Problem Solving Styles in Autism Spectrum Disorder and the development of higher cognitive functions

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Abstract

The Vygotsky Blocks Test (VBT) assesses problem-solving styles within a theoretical framework for the development of higher mental processes devised by Vygotsky (Daniels et al., 2007). Because both the theory and the associated test situate cognitive development within the child's social and linguistic context, they address conceptual issues around the developmental relation between language and thought that are pertinent to development in autism. Our aim was to document the performance of adults with Autism Spectrum Disorder (ASD) on the VBT, and our results showed that they made more errors than the typically developing (TD) participants and that these errors correlated with performance IQ. The ASD group also required more cues than the TD group to discern the conceptual structure of the blocks, a pattern that correlated with ADOS Communication and Imagination/Creativity sub-scales. When asked to categorize the blocks in new ways, the ASD participants developed fewer principles on which to base new categorizations, which in contrast to the TD group, correlated with verbal IQ and with the Imagination/Creativity sub-scale of the ADOS. These results are in line with a number of existing findings in the ASD literature and confirm that conceptualization in ASD seems to rely more on non-verbal and less on imaginative processes than in TD individuals. The findings represent first steps to the possibility of outlining a testable account of psychological development in ASD that integrates verbal, non-verbal and social factors into the transition from elementary to higher-level processes.

Introduction

Autism Spectrum Disorder (ASD) comprises a diverse set of neurodevelopmental disorders currently diagnosed on the basis of difficulties in social communication and interaction and by the presence of significantly restricted and repetitive behaviours with an onset in early neurodevelopmental period and often leading to significant difficulties in adaptation (DSM-5: American Psychiatric Association, 2013). For many decades, attempts to provide a comprehensive psychological account of ASD have hinged around several domains of functioning ranging from attention through perception and memory to more complex processes such as 'Theory of Mind', emotional relatedness, Weak Central Coherence (WCC) and Executive Function (EF; see Boucher 2008; Bowler 2007 for reviews). Some researchers such as Mottron and colleagues (Dawson et al., 2007; Soulières et al., 2011) have used the fact that individuals with ASD perform better on tasks such as the Ravens Progressive Matrices, which measure fluid intelligence, than on vocabulary or language-based measures of intelligence (crystallised intelligence) to argue for more domain general differences between autistic and non-autistic cognition. Specifically, these authors argue that ASD is characterized by a 'different' pattern of intelligence that serves adaptive function more through 'lower-level' perceptual rather than 'higher-level' conceptual processes. Other scientists have attempted to further refine or supplant such domain-general accounts by proposing putative neuropsychological mechanisms thought to underlie the behaviour patterns that gave rise to the earlier more domain-specific accounts. For example, Pellicano and Burr (2012) have suggested that individuals with ASD experience difficulty in the construction or application of *Bayesian priors* - representations that result from earlier perceptual inferences - to on-going behaviour. This results in *hypo-priors,* which influence current perceptual processes in autism-specific ways. A similar approach is that of van de Cruys et al., (2014) who argue for impaired predictive coding which results in people with ASD being highly inflexible in the way they handle on-going violations of expectations that are based on representations built up on the basis of prior experience. Moving from a cognitive to a neural level of analysis, researchers have attempted to account for these phenomena in terms of both increased (Simmons et al., 2007) and reduced (Davis and Plaisted-Grant, 2015) neural noise. Although these different approaches show considerable overlap in the way they attempt to explain the entire clinical picture of autism, scientists have yet to develop a comprehensive theoretical framework that convincingly integrates the social and non-social elements of the clinical picture of ASD in a manner that furthers our understanding of this set of conditions.

For almost a century, however, one particular theoretical framework - the socio-cultural theory of Vygotsky (Towsey, 2009, Yasnitsky and Ferrari 2008) - has attempted to provide a socially-grounded, unified account of typical individuals' development of abstract representations - the so-called higher mental processes (Ursino et al., 2014) based on their concrete experience. The advantage of this framework is that it has been applied to the disruptions observed in intellectual deficiency (Bexkens et al., 2014; Danielsson et al., 2012), and psychopathological conditions such as schizophrenia (Tseng et al., 2015), and more recently in neurodevelopmental disorders such as autism (Wallace and Stevenson, 2014). Vygotsky's theory distinguishes between *elementary mental processes* such as sensation, attention, perception and memory, and *higher mental processes*, which result at least partly from social interaction with others and which enable a more elaborate use of the elementary mental processes (Daniels et al., 2007; Hobson, 1993). A key factor in the development of higher from elementary mental processes is the internalization by the child of social interactions that take place during problem solving. Vygotsky argued that this internalization occurs by means of *inner speech* (Alderson-Day, 2014; Alderson-Day and Fernyhough, 2014; Vygotsky, 1987) which we now know does not become fully functional in typical individuals until the age of 6 or 7 years (Flavell et al., 1997). By proposing a mechanism that links social interaction with the ability to develop higher mental processes out of lower ones through the mechanism of social interaction and inner speech, a Vygotskian approach has potential for providing the foundations of a theory that integrates the disparate elements that constitute our current understanding of the behavioural profile of ASD (Wallace et al., 2009). Although the role of inner speech in the higher mental processes of individuals with ASD has attracted some research interest (see, for example, Williams et al., 2012), there has been no investigation of lower mental processes from a Vygotskyan perspective or of the developmental mechanisms underlying the transition between the two, despite considerable research efforts driven by the theoretical perspectives outlined earlier.

