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

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23 **Abstract**

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

44

45 **Introduction**

46 Autism Spectrum Disorder (ASD) comprises a diverse set of neurodevelopmental
47 disorders currently diagnosed on the basis of difficulties in social communication and
48 interaction and by the presence of significantly restricted and repetitive behaviours with
49 an onset in early neurodevelopmental period and often leading to significant difficulties
50 in adaptation (DSM-5: American Psychiatric Association, 2013). For many decades,
51 attempts to provide a comprehensive psychological account of ASD have hinged
52 around several domains of functioning ranging from attention through perception and
53 memory to more complex processes such as 'Theory of Mind', emotional relatedness,
54 Weak Central Coherence (WCC) and Executive Function (EF; see Boucher 2008;
55 Bowler 2007 for reviews). Some researchers such as Mottron and colleagues (Dawson
56 et al., 2007; Soulières et al., 2011) have used the fact that individuals with ASD
57 perform better on tasks such as the Ravens Progressive Matrices, which measure fluid
58 intelligence, than on vocabulary or language-based measures of intelligence
59 (crystallised intelligence) to argue for more domain general differences between
60 autistic and non-autistic cognition. Specifically, these authors argue that ASD is
61 characterized by a 'different' pattern of intelligence that serves adaptive function more
62 through 'lower-level' perceptual rather than 'higher-level' conceptual processes. Other
63 scientists have attempted to further refine or supplant such domain-general accounts
64 by proposing putative neuropsychological mechanisms thought to underlie the
65 behaviour patterns that gave rise to the earlier more domain-specific accounts. For
66 example, Pellicano and Burr (2012) have suggested that individuals with ASD

67 experience difficulty in the construction or application of *Bayesian priors* -
68 representations that result from earlier perceptual inferences - to on-going behaviour.
69 This results in *hypo-priors*, which influence current perceptual processes in autism-
70 specific ways. A similar approach is that of van de Cruys et al., (2014) who argue for
71 impaired predictive coding which results in people with ASD being highly inflexible in
72 the way they handle on-going violations of expectations that are based on
73 representations built up on the basis of prior experience. Moving from a cognitive to a
74 neural level of analysis, researchers have attempted to account for these phenomena
75 in terms of both increased (Simmons et al., 2007) and reduced (Davis and Plaisted-
76 Grant, 2015) neural noise. Although these different approaches show considerable
77 overlap in the way they attempt to explain the entire clinical picture of autism, scientists
78 have yet to develop a comprehensive theoretical framework that convincingly
79 integrates the social and non-social elements of the clinical picture of ASD in a manner
80 that furthers our understanding of this set of conditions.

81

82 For almost a century, however, one particular theoretical framework - the socio-cultural
83 theory of Vygotsky (Towsey, 2009, Yasnitsky and Ferrari 2008) - has attempted to
84 provide a socially-grounded, unified account of typical individuals' development of
85 abstract representations - the so-called higher mental processes (Ursino et al., 2014)
86 based on their concrete experience. The advantage of this framework is that it has
87 been applied to the disruptions observed in intellectual deficiency (Bexkens et al.,
88 2014; Danielsson et al., 2012), and psychopathological conditions such as

89 schizophrenia (Tseng et al., 2015), and more recently in neurodevelopmental disorders
90 such as autism (Wallace and Stevenson, 2014). Vygotsky's theory distinguishes
91 between *elementary mental processes* such as sensation, attention, perception and
92 memory, and *higher mental processes*, which result at least partly from social
93 interaction with others and which enable a more elaborate use of the elementary
94 mental processes (Daniels et al., 2007; Hobson, 1993). A key factor in the
95 development of higher from elementary mental processes is the internalization by the
96 child of social interactions that take place during problem solving. Vygotsky argued that
97 this internalization occurs by means of *inner speech* (Alderson-Day, 2014; Alderson-
98 Day and Fernyhough, 2014; Vygotsky, 1987) which we now know does not become
99 fully functional in typical individuals until the age of 6 or 7 years (Flavell et al., 1997).

