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Automatic and controlled processing and the Broad Autism Phenotype

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ABSTRACT

Research related to verbal fluency in the Broad Autism Phenotype (BAP) is limited and dated, but generally suggests intact abilities in the context of weaknesses in other areas of executive function (Hughes et al., 1999; Wong et al., 2006; Delorme et al., 2007). Controlled processing, the generation of search strategies after initial, automated responses are exhausted (Spat, 2013), has yet to be investigated in the BAP, and may be evidenced in verbal fluency tasks. One hundred twenty-nine participants completed the Delis–Kaplan Executive Function System Verbal Fluency test (D-KEFS; Delis et al., 2001) and the Broad Autism Phenotype Questionnaire (BAPQ; Hurley et al., 2007). The BAP group ($n=53$) produced significantly fewer total words during the 2nd 15″ interval compared to the Non-BAP ($n=76$) group. Partial correlations indicated similar relations between verbal fluency variables for each group. Regression analyses predicting 2nd 15″ interval scores suggested differentiation between controlled and automatic processing skills in both groups. Results suggest adequate automatic processing, but slowed development of controlled processing strategies in the BAP, and provide evidence for similar underlying cognitive constructs for both groups. Controlled processing was predictive of Block Design score for Non-BAP participants, and was predictive of Pragmatic Language score on the BAPQ for BAP participants. These results are similar to past research related to strengths and weaknesses in the BAP, respectively, and suggest that controlled processing strategy use may be required in instances of weak lower-level skills.

1. Introduction

The Broad Autism Phenotype (BAP) refers to characteristics of the core symptoms of autism (disordered communication, poor social interest, and stereotyped behaviors) that are of insufficient severity for a diagnosis of autism spectrum disorder (Davidson et al., 2014; McCray et al., 2014). Executive function weaknesses are observed in the Broad Autism Phenotype (Hughes and Ensor, 2010; McLean et al., 2014). Verbal fluency is a frequently researched component of executive function (Andreou and Trott, 2013; Metternich et al., 2014; Herbert et al., 2014; Czermainski et al., 2014). Verbal fluency tasks require generation of words within a time limit according to either a letter cue (phonemic/letter fluency) or a category cue (semantic/category fluency) (Delis et al., 2001; Malek-Ahmadi et al., 2011). Verbal fluency tasks overall are thought to be indicative of cognitive flexibility and the ability to generate a search strategy (Kenworthy et al., 2013). Research in this area is important because it has implications regarding adaptive behavior, academic achievement, and occupational outcomes for those with autism characteristics, as well as in helping understand the cognitive weaknesses observed in those with an autism spectrum diagnosis (Kenworthy et al., 2009, 2013; Barkley and Fischer, 2011; Culbertson et al., 2013; Panerai et al., 2014; Pugliese et al., 2015).

The relatively limited research related to verbal fluency in the BAP is dated, but does provide some evidence for weaknesses in this area compared to controls. In one study, siblings of individuals with autism obtained lower scores on tasks of letter and semantic verbal fluency compared to control siblings (Hughes et al., 1999). However, other findings indicate that although parents of children with autism demonstrated weaker performance in ideational fluency compared to control parents, no differences in semantic verbal fluency scores were observed (Hughes et al., 1999; Wong et al., 2006). Other research has further supported the idea that no significant differences between parents of children with autism and controls exist for either letter or semantic fluency (Delorme et al., 2007). It is possible that verbal fluency is a relatively preserved area of executive functioning in the BAP population.

1.1. Limitations of previous research

However, the above studies may not have adequately assessed verbal fluency weaknesses. One limitation concerns adequate measurement of processing strategies. Automatic processing refers to the production of information relatively easily due to extensive

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familiarity and practice (Hurks et al., 2006). Controlled processing refers to the generation of search strategies in production of information after initial, automatic responses are exhausted (Vannorsdall et al., 2014; Spat, 2013). A study utilizing the Delis–Kaplan Executive Function System's Verbal Fluency task, which allows for computation of time-based normative scores, demonstrated the potential usefulness of the evaluation of the number of words generated in the four 15″ intervals of verbal fluency tasks (Hurks et al., 2006). In this study, it was suggested that Total Words Generated in each of the 2nd through 4th 15″ intervals were reflective of controlled processing strategies, whereas words generated during the 1st 15″ interval were reflective of automatic processing (Hurks et al., 2006). Automatic versus controlled processing, especially regarding time intervals in verbal fluency tasks, has yet to be studied in the BAP population. It is possible that intact or better than average automatic processing skills, coupled with weak or slow to develop controlled processing skills, are related to the overall intact performance in the BAP group compared to controls. The current study will investigate this idea. Additionally, the limited available research on automatic and controlled processing does not include evidence for construct validity; the current study will address this lack of evidence.