One way in which the tenets of Vygotskian socio-cultural theory have been operationalized and tested was by means of a procedure we refer to here as the *Vygotsky Blocks Test* (VBT; Vygotsky 1987), which was based on a test originally developed by Saharov (1930), which in turn was based on the ideas of Ach (1921). The first part of the VBT presents the individual with a *structured* task to explore convergent thinking - the capacity to arrive at the predetermined 'correct' solution to a problem (Guilford, 1967) and which is tapped by most standard verbal psychometric tests of crystallized intelligence. In this part of the test, the participant sees a set of wooden blocks that vary according to colour, height, shape and width, with an exemplar of one of the four subsets of blocks, designated by a nonsense word. The task is to discover the underlying concept that defines that particular set of blocks by means of a series of guesses. Cues are permitted for the first two subsets of the blocks and in addition to the overall number of cues provided; a record is made of perseverative and non-perseverative errors. Several predictions about the performance of individuals with ASD on the VBT can be derived from existing psychological research into autism. The VBT's requirement for the participant to alter strategy based on changing feedback resembles the Wisconsin Card Sorting Test (WCST; Axelrod et al., 1996) on which people with ASD are known to have difficulties (Landry and Al-Taie, 2016), showing a characteristic perseverative pattern of responding (Liss et al., 2003; Memari et al., 2013). We would therefore predict greater perseverative errors in ASD compared to TD participants. The VBT also taxes memory by requiring participants to recall which dimensions they have volunteered as guesses to discover the concepts of the different sets and also to remember the feedback associated with these guesses. Memory difficulties in people with ASD are more likely on tasks with a strong recall rather than recognition component or which involve complex manipulation of remembered material in the absence of physical support such as a log of previous guesses (see Boucher and Bowler, 2008; Bowler, 2007). On this basis, we would therefore also expect greater perseverative errors in ASD compared to TD participants. Finally, based on the suggestion of a ‘different’ intelligence in ASD that favours the contribution of fluid rather than a crystallized intelligence to task performance (e.g., Dawson et al., 2007), we would expect that performance by individuals with ASD on this part of the task would be correlated more strongly with measures of fluid than crystallized intelligence as operationalised in terms of participants’ non-verbal and verbal IQ respectively.

The second part of the VBT is *unstructured,* and allows the participant to utilize *divergent thinking* - the ability to arrive at novel, non-predetermined solutions through the generation and manipulation of new ideas (Guilford, 1967) - to form their own groupings of the blocks based upon the blocks' physical properties. Existing research on categorization in ASD has reported few difficulties when tasks require categorization along a single perceptual dimension or when perceptual prototypes have to be extracted (Molesworth et al., 2005, 2008; Vladusich et al., 2010). In contrast, when verbal labels are needed in order to solve the categorization task or when language-based categories need to be organized hierarchically; those with ASD begin to show subtle difficulties (Gastgeb et al., 2006), being less likely than typical individuals to use categorical information to aid performance in verbal free recall tasks (Bowler et al., 1997, 2009, 2010; Gaigg et al., 2008). Impaired generativity, creativity and symbolic play have long been known to be features of autism (D'Cruz et al., 2013; Dichter et al., 2009; Hobson et al., 2009, 2013; Takeyuchi et al., 2014; but see Kasirer and Mashal, 2014), which can also be associated with difficulties with executive function especially planning and cognitive flexibility (see Kenworthy et al., 2008, 2009). Taken together, these observations lead us to predict that individuals with ASD would show diminished performance compared to a matched typically developing group on the divergent part of the VBT. Both from the wider perspective of Vygotskian theory, which sees the internalization of social interaction and mediation by inner speech as the main drivers of development of higher mental processes and from the perspective of existing research on executive functions, memory and concept formation in autism, we predict that adults with ASD will show diminished performance on the VBT and that the patterning of this diminished performance may provide pointers to further studies to help refine a more integrated account of the psychological development of individuals with ASD.

Methods

Participants

Forty-seven individuals participated in the study, who either had a diagnosis of ASD or were TD individuals. The ASD group N=23, (21 male, 2 female, M_{age} = 40.35 years, age range: 26-66 years) and the TD group N=24, (22 male, 2 female, M_{age} = 38.71 years, age range: 22-65 years) were matched on gender, chronological age, verbal (VIQ), performance (PIQ) and full-scale intelligence quotient (FIQ; see Table 1) as measured by the third or fourth edition of the Wechsler Adult Intelligence Scale (WAIS-III^{UK} or WAIS-IV^{UK}; The Psychological Corporation, 2000, 2008). Due to the release of the WAIS-IV at the time of recruiting participants for this experiment, different participants completed either the WAIS-III^{UK} or WAIS-IV^{UK}. The ASD participants were diagnosed by experienced clinicians through the National Health Service and a review of their available medical records confirmed they all met DSM-IV-TR criteria for ASD (American Psychiatric Association, 2000). For 17 ASD participants, it was possible to administer the Autism Diagnostic Observational Schedule (ADOS; Lord et al., 1989), which further confirmed difficulties in reciprocal social and communication behaviours that constitute the hallmark clinical features of the disorder. Due to time constraints on the day of testing, the ADOS was not administered to the remaining six ASD participants; however, since available records clearly confirmed their diagnosis, all participants were retained for analysis in this group. It is worth noting, that re-running all the analyses presented below excluding ASD participants that did not take part in the ADOS did not change any of the results reported.