100 By proposing a mechanism that links social interaction with the ability to develop higher
101 mental processes out of lower ones through the mechanism of social interaction and
102 inner speech, a Vygotskian approach has potential for providing the foundations of a
103 theory that integrates the disparate elements that constitute our current understanding
104 of the behavioural profile of ASD (Wallace et al., 2009). Although the role of inner
105 speech in the higher mental processes of individuals with ASD has attracted some
106 research interest (see, for example, Williams et al., 2012), there has been no
107 investigation of lower mental processes from a Vygotskian perspective or of the
108 developmental mechanisms underlying the transition between the two, despite
109 considerable research efforts driven by the theoretical perspectives outlined earlier.

110

111 One way in which the tenets of Vygotskian socio-cultural theory have been
112 operationalized and tested was by means of a procedure we refer to here as the
113 *Vygotsky Blocks Test* (VBT; Vygotsky 1987), which was based on a test originally
114 developed by Saharov (1930), which in turn was based on the ideas of Ach (1921).
115 The first part of the VBT presents the individual with a *structured* task to explore
116 convergent thinking - the capacity to arrive at the predetermined 'correct' solution to a
117 problem (Guilford, 1967) and which is tapped by most standard verbal psychometric
118 tests of crystallized intelligence. In this part of the test, the participant sees a set of
119 wooden blocks that vary according to colour, height, shape and width, with an
120 exemplar of one of the four subsets of blocks, designated by a nonsense word. The
121 task is to discover the underlying concept that defines that particular set of blocks by
122 means of a series of guesses. Cues are permitted for the first two subsets of the blocks
123 and in addition to the overall number of cues provided; a record is made of
124 perseverative and non-perseverative errors. Several predictions about the performance
125 of individuals with ASD on the VBT can be derived from existing psychological
126 research into autism. The VBT's requirement for the participant to alter strategy based
127 on changing feedback resembles the Wisconsin Card Sorting Test (WCST; Axelrod et
128 al., 1996) on which people with ASD are known to have difficulties (Landry and Al-Taie,
129 2016), showing a characteristic perseverative pattern of responding (Liss et al., 2003;
130 Memari et al., 2013). We would therefore predict greater perseverative errors in ASD
131 compared to TD participants. The VBT also taxes memory by requiring participants to
132 recall which dimensions they have volunteered as guesses to discover the concepts of

133 the different sets and also to remember the feedback associated with these guesses.
134 Memory difficulties in people with ASD are more likely on tasks with a strong recall
135 rather than recognition component or which involve complex manipulation of
136 remembered material in the absence of physical support such as a log of previous
137 guesses (see Boucher and Bowler, 2008; Bowler, 2007). On this basis, we would
138 therefore also expect greater perseverative errors in ASD compared to TD participants.
139 Finally, based on the suggestion of a 'different' intelligence in ASD that favours the
140 contribution of fluid rather than a crystallized intelligence to task performance (e.g.,
141 Dawson et al., 2007), we would expect that performance by individuals with ASD on
142 this part of the task would be correlated more strongly with measures of fluid than
143 crystallized intelligence as operationalised in terms of participants' non-verbal and
144 verbal IQ respectively.

145

146 The second part of the VBT is *unstructured*, and allows the participant to utilize
147 *divergent thinking* - the ability to arrive at novel, non-predetermined solutions through
148 the generation and manipulation of new ideas (Guilford, 1967) - to form their own
149 groupings of the blocks based upon the blocks' physical properties. Existing research
150 on categorization in ASD has reported few difficulties when tasks require categorization
151 along a single perceptual dimension or when perceptual prototypes have to be
152 extracted (Molesworth et al., 2005, 2008; Vladusich et al., 2010). In contrast, when
153 verbal labels are needed in order to solve the categorization task or when language-
154 based categories need to be organized hierarchically; those with ASD begin to show

155 subtle difficulties (Gastgeb et al., 2006), being less likely than typical individuals to use
156 categorical information to aid performance in verbal free recall tasks (Bowler et al.,
157 1997, 2009, 2010; Gaigg et al., 2008). Impaired generativity, creativity and symbolic
158 play have long been known to be features of autism (D’Cruz et al., 2013; Dichter et al.,
159 2009; Hobson et al., 2009, 2013; Takeyuchi et al., 2014; but see Kasirer and Mashal,
160 2014), which can also be associated with difficulties with executive function especially
161 planning and cognitive flexibility (see Kenworthy et al., 2008, 2009). Taken together,
162 these observations lead us to predict that individuals with ASD would show diminished
163 performance compared to a matched typically developing group on the divergent part
164 of the VBT. Both from the wider perspective of Vygotskian theory, which sees the
165 internalization of social interaction and mediation by inner speech as the main drivers
166 of development of higher mental processes and from the perspective of existing
167 research on executive functions, memory and concept formation in autism, we predict
168 that adults with ASD will show diminished performance on the VBT and that the
169 patterning of this diminished performance may provide pointers to further studies to
170 help refine a more integrated account of the psychological development of individuals
171 with ASD.

