. typically developing individuals, as the same style can result from entirely different brain mechanisms.

While a local processing bias has been found in the general population of individuals with ASD, few studies have investigated the perceptual skills of individuals with ASD talented in drawing. We are now investigating whether drawing talent in individuals with ASD is related to strength of local processing bias, and whether local processing, repetitive behavior tendencies, and a heightened incidence of autism in first degree relatives can be found in non-autistic adult visual artists skilled in realistic drawing.

Acknowledgments We thank John Goodnough and Joanne Leunig, Director and Manager, respectively, of ActonArt Drawing School, Acton, Massachusetts; Laura-Marie Small of Kidcasso Art Studio in Wakefield, Massachusetts; and Pat Walker, Director of Education at the Danforth Museum of Art, Danforth, Massachusetts, for opening their doors to us and generously allowing us to test the children in their programs.

References

American Psychiatric Association. (1994). *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Bölte, S., & Poustka, F. (2006). The broader cognitive phenotype of autism in parents: How specific is the tendency for local processing and executive dysfunction? *Journal of Child Psychology and Psychiatry, 47*, 639–645.

Brown, W. A., Cammuso, K., Sachs, H., Winklosky, B., Mullane, J., Bernier, R., et al. (2003). Autism-related language, personality, and cognition in people with absolute pitch: Results of a preliminary study. *Journal of Autism and Developmental Disorders, 33*, 163–167.

Caron, M. J., Mottron, L., Berthiaume, C., & Dawson, M. (2006). Cognitive mechanisms, specificity and neural underpinnings of visuospatial peaks in autism. *Brain: A Journal of Neurology, 129*, 1789–1802.

Constantino, J. N., & Todd, R. D. (2003). Autistic traits in the general population: A twin study. *Archives of General Psychiatry, 60*, 524–530.

Edgin, J. O., & Pennington, B. F. (2005). Spatial cognition in autism spectrum disorders: Superior impaired or just intact? *Journal of Autism and Developmental Disorders, 35*, 729–745.

Edwards, B. (1989). *Drawing on the right side of the brain*. Tarcher.

Golomb, C. (1992). *The child's creation of a pictorial world*. Berkeley, CA: University of California Press.

Grinter, E. J., Ban Beek, P. L., Maybery, M. T., & Badcock, D. R. (2009). Brief report: Visuospatial analysis and self-rated autistic-like traits. *Journal of Autism and Developmental Disorders, 39*, 670–677.

Happé, F., & Ronald, A. (2008). The 'fractionable autism triad': A review of evidence from behavioural, genetic, cognitive and neural research. *Neuropsychological Review, 18*, 287–304.

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*, 527–534.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman brief intelligence test* (2nd ed.). Circle Pines, MN: American Guidance Service.

Kuschner, E. S., Bodner, K. E., & Minshew, N. J. (2009). Local vs. global approaches to reproducing the Rey Osterrieth Complex Figure by children, adolescents, and adults with high-functioning autism. *Journal of Autism and Developmental Disorders* (in press).

Mandy, W. P., & Skuse, D. H. (2008). Research review: What is the association between the social-communication element of autism and repetitive interests, behaviours and activities? *Journal of Child Psychology and Psychiatry, 49*, 795–808.

Milbrath, C. (1998). *Patterns of artistic development in children: Comparative studies of talent*. Cambridge, UK: Cambridge University Press.

Mottron, L., & Belleville, S. (1993). A study of perceptual analysis in a high-level autistic subject with exceptional graphic abilities. *Brain and Cognition, 23*, 279–309.

Mottron, L., Belleville, S., & Ménard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: Perceptual hierarchization or working memory deficit? *Journal of Child Psychology and Psychiatry, 40*, 743–755.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S., & Enns, J. T. (2003). Locally oriented perception with intact global processing among adolescents with high functioning autism: Evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry, 44*, 904–913.

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*, 27–43.

Nicolaides, K. (1990). *The natural way to draw: A working plan for art study*. New York: Houghton Mifflin.

Norton, A., Winner, E., Cronin, K., Overy, K., Lee, D. J., & Schlaug, G. (2005). Are there pre-existing neural, cognitive, or motoric markers for music ability? *Brain and Cognition, 59*, 124–134.

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, 181*, 77–98.

Plaisted, K. C. (2001). Reduced generalization in autism: An alternative to weak central coherence. In J. A. Burack & T. Charman (Eds.), *The development of autism: Perspectives from* *theory and research* (pp. 149–169). Mahwah: Lawrence Erlbaum Associates.

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*, 733–742.

Pring, L., Hermelin, B., & Heavey, L. (1995). Savants, segments, art and autism. *Journal of Child Psychology and Psychiatry, 36*, 1065–1076.

Rimland, B., & Fein, D. (1988). Special talents of autistic savants. In L. Obler & D. Fein (Eds.), *The exceptional brain: Neuropsychology of talent and superior abilities* (pp. 341–363). New York: Guilford Press.

Ronald, A., Happé, F., Bolton, P., Butcher, L. M., Price, T. S., Wheelwright, S., et al. (2006). Genetic heterogeneity between the three components of the autism spectrum: A twin study. *Journal of the American Academy of Child and Adolescent Psychiatry, 45*, 691–699.

Ropar, D., & Mitchell, P. (2002). Shape and constancy in autism: The role of prior knowledge and perspective cues. *Journal of Child Psychology and Psychiatry, 43*, 647–653.

Sacks, O. (1995). *An anthropologist on Mars: Seven paradoxical tales*. New York: Knopf.

Selfe, L. (1977). *Nadia: A case of extraordinary drawing ability in an autistic child*. New York: Academic Press.

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24*, 613–620.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry, 34*, 1351–1364.

Sheppard, E., Ropar, D., & Mitchell, P. (2007). The impact of meaning and dimensionality on copying accuracy in individuals with autism. *Journal of Autism and Developmental Disorders, 37*, 1913–1924.

Siegel, D. J., Minshew, N. J., Goldstein, G., & Wechsler, I. Q. (1996). Profile in diagnosis of high-functioning autism. *Journal of Autism and Developmental Disorders, 26*, 389–406.

Stewart, M. E., Watson, J., Allcock, A.-J., & Yaqoob, T. (2009). Autistic traits predict performance on the block design. *Autism, 13*, 133–142.

Vital, P. M., Ronald, A., Wallace, G. L., & Happé, F. (2009). Relationship between special abilities and autistic-like traits in a large population-based sample of 8-year-olds. *Journal of Child Psychology and Psychiatry, 50*, 1093–1101.

Wang, L. X., Mottron, L., Peng, D. L., 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*, 550–574.

Williams, J., Scott, F., Stott, C., Allison, C., Bolton, P., Baron-Cohen, S., et al. (2005). The cast (childhood Asperger syndrome test): Test accuracy. *Autism, 9*, 45–68.

Winner, E. (1996). *Gifted children: Myths and realities*. New York: Basic Books.

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *Group Embedded Figures Test Manual*. Palo Alto, CA: Consulting Psychology Press.