All participants completed the adult Autism-Spectrum Quotient (AQ) (Baron-Cohen et al., 2001) to further corroborate the ASD diagnosis and to exclude TD participants who reported difficulties that may be commensurate with ASD such as an AQ >26 (Baron-

Cohen et al., 2001; Woodbury-Smith et al., 2005). All participants were native English speakers and were recruited from a database of individuals with whom the Autism Research Group at City University London is in regular contact and through advertisements within the university. TD individuals were only included if they did not report taking any drugs or psychotropic medication and did not have an own or family history of a psychiatric or neurodevelopmental disorder including ASD. All participants in the study were reimbursed for their time and transport costs. Permission from the City University London Psychology Research Ethics Committee was obtained with all participants giving their informed consent before taking part in the study, which adhered to the tenets of the declaration of Helsinki. See Table 1 for the participants' details.

	TD (22m, 2f)		**ASD (21m, 2f)**				
	M	***S.D***	***M***	***S.D***	***t*(34)**	***p***	**Cohen's *d***
Age (years)	38.71	12.4	40.35	12.3	0.46	.65	0.13
VIQ[a]	117	13.7	110	19.3	1.45	.15	0.42
PIQ[b]	111	16.4	109	19.5	0.42	.68	0.12
FIQ[c]	115	16.4	111	19.2	0.80	.43	0.25
AQ[d]	14.38	6.4	35.6	6.2	11.62	.00	3.39
ADOS-C[e]			2.71 (0-6)	1.5			

ADOS-RSI[f]			5.29 (1-13)	2.8			
ADOS-Total[g]			8.00 (3-17)	3.8			
ADOS-I[h]			1.27 (0-2)	0.7			
ADOS-SB[i]			1.13 (0-5)	1.4			

Table 1.

Participant characteristics for Autism Spectrum Disorder (ASD) and typically developing (TD) individuals.

Note. [a]Verbal IQ (WAIS-III[UK] or WAIS-IV[UK]). [b]Performance IQ (WAIS-III[UK] or WAIS-IV[UK]). [c]Full-scale IQ (WAIS-III[UK] or WAIS-IV[UK]). [d]AQ- Autism-Spectrum Quotient. [e]ADOS- Communication subscale. [f]ADOS- Reciprocal Social Interaction subscale. [g]ADOS Total score- Communication and Reciprocal Social Interaction. [h]ADOS-Imagination/ Creativity subscale. [i]ADOS- Stereotyped Behaviors and Restricted Interests. ADOS scores range in brackets.

Materials

Materials for the VBT were the twenty-two wooden blocks from the Modified Vygotsky Concept Formation Test (Hanfmann and Kasanin, 1942; Stoelting, IL, USA) using the modified scoring sheet of Wang (1984). The blocks differed on a number of dimensions including their color (blue, yellow, orange, green and white), shape (square, triangle, circle, semicircle, trapezoid and hexagon), height (low or tall) and width (narrow or wide). In addition, the blocks were divided into four groups according to nonsense words (CEV, LAG, BIK and MUR) that were printed on one face and formed the four sets in task one. The words corresponded to the volume of the blocks with the CEV group formed by six narrow and low blocks LAG by five tall and wide blocks, BIK by six low and wide blocks and MUR by five narrow and tall blocks. Figure 1 shows the Vygotsky blocks with one CEV block turned over.

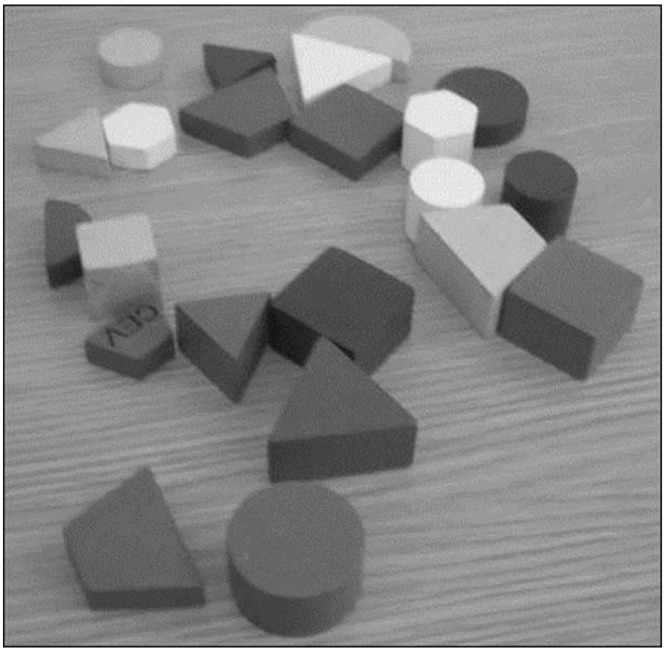

Figure 1. The twenty-two blocks that form the VBT. Each block can be grouped according to colour, shape, height, width, number of sides, volume, curve or the ability to roll. The 'CEV' block is over-turned for the start of the first set of the convergent

thinking task. The participant would be asked- ‘which of the other blocks might have the word CEV written underneath also?’

Procedure

As noted above, the VBT has two parts that investigate convergent and divergent thinking strategies respectively. The words written on one face were relevant for the first convergent thinking part of the VBT (Task 1). In the second, divergent thinking part (Task 2), the instructor (PC or MR) gave verbal instructions and noted down the participants’ selection of the blocks for both tasks.