172

173 **Methods**

174 ***Participants***

175 Forty-seven individuals participated in the study, who either had a diagnosis of ASD or
176 were TD individuals. The ASD group N=23, (21 male, 2 female, $M_{age} = 40.35$ years,

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

195

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

199 Cohen et al., 2001; Woodbury-Smith et al., 2005). All participants were native English
 200 speakers and were recruited from a database of individuals with whom the Autism
 201 Research Group at City University London is in regular contact and through
 202 advertisements within the university. TD individuals were only included if they did not
 203 report taking any drugs or psychotropic medication and did not have an own or family
 204 history of a psychiatric or neurodevelopmental disorder including ASD. All participants
 205 in the study were reimbursed for their time and transport costs. Permission from the
 206 City University London Psychology Research Ethics Committee was obtained with all
 207 participants giving their informed consent before taking part in the study, which
 208 adhered to the tenets of the declaration of Helsinki. See Table 1 for the participants'
 209 details.
 210

	TD (22m, 2f)		ASD (21m, 2f)				
	<i>M</i>	<i>S.D</i>	<i>M</i>	<i>S.D</i>	<i>t</i> (34)	<i>p</i>	Cohen's <i>d</i>
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-SBⁱ			1.13 (0-5)	1.4			

211

212 **Table 1.**

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

215

216 Note. ^aVerbal IQ (WAIS-III^{UK} or WAIS-IV^{UK}). ^bPerformance IQ (WAIS-III^{UK} or WAIS-
217 IV^{UK}). ^cFull-scale IQ (WAIS-III^{UK} or WAIS-IV^{UK}). ^dAQ- Autism-Spectrum Quotient.

218 ^eADOS- Communication subscale. ^fADOS- Reciprocal Social Interaction subscale.

219 ^gADOS Total score- Communication and Reciprocal Social Interaction. ^hADOS-

220 Imagination/ Creativity subscale. ⁱADOS- Stereotyped Behaviors and Restricted

221 Interests. ADOS scores range in brackets.

222

223

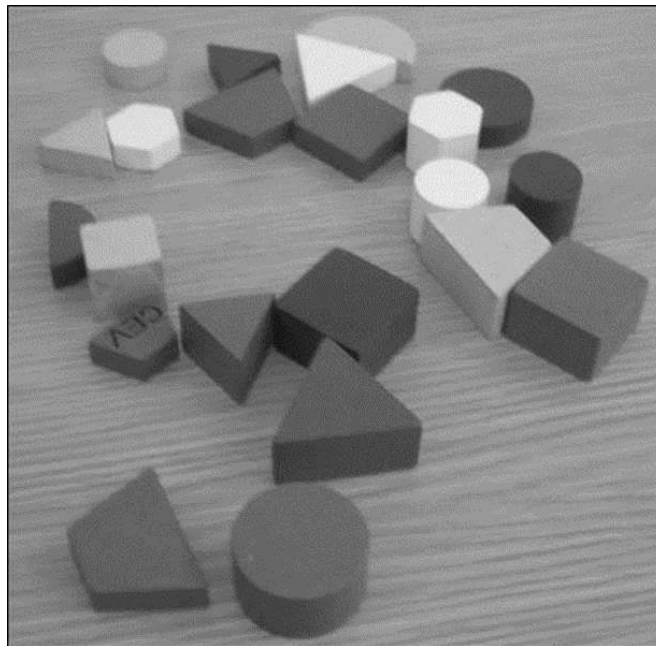
224 **Materials**

225 Materials for the VBT were the twenty-two wooden blocks from the Modified Vygotsky

226 Concept Formation Test (Hanfmann and Kasanin, 1942; Stoelting, IL, USA) using the

227 modified scoring sheet of Wang (1984). The blocks differed on a number of dimensions