Another limitation of the above studies is related to sampling. Many studies, including the available studies regarding verbal fluency, utilize the presence/absence of a child or sibling with an autism spectrum disorder (ASD) to classify individuals into BAP and Non-BAP groups, respectively (e.g., Hughes et al., 1999; Kadak et al., 2014; Martinez-Sanchis et al., 2014). This classification is based on the extant research indicating a strong heritability of autism spectrum disorders (Colvert et al., 2015). Twin and singleton autism sibling studies indicate greater similarity in symptoms and diagnosis with higher proportion of shared genes (Zhao et al., 2007; Taylor et al., 2013; Frazier et al., 2014), and more pronounced autism traits have been observed in non-autism siblings in multiplex than simplex families (Pisula and Zeigart-Sadowks, 2015; Tayor et al., 2015). The 200+ specific genes identified in autism diagnoses have been implicated in sub-clinical autism characteristics as well (Nishiyama et al., 2014; Robinson et al., 2014). However, using child diagnosis as a classification method may misclassify many parents. Studies suggest an increasing number of children are born to families considered "low risk" for having a child with autism (Losh et al., 2008; Nishiyama et al., 2014; Iossifov et al., 2014; Davidson et al., 2014). De novo mutations, epigenetically modified genes, and perinatal complications have been implicated in autism diagnosis (Chaste and Leboyer, 2012; Flashner et al., 2013; Taylor et al., 2013; Tordjman et al., 2014). Much of the research investigating cognitive profiles in the BAP, and particularly regarding verbal fluency in the BAP, does not consistently differentiate between single and multiple incidence families or utilize both parents in their sample (e.g., Hughes et al., 1999; Wong et al., 2006; Delorme et al., 2007; Levy and Bar-Yuda, 2011; Kadak et al., 2014; Martinez-Sanchis et al., 2014). Additionally, group classification on the basis of child diagnosis systematically excludes those with the BAP who do not have children, or whose child does not yet have a diagnosis of ASD.

1.2. Purpose of the current study

The current study purported to determine if weaknesses in verbal fluency in the BAP could be attributed to automatic and controlled processing abilities, and provide evidence of validity of these constructs. Planned analyses, including *t*-tests, correlations, and regressions were conducted with verbal fluency variables to examine group differences, and to provide evidence for the validity of automatic and controlled processing strategies in each group. Additional exploratory analyses were conducted to determine how automatic and controlled processing skills related to BAP characteristics.

2. Method

2.1. Participants

The 129 participants included 107 females (82.90%) and 22 males with a mean age of 33.10 ($SD=11.07$) years. The sample was predominantly (86.00%) right handed, and all had English as their first language. Participants were predominantly Canadian (66.70%). The "other" ethnicity category consisted of several ethnic groupings with fewer than 8 people per group, including Italian, Chinese, French, and African-Canadian. Average socio-economic status as assessed by Hollingshead Four Factor Index was 45.45 ($SD=14.46$), corresponding to middle-class (Hollingshead, 1975). The majority (61.6%) of participants had children.

As the current study was attempting to address the limitations of classification methods of previous studies while obtaining a sample of persons likely to demonstrate the BAP, the sample included parents of children with autism ($n=31$, 24.00%), parents of children with other developmental disabilities ($n=34$, 26.40%), and undergraduate students who had either had no children or whose children did not have any disabilities ($n=64$, 49.60%). Parents of children with autism or another developmental disability were automatically eligible for participation. Undergraduates without children, or whose children did not have disabilities, were screened for participation based on scores ± 1.5 standard deviations above or below the overall mean in the standardization sample for the BAPQ (Hurley et al., 2007) in order to ensure adequate variability in the sample.

Participants were classified into Broad Autism Phenotype (BAP) ($n=53$, 41.10%) and Non-Broad Autism Phenotype groups (Non-BAP) ($n=76$, 58.90%) based on gender-normed cutoff scores on the Broad Autism Phenotype Questionnaire (Hurley et al., 2007). Chi Square and *t*-tests indicated no significant differences between groups regarding demographic variables or Vocabulary or Block Design scores (all X^2s ≤ 4.939, all $ps \geq 0.09$; all $ts < 1.53$, all $ps \geq 0.13$). Of the 64 screened undergraduate participants who completed the study, 50.2% met criteria for the BAP based on the gender normed means and 49.8% did not. No significant differences in instance of the BAP were observed between parents of children with autism or parents of children with other developmental disabilities ($X^2(1,65)=9.685$, $p=0.408$). When these two groups were compared with the pre-screen undergraduate sample ($n=763$), no significant differences in the BAP incidence were observed ($X^2(2,828)=1.013$, $p=0.603$). Refer to Table 1 for demographic characteristics of the resulting BAP and Non-BAP subgroups. As there were no systematic differences between groups on any demographic variables, cognitive abilities, or incidence of the BAP, and because BAP classification was the primary grouping variable of interest in this study, the three groups (autism parents, other developmental disability parents, and undergraduates) were collapsed in future analyses.

2.2. Measures

2.2.1. General cognitive ability

General cognitive ability was estimated using the Block Design and Vocabulary Subtests from the Wechsler Adult Intelligence Scale-IV (WAIS-IV; Wechsler, 2008), which together provide a reliable and valid estimate of an individual's overall IQ (Sattler, 2001; Wechsler, 2008). The Block Design subtest requires the examinee to reconstruct a block pattern within a time limit. This test correlates at 0.69 with the Full Scale IQ (FSIQ) score. The Vocabulary