Task 1 (Convergent thinking) with four sets (CEV, BIK, MUR and LAG): The jumbled blocks were placed in front of the participant on a table with the word face down. The first set started with the small blue triangle with “CEV” written on it. “CEV” was read aloud to the participant and they were asked to choose another block that might have “CEV” also written on the underside. If the participant chose a block that belonged to the ‘CEV’ group, it was turned over and placed adjacent to the starting ‘CEV’ block to form the group. If the participant pointed to a block that did not belong to the ‘CEV’ group, they were told that their choice was not correct but to try again.

For Task 1 an incorrect choice in the first two sets (CEV and LAG) scored one *general error* point. If the participant made three consecutive general errors, then a cue was given with the instructor turning over a block that belonged to the set being tested. A *perseverative error* occurred if the participant selected three consecutive blocks that shared one or more common attributes (one perseverative error per common attribute). For example, a perseverative error would occur if a participant chose three triangular shaped blocks in a row. The set ended when all of the blocks in the group were selected, if participants committed fifteen general errors for set 1 (i.e., exhausting five cues for the six CEV blocks) or if they committed twelve general errors for set 2 (i.e., exhausting the four cues for the five LAG blocks). For the remaining two sets, BIK (6 blocks) and MUR (5 blocks) no cues were given and these sets were terminated if the participant made five consecutive incorrect choices, yielding a maximum error score of twenty-five for the BIK and twenty for the MUR set. For these two sets a perseverative error occurred if the participant selected three or five blocks with identical attributes respectively. The total numbers of general and perseverative errors for each set as well as the total number of cues required for the first two sets (CEV and LAG) were recorded for analysis (see Table 2).

Task 2 (divergent thinking): The instructor placed all of the blocks face down and then sorted the blocks by their colour into separate groups. The instructor then told the participant, ‘look I have made some groups based on colour, how many other ways can you group these blocks together?’ The blocks were then randomly jumbled again face down and the participant began to group the blocks according to a *Principle* they defined for each group such as height or shape.

The maximum number of Principles by which the blocks could be grouped was seven excluding the demonstration set of color. The Principles were: Shape, Width, Height, Number of Sides, Volume, Roll and Curve. Participants scored a point for each correct Principle as well as a point for the number of *Sub-Groups* formed according to each principle (Number of Sub-Groups, Table 3). For example, for the Principle of Shape there were six possible Sub-Groups: triangle, square, trapezoid, circle, semi-circle or hexagon. The participant scored a point for each correct Sub-Group of the shapes and one point for the overall Principle giving a maximum possible score of seven for the Principle of Shape. However, the participant needed to define a minimum number of Sub-Groups in order for the Principle to be credited. For example, a minimum of four Sub-Groups were required for the principle of Shape. If the participant only identified triangles and squares (two Sub-Groups), then the principle of Shape was not scored and only two points for the identified Sub-Groups were counted. There was no time limit for this task but the task finished when the participant could not generate any more Sub-Groups or had attempted to form two consecutive groupings that did not follow one of the seven Principles (e.g. making a pattern out of the blocks). Hanfmann and Kasanin, (1942) and Wang (1984) also proposed calculating a weighted score based on a hierarchical organization of the Principles. When this model was applied to the data, the results were not markedly different from the results reported here.

Statistical Methods

The results were analyzed using independent samples t-tests, repeated measures ANOVAs, Spearman's rho correlations and Chi-Squared tests. If the Sphericity assumption was violated Greenhouse Geisser Correction (GGC) was used (SPSS, ver. 22). The significance level chosen was at $p < .05$ for all tests. Cohen's *d* and partial eta squared are reported as measures of effect size as appropriate. Results are expressed as mean (M) ± standard deviation (S.D.) unless otherwise specified.

Results

Convergent thinking

Summary error scores for both groups are presented in Table 2 and Figure 1 as general errors (incorrect choice), perseverative errors (repeatedly choosing a block based on one characteristic) and the numbers of cues given for the CEV and LAG sets. General and perseverative errors were analyzed using a 4 (Set [CEV, LAG, BIK, MUR]) x 2 (Group [ASD, TD]) repeated measures ANOVA. For general errors there was a significant main effect of Group, $F(1,45) = 5.38$, $p = .03$, $\eta_p^2 = .11$, with more errors for the ASD ($M = 11.96$, $SD = 6.71$) compared to the TD group ($M = 4.25$, $SD = 3.29$). There was also a significant main effect of set, $F(2.03, 91.35) = 11.49$, $p < .001$, $\eta_p^2 = .20$, GGC, with significantly more mistakes in the first compared to second and third set ($p_{max} = .005$, Cohen's $d_{min} = 0.52$). A significant Set x Group interaction, $F(2.03, 91.35) = 3.10$, $p = .049$, $\eta_p^2 = .06$, GGC, showed that this was only true for the TD group with more mistakes in the first compared to the remaining three sets ($p_{max} = .009$, Cohen's $d_{min} = 0.69$). In contrast, the ASD group made more errors in the first and fourth compared to the second set (p_{max} = .02, Cohen's d_{min} = 0.71) but showed a similar level of errors in the first, third and fourth set (p_{min} = .61, Cohen's d_{max} = 0.35). A direct comparison of the two groups showed significantly more errors for the ASD compared to the TD group for the second and fourth set (p_{max} = .02, Cohen's d_{min} = 0.73).