228 including their color (blue, yellow, orange, green and white), shape (square, triangle,
229 circle, semicircle, trapezoid and hexagon), height (low or tall) and width (narrow or
230 wide). In addition, the blocks were divided into four groups according to nonsense
231 words (CEV, LAG, BIK and MUR) that were printed on one face and formed the four
232 sets in task one. The words corresponded to the volume of the blocks with the CEV
233 group formed by six narrow and low blocks LAG by five tall and wide blocks, BIK by six
234 low and wide blocks and MUR by five narrow and tall blocks. Figure 1 shows the
235 Vygotsky blocks with one CEV block turned over.
236



237
238 **Figure 1.** The twenty-two blocks that form the VBT. Each block can be grouped
239 according to colour, shape, height, width, number of sides, volume, curve or the ability
240 to roll. The 'CEV' block is over-turned for the start of the first set of the convergent

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

243

244 **Procedure**

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

250

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

259

260 For Task 1 an incorrect choice in the first two sets (CEV and LAG) scored one *general*
261 *error* point. If the participant made three consecutive general errors, then a cue was
262 given with the instructor turning over a block that belonged to the set being tested. A

263 *perseverative error* occurred if the participant selected three consecutive blocks that
264 shared one or more common attributes (one perseverative error per common attribute).
265 For example, a perseverative error would occur if a participant chose three triangular
266 shaped blocks in a row. The set ended when all of the blocks in the group were
267 selected, if participants committed fifteen general errors for set 1 (i.e., exhausting five
268 cues for the six CEV blocks) or if they committed twelve general errors for set 2 (i.e.,
269 exhausting the four cues for the five LAG blocks). For the remaining two sets, BIK (6
270 blocks) and MUR (5 blocks) no cues were given and these sets were terminated if the
271 participant made five consecutive incorrect choices, yielding a maximum error score of
272 twenty-five for the BIK and twenty for the MUR set. For these two sets a perseverative
273 error occurred if the participant selected three or five blocks with identical attributes
274 respectively. The total numbers of general and perseverative errors for each set as well
275 as the total number of cues required for the first two sets (CEV and LAG) were
276 recorded for analysis (see Table 2).

277

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

284

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

304

305 ***Statistical Methods***

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

312

313 **Results**

314 ***Convergent thinking***

315 Summary error scores for both groups are presented in Table 2 and Figure 1 as
316 general errors (incorrect choice), perseverative errors (repeatedly choosing a block
317 based on one characteristic) and the numbers of cues given for the CEV and LAG sets.
318 General and perseverative errors were analyzed using a 4 (Set [CEV, LAG, BIK,
319 MUR]) \times 2 (Group [ASD, TD]) repeated measures ANOVA. For general errors there
320 was a significant main effect of Group, $F(1,45) = 5.38$, $p = .03$, $\eta_p^2 = .11$, with more
321 errors for the ASD ($M = 11.96$, $SD = 6.71$) compared to the TD group ($M = 4.25$, $SD =$
322 3.29). There was also a significant main effect of set, $F(2.03, 91.35) = 11.49$, $p < .001$,
323 $\eta_p^2 = .20$, GGC, with significantly more mistakes in the first compared to second and
324 third set ($p_{max} = .005$, Cohen's $d_{min} = 0.52$). A significant Set \times Group interaction, $F(2.03,$
325 $91.35) = 3.10$, $p = .049$, $\eta_p^2 = .06$, GGC, showed that this was only true for the TD
326 group with more mistakes in the first compared to the remaining three sets ($p_{max} = .009$,
327 Cohen's $d_{min} = 0.69$). In contrast, the ASD group made more errors in the first and

328 fourth compared to the second set ($p_{max} = .02$, Cohen's $d_{min} = 0.71$) but showed a
329 similar level of errors in the first, third and fourth set ($p_{min} = .61$, Cohen's $d_{max} = 0.35$). A
330 direct comparison of the two groups showed significantly more errors for the ASD
331 compared to the TD group for the second and fourth set ($p_{max} = .02$, Cohen's $d_{min} =$
332 0.73).

