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**1** **Problem Solving Styles in Autism Spectrum Disorder and the development of**

**2** **higher cognitive functions**

**3** Paul A Constable[1,2] Melanie Ring[2] Sebastian B Gaigg[2] Dermot M Bowler[2]

**4**

**5** 1 Department of Optometry and Vision Science, Flinders University, GPO Box 2100,

**6** Adelaide 5001, South Australia, Australia

**7**

**8** 2 Autism Research Group, Department of Psychology, City University London,

**9** Northampton Square, EC1V 0HB United Kingdom

**10**

**11** **Contact Details Corresponding author**

**12** Dr Paul Constable

**13** Flinders University

**14** Department of Optometry and Vision Science

**15** GPO Box 2100

**16** Adelaide 5001

**17** South Australia

**18** Australia

**19** Ph +61 8 7221 8400

**20** Fax +61 8 7221 8399

**21** paul.constable@flinders.edu.au

**22**

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

**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

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 Vygotskyan 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) | | | | |
|---|---|---|---|---|---|---|---|
|  | *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 | | |

211

212 **Table 1.**

213 Participant characteristics for Autism Spectrum Disorder (ASD) and typically

214 developing (TD) individuals.

215

216 Note. [a]Verbal IQ (WAIS-III[UK] or WAIS-IV[UK]). [b]Performance IQ (WAIS-III[UK] or WAIS-

217 IV[UK]). [c]Full-scale IQ (WAIS-III[UK] or WAIS-IV[UK]). [d]AQ- Autism-Spectrum Quotient.

218 [e]ADOS- Communication subscale. [f]ADOS- Reciprocal Social Interaction subscale.

219 [g]ADOS Total score- Communication and Reciprocal Social Interaction. [h]ADOS-

220 Imagination/ Creativity subscale. [i]ADOS- 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
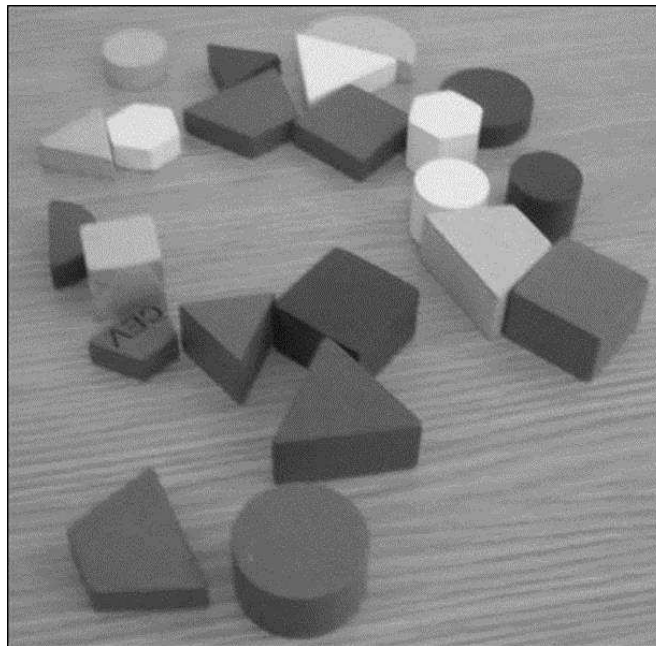


237

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) ± 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]) x 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 x 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
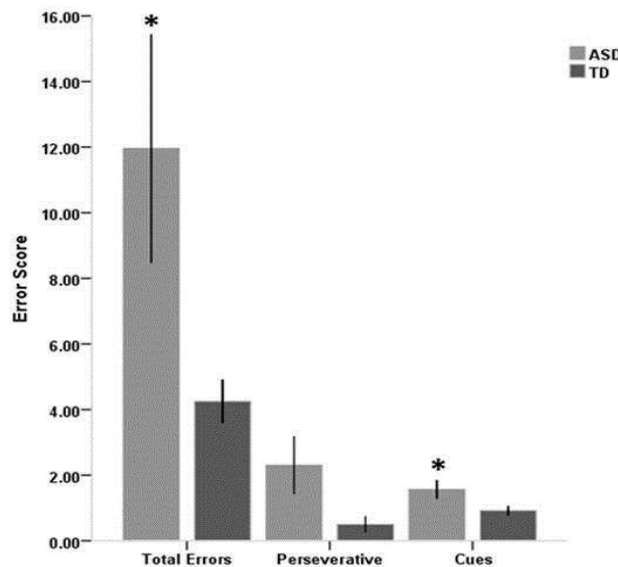


352

353 **Figure 2** Results of the Convergent thinking task (Mean ± 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) *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* |

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 ±

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
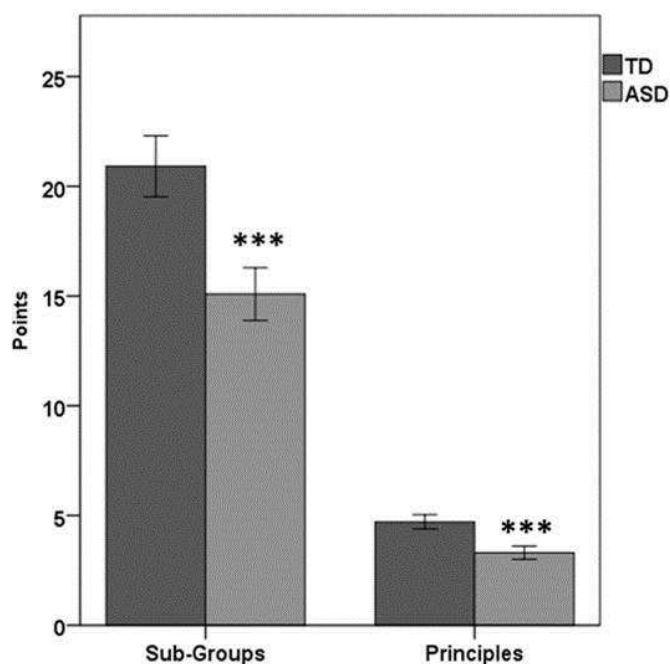


**Figure 3** Results of the Divergent thinking task (Mean ± SEM) with a significantly

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).

384

| 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 |

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 ($x^2$ = 4.77, $p$ < .03);

394     Volume ($x^2$ = 4.77, $p$ < .03); Height ($x^2$ = 4.45, $p$ < .04) and Roll ($x^2$ = 4.37, $p$ < .04) but

395     not for the principles of Width ($x^2$ = 3.61, $p$ = .06); Shape ($x^2$ = 1.00, $p$ = .32) and Curve

396     ($x^2$ = 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 participant s 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

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** |

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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