The ASD participants made more perseverative errors (*M* = 2.30, *SD* = 4.19) than the TD group (*M* = 0.50, *SD* = 1.22), indicating a trend towards more errors in the ASD group, $F(1,45) = 3.86$, $p = .056$, $\eta_p^2 = .08$, (but see below for analysis of covariance). There was no main effect of Set, $F(2.52,113.44) = 1.75$, $p = .17$, $\eta_p^2 = .04$, GGC, but a significant Set x Group interaction, $F(2.52,113.44) = 3.74$, $p = .02$, $\eta_p^2 = .08$, GGC, with a decrease in perseverative errors for the TD but an increase for the ASD participants across the four sets. Importantly, the ASD participants made more perseverative errors in the final set (MUR) compared to the TD participants suggesting that the ASD group maintained the same restricted approach to each of the sets ($p = .01$, Cohen's d = 0.78).

The ASD participants required more cues (*M* = 1.57, *SD* = 1.38) compared to the TD participants (0.92 ± 0.72), $F(1,45) = 4.16$, p =.047, $\eta_p^2 = .09$, and more cues were required in the first 'CEV' set compared to the second 'LAG' set in Task 1 for the ASD participants, $F(1,45) = 59.29$, $p = .000$, $\eta_p^2 = .57$. However, there was no overall Set x

Group interaction, $F(1,45) = 0.04$, $p = .84$, $\eta_p^2 = .00$, for the ASD and TD groups (see Table 2).

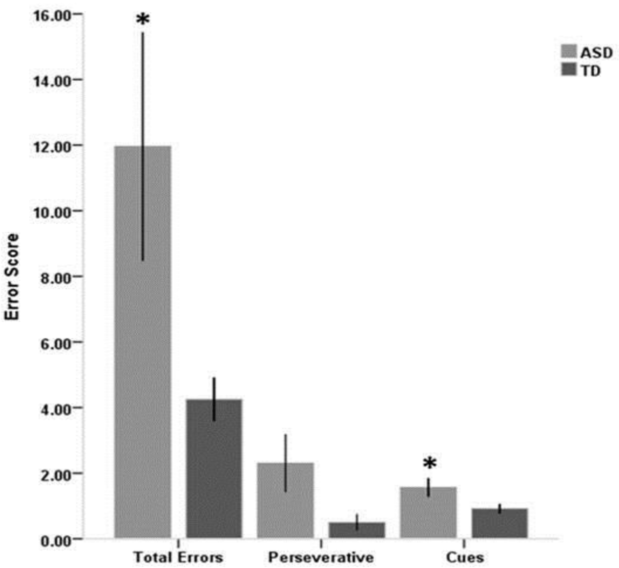

Figure 2 Results of the Convergent thinking task (Mean ± SEM) with a significantly higher number of cues (*p = .03)* and cues (*p* = .047) required by the ASD group in task 1. (ASD: Autism Spectrum Disorder, TD: Typically Developing, * = $p < .05$).

	TD (n=24) ***M*** **(*S.D.*)**	**ASD (n=23)** ***M*** **(*S.D.)***	***p***
Convergent Thinking			
General Errors			
CEV	3.08 (2.26)	3.91 (2.74)	

LAG	0.21 (0.66)	1.26 (1.86)	
BIK	0.67 (2.10)	2.70 (5.70)	
MUR	0.29 (0.75)	3.74 (6.70)	
Total General Errors	*4.25 (3.29)*	*11.96 (16.71)*	*0.030*
Perseverative Errors			
CEV	0.42 (1.18)	0.30 (0.76)	
LAG	0.00 (0.00)	0.26 (0.69)	
BIK	0.08 (0.41)	0.57 (1.75)	
MUR	0.00 (0.00)	1.13 (2.07)	
Total Perseverative Errors	*0.50 (1.22)*	*2.30 (4.19)*	*0.056*
Cues			
CEV	0.92 (0.72)	1.22 (0.95)	
LAG	0.00 (0.00)	0.35 (0.65)	
Total Cues	*0.92 (0.72)*	*1.57 (1.38)*	*0.047*

Table 2. Group results for TD and ASD individuals for the Vygotsky Block Test. Four sets of convergent thinking task (CEV, LAG, LAG, MUR- no cues were presented in the last two sets) and the divergent thinking task for the seven test principles of Height, Width, Volume, Shape, Number of Sides, Curve and Roll. The number of Principles, and Divergent sub-groups formed for the principles are shown. The Total Weighted Principle (TWP) score is the number of principles identified multiplied by the weighting

of their level of concreteness. (ASD: Autism Spectrum Disorder; TD: Typically Developing; M: Mean; S.D.: Standard Deviation).

Divergent thinking

The number of divergent thinking Principles and divergent Sub-Grouping points are shown in Table 3 and Figure 3 with the ASD participants demonstrating inferior performance with this task. The ASD participants identified fewer governing Principles by which the blocks could be sorted (ASD: M = 3.30, SD = 1.43; TD: M= 4.71, SD = 1.60: $t(45) = 3.17$, $p < .004$, Cohen's d = 0.93). Similarly, the ASD group identified fewer of the Sub-Groups in the divergent task that defined the principle (ASD: 15.09 ± 5.78; TD: 20.92 ± 6.81: $t(45) = 3.16$, $p < .005$, Cohen's d = 0.93). These findings indicate the extent of the ASD participants' difficulties with identifying concepts by which the blocks could be grouped based on their physical properties.