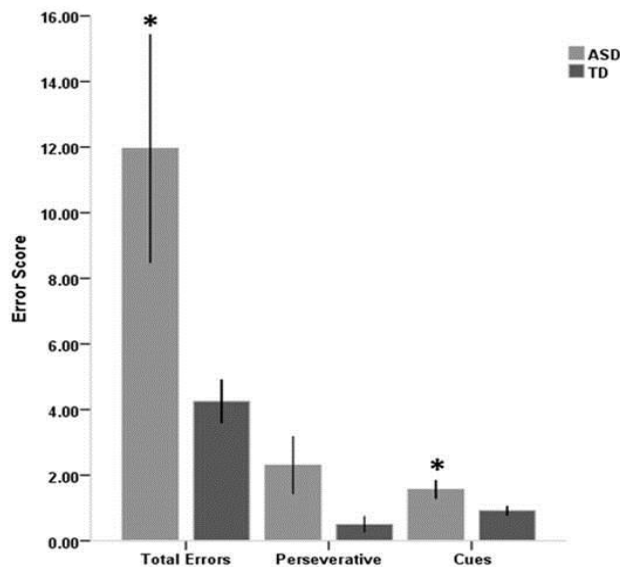
333

334 The ASD participants made more perseverative errors ($M = 2.30$, $SD = 4.19$) than the
335 TD group ($M = 0.50$, $SD = 1.22$), indicating a trend towards more errors in the ASD
336 group, $F(1,45) = 3.86$, $p = .056$, $\eta_p^2 = .08$, (but see below for analysis of covariance).
337 There was no main effect of Set, $F(2.52,113.44) = 1.75$, $p = .17$, $\eta_p^2 = .04$, GGC, but a
338 significant Set x Group interaction, $F(2.52,113.44) = 3.74$, $p = .02$, $\eta_p^2 = .08$, GGC, with
339 a decrease in perseverative errors for the TD but an increase for the ASD participants
340 across the four sets. Importantly, the ASD participants made more perseverative errors
341 in the final set (MUR) compared to the TD participants suggesting that the ASD group
342 maintained the same restricted approach to each of the sets ($p = .01$, Cohen's $d =$
343 0.78).

344

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

349 Group interaction, $F(1,45) = 0.04$, $p = .84$, $\eta_p^2 = .00$, for the ASD and TD groups (see
 350 Table 2).
 351



352
 353 **Figure 2** Results of the Convergent thinking task (Mean \pm SEM) with a significantly
 354 higher number of cues ($p = .03$) and cues ($p = .047$) required by the ASD group in task
 355 1. (ASD: Autism Spectrum Disorder, TD: Typically Developing, * = $p < .05$).

356

	TD (n=24) <i>M (S.D.)</i>	ASD (n=23) <i>M (S.D.)</i>	<i>p</i>
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)	
<i><u>Total General Errors</u></i>	<i><u>4.25 (3.29)</u></i>	<i><u>11.96 (16.71)</u></i>	<i>0.030</i>
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)	
<i><u>Total Perseverative Errors</u></i>	<i><u>0.50 (1.22)</u></i>	<i><u>2.30 (4.19)</u></i>	<i>0.056</i>
Cues			
CEV	0.92 (0.72)	1.22 (0.95)	
LAG	0.00 (0.00)	0.35 (0.65)	
<i><u>Total Cues</u></i>	<i><u>0.92 (0.72)</u></i>	<i><u>1.57 (1.38)</u></i>	<i>0.047</i>