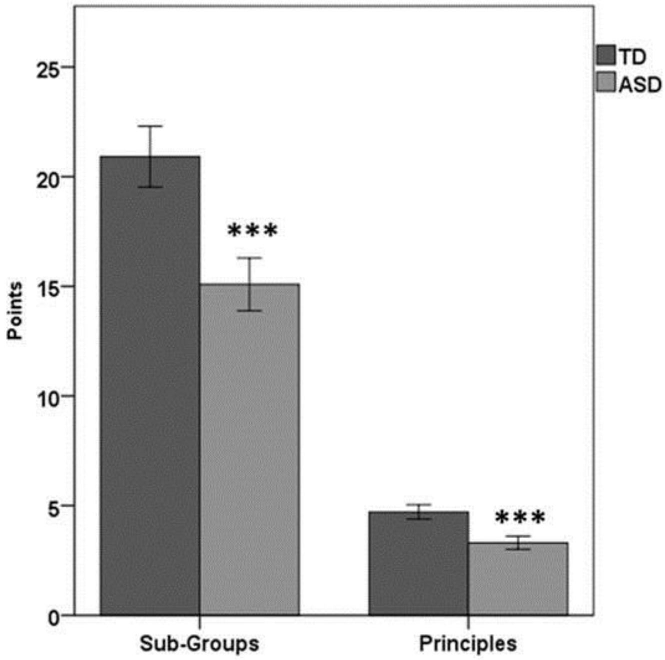

Figure 3 Results of the Divergent thinking task (Mean ± SEM) with a significantly higher number of Categorizing Principles (*p* = .003*)* and Sub-Groups (*p* = .003) identified overall, by the TD group in both parts supporting a more flexible cognitive style in generating new concepts in task 2. (ASD: Autism Spectrum Disorder, TD: Typically Developing, ** = *p* <.01).

Divergent Thinking			
	TD (n=24) ***M* (*S.D*)**	**ASD (n=23)** ***M* (*S.D)***	***p***
Number of Principles	4.71 (1.60)	3.30 (1.43)	0.003
Number of Sub-Groups	20.92 (6.80)	15.09 (5.78)	0.003

Table 3. Group results for TD and ASD individuals for the Vygotsky Block Test for the divergent thinking task. The number of principles (maximum score 7), number of sub groups and number of participants (ASD or TD) identifying each of the principle categories. (ASD: Autism Spectrum Disorder, TD: Typically Developing).

Types of Principle

The seven categories of Principle in the divergent thinking task showed some differences between groups for the Principles of Number of Sides ($\chi^2 = 4.77$, $p < .03$); Volume ($\chi^2 = 4.77$, $p < .03$); Height ($\chi^2 = 4.45$, $p < .04$) and Roll ($\chi^2 = 4.37$, $p < .04$) but not for the principles of Width ($\chi^2 = 3.61$, $p = .06$); Shape ($\chi^2 = 1.00$, $p = .32$) and Curve ($\chi^2 = 0.22$, $p = .64$; see Table 4).

Principle	**TD (n=24)**	**ASD (n= 23)**	***p*-**
Number of Sides	16	8	.029
Volume	16	8	.029
Height	23	17	.035
Roll	11	4	.037
Width	15	8	.057
Shape	21	22	.317
Curve	11	9	.642

Table 4. The number of participant s in each group correctly identifying the principles by which the blocks could be categorized. The ASD participants had greatest difficulty with forming principles based on Number of Sides, Volume, Height and Roll whilst both groups were equivalent at identifying the principles of Width, Shape and Curve. (Pearson's Chi Squared p=value). (ASD: Autism Spectrum Disorder, TD: Typically Developing).

Correlations between VBT performance and other measures.

A series of separate Spearman 'rho' (r_s) correlations for the TD and ASD groups between VBT performance measures and PIQ, VIQ, and the Communication and Imagination/Creativity sub-scales of the ADOS are reported in Tables 5a (TD participants) and 5b (ASD participants). No significant correlations with age were found for all participants with the VBT measures (p >.15). However, there was a negative correlation with the TD participants and their age (r_s = -.42, p <.05) indicating that the older TD participants identified fewer principles. As predicted, for the ASD participants, PIQ negatively correlated with the number of general errors (r_s = -.46, p < .03) and the number of perseverative errors for the convergent thinking task (r_s = -.52, p < .02), suggesting that they relied heavily on their fluid intelligence during this structured part of the VBT. When PIQ was included as a covariate in the between-group analyses of the CEV and LAG cue sets of Task 1 reported earlier, the interaction between Group and Set for general errors became non-significant, F(2.14, 94.42) = 2.27, p = .053, η_p^2 = 0.06, GGC, and the between-group difference in perseverative errors fell just on the cusp of significance, $F(1,44) = 4.07$, $p = .05$, $\eta_p^2 = 0.09$, reflecting the protective effect of higher PIQ against perseverative responding in ASD vis-à-vis the comparison group. Turning to the divergent thinking part of the VBT, here VIQ in the ASD group correlated with the number of Principles and the number of Sub-Groups the participants generated (r_s =.54, $p < .01$ and $r_s = .59$, $p < .01$ respectively), suggesting that they relied more on verbal ability when engaging in divergent thinking. In the comparison group, none of the associations between task performance and verbal or non-verbal IQ was reliable. Including VIQ and PIQ as covariates in the analysis of Task 2 did not change the overall pattern of results apart from yielding a significant group difference in perseveration for the final stimulus set in the sequence, (MUR), which survived partialling out of PIQ ($F(1,45) = 7.14$, $p < .02$, $\eta_p^2 = 0.14$).