357

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

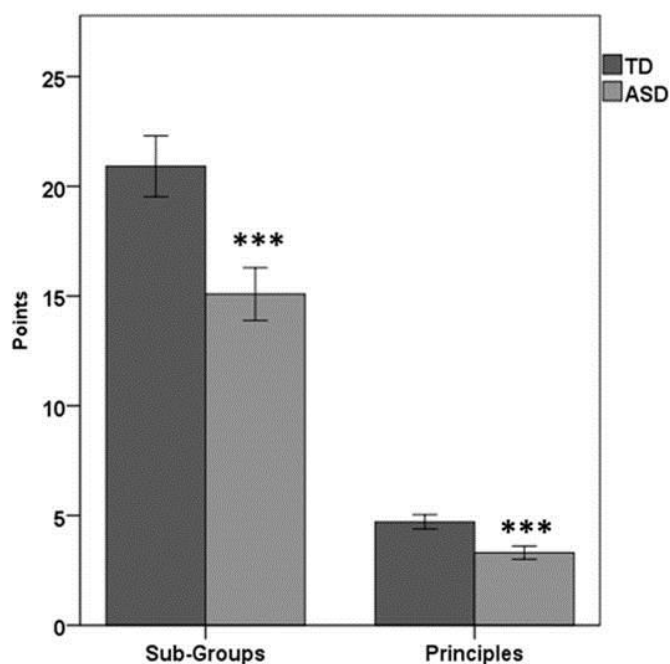
364 of their level of concreteness. (ASD: Autism Spectrum Disorder; TD: Typically
365 Developing; M: Mean; S.D.: Standard Deviation).

366

367 ***Divergent thinking***

368 The number of divergent thinking Principles and divergent Sub-Grouping points are
369 shown in Table 3 and Figure 3 with the ASD participants demonstrating inferior
370 performance with this task. The ASD participants identified fewer governing Principles
371 by which the blocks could be sorted (ASD: $M = 3.30$, $SD = 1.43$; TD: $M = 4.71$, $SD =$
372 1.60 ; $t(45) = 3.17$, $p < .004$, Cohen's $d = 0.93$). Similarly, the ASD group identified
373 fewer of the Sub-Groups in the divergent task that defined the principle (ASD: $15.09 \pm$
374 5.78 ; TD: 20.92 ± 6.81 ; $t(45) = 3.16$, $p < .005$, Cohen's $d = 0.93$). These findings
375 indicate the extent of the ASD participants' difficulties with identifying concepts by
376 which the blocks could be grouped based on their physical properties.

377



378

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

384

Divergent Thinking			
	TD (n=24)	ASD (n=23)	<i>p</i>
	<i>M (S.D)</i>	<i>M (S.D)</i>	
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

385

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

390

391 ***Types of Principle***

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

397

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

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

404

405 ***Correlations between VBT performance and other measures.***

406 A series of separate Spearman 'rho' (r_s) correlations for the TD and ASD groups
407 between VBT performance measures and PIQ, VIQ, and the Communication and
408 Imagination/Creativity sub-scales of the ADOS are reported in Tables 5a (TD
409 participants) and 5b (ASD participants). No significant correlations with age were found
410 for all participants with the VBT measures ($p > .15$). However, there was a negative
411 correlation with the TD participants and their age ($r_s = -.42, p < .05$) indicating that the
412 older TD participants identified fewer principles. As predicted, for the ASD participants,
413 PIQ negatively correlated with the number of general errors ($r_s = -.46, p < .03$) and the
414 number of perseverative errors for the convergent thinking task ($r_s = -.52, p < .02$),
415 suggesting that they relied heavily on their fluid intelligence during this structured part
416 of the VBT. When PIQ was included as a covariate in the between-group analyses of
417 the CEV and LAG cue sets of Task 1 reported earlier, the interaction between Group
418 and Set for general errors became non-significant, $F(2.14, 94.42) = 2.27, p = .053, \eta_p^2$
419 $= 0.06$, GGC, and the between-group difference in perseverative errors fell just on the

420 cusp of significance, $F(1,44) = 4.07, p = .05, \eta_p^2 = 0.09$, reflecting the protective effect
421 of higher PIQ against perseverative responding in ASD vis-à-vis the comparison group.
422 Turning to the divergent thinking part of the VBT, here VIQ in the ASD group correlated
423 with the number of Principles and the number of Sub-Groups the participants
424 generated ($r_s = .54, p < .01$ and $r_s = .59, p < .01$ respectively), suggesting that they
425 relied more on verbal ability when engaging in divergent thinking. In the comparison
426 group, none of the associations between task performance and verbal or non-verbal IQ
427 was reliable. Including VIQ and PIQ as covariates in the analysis of Task 2 did not
428 change the overall pattern of results apart from yielding a significant group difference in
429 perseveration for the final stimulus set in the sequence, (MUR), which survived
430 partialling out of PIQ ($F(1,45) = 7.14, p < .02, \eta_p^2 = 0.14$).

431

432 Turning to correlations with clinical symptoms, the Communication scale of the ADOS
433 correlated with the number of cues ($r_s = .53, p < .04$) participants with ASD required on
434 the convergent thinking part of the VBT, indicating that the more communicatively
435 impaired individuals with ASD required greater task support in terms of more cues to
436 complete the task successfully. A significant positive correlation between the
437 Imagination/Creativity sub-scale of the ADOS and VBT perseverative errors ($r_s = .62, p$
438 $< .02$) indicates that the ASD individuals who had less imaginative capacity made more
439 perseverative errors on the VBT. The significant negative correlations between the
440 ADOS Imagination/Creativity sub-scale and the number of Principles on the divergent
441 thinking part of the VBT ($r_s = -.68, p < .01$); and number of Sub-Groups identified for the

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

444

445 **(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

446

447 **(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)	.50	.62*	.54*	-.68*	-.72**
Imagination					

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

454

455 **Discussion**

456 The primary aims of the present study were to document the performance of adults
457 with ASD on the VBT with a view to taking the first steps towards systematic
458 investigations of autistic individuals' development of the higher mental processes out of
459 elementary mental processes both within the framework of Vygotskyan theory and of
460 wider theories of autistic cognitive dysfunction. As discussed in the Introduction,
461 Vygotskyan theory sees the higher mental processes arising out of internalized social
462 interactions and mediated by inner dialogue. Our broad prediction was that the
463 performance of adults with ASD on the VBT, because of their particular behavioural
464 profile of social impairment and 'different' intelligence, would differ from that of typically
465 developed adults. We also made more specific predictions based on existing research
466 on autistic populations in areas tapped by the VBT, such as concept formation and

467 perseverative behaviour. Accordingly, we discuss its results in terms of their relation to
468 existing executive dysfunction-based accounts of the difficulties experienced by
469 individuals with ASD when developing new concepts. We also highlight ways in which
470 observations based on the VBT might offer pointers to future research into underlying
471 psychological processes in ASD, particularly into the role of fluid, non-verbal
472 intelligence as a possible compensatory contributor to overall performance (Mottron
473 2004) and in particular to diminished inner dialogue (Wallace et al., 2009). Finally, we
474 raise the question of how the present pattern of findings might be integrated into more
475 recent accounts of autistic cognitive dysfunction.

476

477 The findings of the convergent thinking task (Task 1) are broadly consistent with the
478 existing literature on errors and perseveration on executive functioning tests by ASD
479 individuals (Landry and Al-Taie, 2016; Liss et al., 2001; Sokhadze et al., 2010). The
480 fact that the overall ASD-related higher rate of perseverative errors was reduced when
481 PIQ was controlled suggests that variability resulting from individual differences in fluid
482 intelligence may have contributed to increased perseveration on this task. This finding
483 suggests that our ASD sample may have used their non-verbal skills to overcome a
484 tendency to perseverate on the convergent part of the VBT. Taken together with our
485 finding that the group difference for the last stimulus set (MUR) survived partialling out
486 of PIQ, these findings suggest that there may be limits to the effectiveness of
487 compensatory strategies mediated by non-verbal IQ and that perseveration may only
488 become problematic for the ASD participants after prolonged testing. A recent study

489 using the WCST in matched Japanese adults with ASD and TD participants also found
490 that Milner type perseverative error scores correlated negatively with VIQ and FIQ in
491 the ASD participants but not the TD group. That study reported no other correlations
492 with AQ or IQ measures on other WCST measures suggesting that a higher VIQ
493 protects against perseverative errors (Yasuda et al., (2014).

494

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

505

506 Increased perseveration may also result from less inhibition during the task (Cepeda
507 and Munakata, 2007), which would prevent the ASD participants from developing new
508 grouping structures (D'Cruz et al., 2013; Mosconi et al., 2009). The convergent thinking
509 task is based on classifying according to the physical dimension of Volume, which may
510 be more obscure than the features of Colour or Shape to identify One explanation may

511 be that performance on the VBT may rely on reduced ability to inhibit or ignore the
512 more prominent Colour or Shape of the blocks in preference for Volume (Faja et al.,
513 2016).