Turning to correlations with clinical symptoms, the Communication scale of the ADOS correlated with the number of cues ($r_s = .53$, $p < .04$) participants with ASD required on the convergent thinking part of the VBT, indicating that the more communicatively impaired individuals with ASD required greater task support in terms of more cues to complete the task successfully. A significant positive correlation between the Imagination/Creativity sub-scale of the ADOS and VBT perseverative errors ($r_s = .62$, $p < .02$) indicates that the ASD individuals who had less imaginative capacity made more perseverative errors on the VBT. The significant negative correlations between the ADOS Imagination/Creativity sub-scale and the number of Principles on the divergent thinking part of the VBT ($r_s = -.68$, $p < .01$); and number of Sub-Groups identified for the

Principles (r_s = -.72, p < .003) (Table 5b) suggests that more imaginatively impaired individuals performed less well on this aspect of the VBT.

(a) TD participants

	Task 1 (Convergent)			**Task 2 (Divergent)**	
	General	**Perseverative**	**Cues**	**Principles**	**Sub-Groups**
Age	.19	.21	.22	-.42*	
VIQ (n=24)	.04	-.28	-.17	.09	.17
PIQ (n=24)	-.27	-.31	-.28	.26	.29

(b) ASD participants

	Task 1 (Convergent)			***Task 2 (Divergent)***	
	General	**Perseverative**	**Cues**	**Principles**	**Sub-Groups**
	-.51	-.37	-.33	-.07	
VIQ (n=23)	-.24	-.39	-.19	.54**	.59**
PIQ (n=23)	-.46*	-.52*	-.37	.24	.54**
ADOS (n=17)	.36	.46	.53*	-.26	-.33

Communication					
ADOS (n=17) **Imagination**	.50	.62*	.54*	-.68*	-.72**

Table 5 Spearman's 'rho' correlations between verbal and performance IQ and ADOS sub-scores for communication and imagination for TD participants (a) and ASD participants (b) for the Vygotsky Block Test (VBT). No IQ measures correlated with the VBT for the TD participants. For the ASD group significant negative correlations were present across divergent thinking categories with the imaginative ADOS sub-scale scores. (* = $p < .05$; ** = $p < .01$).

Discussion

The primary aims of the present study were to document the performance of adults with ASD on the VBT with a view to taking the first steps towards systematic investigations of autistic individuals' development of the higher mental processes out of elementary mental processes both within the framework of Vygotskyan theory and of wider theories of autistic cognitive dysfunction. As discussed in the Introduction, Vygotskyan theory sees the higher mental processes arising out of internalized social interactions and mediated by inner dialogue. Our broad prediction was that the performance of adults with ASD on the VBT, because of their particular behavioural profile of social impairment and 'different' intelligence, would differ from that of typically developed adults. We also made more specific predictions based on existing research on autistic populations in areas tapped by the VBT, such as concept formation and perseverative behaviour. Accordingly, we discuss its results in terms of their relation to existing executive dysfunction-based accounts of the difficulties experienced by individuals with ASD when developing new concepts. We also highlight ways in which observations based on the VBT might offer pointers to future research into underlying psychological processes in ASD, particularly into the role of fluid, non-verbal intelligence as a possible compensatory contributor to overall performance (Mottron 2004) and in particular to diminished inner dialogue (Wallace et al., 2009). Finally, we raise the question of how the present pattern of findings might be integrated into more recent accounts of autistic cognitive dysfunction.

The findings of the convergent thinking task (Task 1) are broadly consistent with the existing literature on errors and perseveration on executive functioning tests by ASD individuals (Landry and Al-Taie, 2016; Liss et al., 2001; Sokhadze et al., 2010). The fact that the overall ASD-related higher rate of perseverative errors was reduced when PIQ was controlled suggests that variability resulting from individual differences in fluid intelligence may have contributed to increased perseveration on this task. This finding suggests that our ASD sample may have used their non-verbal skills to overcome a tendency to perseverate on the convergent part of the VBT. Taken together with our finding that the group difference for the last stimulus set (MUR) survived partialling out of PIQ, these findings suggest that there may be limits to the effectiveness of compensatory strategies mediated by non-verbal IQ and that perseveration may only become problematic for the ASD participants after prolonged testing. A recent study using the WCST in matched Japanese adults with ASD and TD participants also found that Milner type perseverative error scores correlated negatively with VIQ and FIQ in the ASD participants but not the TD group. That study reported no other correlations with AQ or IQ measures on other WCST measures suggesting that a higher VIQ protects against perseverative errors (Yasuda et al., (2014).

Our finding that the ASD participants required a greater number of attempts to form sets of blocks based on Volume and required more cues in order to complete the first two sets successfully in Task 1 are also in line with research showing shallower learning curves in ASD (Bowler et al., 2009), as well as with current theories that posit a greater need for task support to achieve successful task completion by individuals with ASD (Bowler et al., 2004). Precisely how these aspects of conceptual abstraction in ASD are interrelated is a matter of conjecture and further investigations are required into how a cognitive processing system biased towards features tapped by non-verbal IQ measures and away from verbal measures leads both to perseveration and to a greater reliance on task support.