514

515 Over-reliance by the ASD by comparison with the TD participants on processes tapped
516 by the PIQ measure coupled with their having less recourse to VIQ-related processing
517 constitutes the first over-arching theme running through the results of the present study.

518 Superior non-verbal over verbal intelligence is characteristic of a sub-set of the ASD
519 population (Ghaziuddin and Mountain-Kimchi, 2004; Siegel et al., 1996) and

520 researchers have argued that ASD individuals may exhibit a 'different' intelligence that
521 may be underestimated by verbally loaded measures of intelligence (Mottron 2004;

522 Nader et al., 2016). Mottron and colleagues have also argued that this 'different'

523 intelligence results from a preference for lower-level perceptual over higher-level

524 conceptual processing (Mottron et al., 2006), which on the VBT, may have resulted in

525 slower identification of Sets on the Convergent task and poorer identification of

526 Principles on the Divergent task, which in Vygotskian terms involves transition from the
527 elementary to higher mental processes.

528

529 The tendency for higher error rates and a greater need for cues on the convergent part
530 of the VBT to correlate with PIQ rather than VIQ in the ASD participants has two

531 implications. As well as indicating a different set of cognitive processes underlying task

532 performance, it may also be a consequence of diminished recruitment of inner speech

533 to enable completion of that part of the VBT with as few errors as possible. This
534 dependence on inner speech constitutes the second overarching theme of the present
535 results, and is evident in the findings of the convergent part of the VBT (Task 2), which
536 explored the individuals' ability to develop their own, higher level concepts based on
537 the lower-level physical properties of the blocks. Here, the ASD group was worse than
538 the comparison participants in their ability to develop principles and formulate sub
539 categories based on the seven principles inherent in the blocks.

540

541 Our demonstration of the ASD group's diminished capability to see as many alternative
542 ways of classifying the blocks according to the divergent thinking Principles and
543 divergent Sub-Grouping points shown in Table 3 coupled with the strong correlation
544 between this capability and both VIQ and the Imagination sub-scale of the ADOS, both
545 confirms earlier findings showing diminished imagination in individuals with ASD (Craig
546 and Baron-Cohen, 1999; Craig et al., 2001; Woodard and van Reet, 2011) and is
547 consistent with work that shows their limited engagement with inner speech, which
548 Vygotsky saw as crucial to the development of novel conceptual structures and for the
549 transition from elementary to higher mental processes (Vygotsky, 1987). Atypical inner
550 speech self-dialogue has been shown in ASD by several researchers (Biro and Russell,
551 2001; Russell-Smith et al., 2014; Wallace et al., 2009). Russell-Smith et al's (2014)
552 findings indicate that children with ASD perform no differently on a card sorting task
553 either when they performed the task whilst repeating a word verbally (inner speech
554 suppression) or when they performed the task without suppression. In contrast, the

555 neurotypical children's performance was worse when using verbal suppression and
556 Williams et al., (2012) reported a similar fall in performance on the Tower of London
557 task with neurotypical adults when they used articulatory suppression but performance
558 was unaffected in the ASD participants suggesting that the ASD group failed to engage
559 in inner dialogue. Of interest in the present context, Williams et al., (2012) found no
560 difference in overall Tower of London performance between the ASD and TD groups,
561 suggesting that the former relied on non-verbal processes to solve the task
562 successfully in a manner analogous to performance on the convergent part of the VBT.
563 One study in a large non-clinical ASD sample found a correlation with autistic traits and
564 an ability to produce novel and creative responses to interpretations of figures,
565 although there was no association between divergent thinking fluency and autistic traits
566 (Best et al., 2015). The VBT may therefore provide a method for further examining
567 divergent thinking patterns in ASD and non-clinical individuals with autistic traits.
568
569 Some limitations of this preliminary study were sample size with the attendant
570 possibility of Type II errors as well as a large variance in the performance by the ASD
571 group resulting in some measures failing to demonstrate clearly significant effects. A
572 further weakness was that no *post-hoc* analysis of the strategies employed by the
573 participants to complete the VBT was performed. Such an analysis might have offered
574 a greater insight into the thought processes exploited by the participants in Tasks 1
575 and 2. Also, a lack of full ADOS scores for all of the ASD participants at the time of the

576 study limited the strength of the associations between ADOS sub-scores and
577 performance on the VBT.

578

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

595

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