Increased perseveration may also result from less inhibition during the task (Cepeda and Munakata, 2007), which would prevent the ASD participants from developing new grouping structures (D’Cruz et al., 2013; Mosconi et al., 2009). The convergent thinking task is based on classifying according to the physical dimension of Volume, which may be more obscure than the features of Colour or Shape to identify One explanation may be that performance on the VBT may rely on reduced ability to inhibit or ignore the more prominent Colour or Shape of the blocks in preference for Volume (Faja et al., 2016).

Over-reliance by the ASD by comparison with the TD participants on processes tapped by the PIQ measure coupled with their having less recourse to VIQ-related processing constitutes the first over-arching theme running through the results of the present study. Superior non-verbal over verbal intelligence is characteristic of a sub-set of the ASD population (Ghaziuddin and Mountain-Kimchi, 2004; Siegel et al., 1996) and researchers have argued that ASD individuals may exhibit a 'different' intelligence that may be underestimated by verbally loaded measures of intelligence (Mottron 2004; Nader et al., 2016). Mottron and colleagues have also argued that this 'different' intelligence results from a preference for lower-level perceptual over higher-level conceptual processing (Mottron et al., 2006), which on the VBT, may have resulted in slower identification of Sets on the Convergent task and poorer identification of Principles on the Divergent task, which in Vygotskian terms involves transition from the elementary to higher mental processes.

The tendency for higher error rates and a greater need for cues on the convergent part of the VBT to correlate with PIQ rather than VIQ in the ASD participants has two implications. As well as indicating a different set of cognitive processes underlying task performance, it may also be a consequence of diminished recruitment of inner speech to enable completion of that part of the VBT with as few errors as possible. This dependence on inner speech constitutes the second overarching theme of the present results, and is evident in the findings of the convergent part of the VBT (Task 2), which explored the individuals' ability to develop their own, higher level concepts based on the lower-level physical properties of the blocks. Here, the ASD group was worse than the comparison participants in their ability to develop principles and formulate sub categories based on the seven principles inherent in the blocks.

Our demonstration of the ASD group's diminished capability to see as many alternative ways of classifying the blocks according to the divergent thinking Principles and divergent Sub-Grouping points shown in Table 3 coupled with the strong correlation between this capability and both VIQ and the Imagination sub-scale of the ADOS, both confirms earlier findings showing diminished imagination in individuals with ASD (Craig and Baron-Cohen,1999; Craig et al., 2001; Woodard and van Reet, 2011) and is consistent with work that shows their limited engagement with inner speech, which Vygotsky saw as crucial to the development of novel conceptual structures and for the transition from elementary to higher mental processes (Vygotsky, 1987). Atypical inner speech self-dialogue has been shown in ASD by several researchers (Biro and Russell, 2001; Russell-Smith et al., 2014; Wallace et al., 2009). Russell-Smith et al's (2014) findings indicate that children with ASD perform no differently on a card sorting task either when they performed the task whilst repeating a word verbally (inner speech suppression) or when they performed the task without suppression. In contrast, the neurotypical children’s performance was worse when using verbal suppression and Williams et al., (2012) reported a similar fall in performance on the Tower of London task with neurotypical adults when they used articulatory suppression but performance was unaffected in the ASD participants suggesting that the ASD group failed to engage in inner dialogue. Of interest in the present context, Williams et al., (2012) found no difference in overall Tower of London performance between the ASD and TD groups, suggesting that the former relied on non-verbal processes to solve the task successfully in a manner analogous to performance on the convergent part of the VBT. One study in a large non-clinical ASD sample found a correlation with autistic traits and an ability to produce novel and creative responses to interpretations of figures, although there was no association between divergent thinking fluency and autistic traits (Best et al., 2015). The VBT may therefore provide a method for further examining divergent thinking patterns in ASD and non-clinical individuals with autistic traits.

Some limitations of this preliminary study were sample size with the attendant possibility of Type II errors as well as a large variance in the performance by the ASD group resulting in some measures failing to demonstrate clearly significant effects. A further weakness was that no *post-hoc* analysis of the strategies employed by the participants to complete the VBT was performed. Such an analysis might have offered a greater insight into the thought processes exploited by the participants in Tasks 1 and 2. Also, a lack of full ADOS scores for all of the ASD participants at the time of the study limited the strength of the associations between ADOS sub-scores and performance on the VBT.

To conclude, the findings of the present preliminary study provide an insight into possible differences in the ways individuals on the autism spectrum process information on a complex task that unfolds over time. It highlights how increased reliance on non-verbal factors together with diminished reliance on language and inner dialogue may interact to produce the clinical picture that characterizes ASD. Future research should be aimed at investigating the various ways in which people on the autism spectrum utilize verbal and non-verbal capacities to construct more abstract conceptual structures on the basis of sensory experience. By exploring the determinants of individual and group differences in the evolution of abstraction over time, such an approach would be useful not only in understanding cognitive processing in ASD, but also in other psychopathological and neurodevelopmental conditions with a view to developing a more general theory of the development of human cognition and its modulation by linguistically mediated social and cultural factors. This was one of the original reasons for developing the VBT (Vygotsky, 1987) and now finds echoes in the Research Domain Criteria (RDoC; Cuthbert and Insel, 2013) approach to studying atypical psychological functioning and psychiatric disorder.

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