Association between attention, nonverbal intelligence and school performance of school-age children with Autism Spectrum Disorder from a public health context in Brazil

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Abstract

Background: Autism Spectrum Disorder (ASD) is characterized by impairments in social interaction, restricted and repetitive behaviour, interests or activities. Difficulties in a broad spectrum of cognitive skills is often present, including attentional processes and nonverbal intelligence, which might be related to academic difficulties. **Aims:** In this study, the association between attentional skills and nonverbal intelligence to school performance of children with ASD was assessed. **Methods and Procedures:** 32 children/adolescents between 8 -14 years old, who attended a treatment unit linked to the public health system of São Paulo-Brazil participated in the study. The following instruments were utilized: Cancellation Attention Test; Raven's Coloured Progressive Matrices; and School Performance Test. **Outcomes and Results:** After correlation analysis, statistically significant associations were found between attention and nonverbal intelligence with school performance. Regression analysis showed that attention drives school performance irrespective of nonverbal intelligence. **Conclusions and Implications:** Results evidence the link between attention and school performance in ASD, suggesting that attentional mechanisms may be a promising route to follow in the design of interventions for school improvement of children and adolescents with ASD.

What this paper adds?

In this paper, we report the association between attention and nonverbal intelligence to academic performance of children and adolescents with ASD from a public health context in São Paulo, Brazil. We show that attention drives school performance above the contribution of nonverbal intelligence. This paper suggests an important link between attention and school performance independent of intelligence in school-age children of a middle-income developing

country. This provides a possible avenue of intervention to aid in the development of children with ASD, suggesting a new pathway to overcoming barriers in learning due to attentional difficulties with attention training and its further far-transfer to academic performance.

Keywords Autism Spectrum Disorder; Attention; School performance; Nonverbal intelligence.

1. Introduction

Autism Spectrum Disorder (ASD) is characterized by impairments in social interaction, and restricted and repetitive behaviour, interests or activities (American Psychiatric Association 2013). Although not part of its core symptomatology, ASD can also be associated with impairments in academic performance. School performance in children and adolescents with ASD tends to be heterogeneous, with evidence pointing to difficulties in some specific (but not all) areas. For example, previous studies reported impairments in writing (Finnegan & Accardo 2017), reading comprehension (Huemer & Mann 2010), and math (Oswald et al. 2015), but also intact reading (May, Rinehart, Wilding & Cornish, 2013). Consequently, prognosis for ASD children can be detrimental for academic attainment.

It is therefore important to consider what aspects in ASD drive academic attainment. For instance, school performance is generally thought to be linked to fluid intelligence (Peng, Wang, Wang & Lin, 2019), a function that can be defined as involving the active maintenance of information, whether verbal or visual-spatial in working memory for purposes of planning and executing goal directed behaviour (Chuderski, Taraday, Nęcka & Smoleń 2012). While a wide range of cognitive abilities are linked to academic performance (e.g. working memory, reasoning, executive function), their contributions for academic performance in ASD might diverge in comparison to neurotypicals (Peng & Kievit, 2020).

Even though school performance varies significantly across ASD (Keen, Webster and Ridley, 2016), reading performance was predominantly in the normal range (average performance) for a group of children with ASD with an IQ> 80, but varied widely at the individual level, including those considered “gifted” (IQ> 120). Among the group of people with an IQ <80, the score in basic reading was also in the normal range. In the study by Mayes and Calhoun (2007), however, the low IQ ASD group was unable to complete the reading comprehension subtest, and the high functioning ASD group scored much lower on the same construct, in relation to their paired peers for nonverbal IQ (Troyb et al., 2014). The performance of people with ASD in basic math, in general, was average, and was positively correlated with IQ, both for low and high groups. Similarly to reading performance in ASD, there are differences in math performance at the individual level. Jones et al. (2009) identified subgroups of 'peak' and 'fall' in the math scores of adolescents with ASD. The peak group exhibited scores of numerical operations in the upper range, and the “fall” group exhibited scores of numerical operations in the bordering range (Jones et al., 2009). In writing skills, children and adolescents with low and high functioning ASD showed normal performance (Keen et al., 2016). However, Mayes and Calhoun (2007) found that the written expression in the Wechsler Individual Achievement Test subtest was significantly less than average. In a previous study (Mayes & Calhoun, 2003), scores on written expression for the high IQ group were significantly lower than expected based on IQ.

Although ASD tends to be heterogeneous in its presentation, several atypical attentional processes are often found in individuals with ASD, with reports of initial difficulties in attention related to the development of ASD symptoms such as joint attention and sociocommunicative deficits (Keehn, Müller, Townsend, 2013). Indeed, attention difficulties such as in disengagement are present from the first year of age in children with ASD (Bryson et al., 2018) and may extend to the broader Autistic Phenotype (Muller Spaniol, Shalev & Mevorach, 2018). Regarding the prevalence of attentional problems in children with ASD, Mayes and Calhoun (2007) identified that 93% of children with ASD exhibited some type of attention problem. Many children with ASD also have an Attention Deficit Hyperactivity Disorder diagnosis, with comorbidity rates of 59–83% through 13 studies (Joshi et al., 2017). Attention can be defined as the process of concentration on selected items of the environment, excluding other unmet stimuli (Pashler, 1998). Attention is composed of three different processes that are articulated, namely, selective, sustained and executive attention (Petersen & Posner, 2012). Difficulties in attention in children with ASD are found in sustained attention (Chien et al., 2015), selective attention (Keehn, Westerfield, Müller & Townsend, 2017) and executive functions such as inhibition, planning, set-shifting and cognitive flexibility (Craig et al., 2016). Given the close link between attention processes and learning (Erickson et al., 2015) it is expected that attention problems in ASD will interfere both directly and indirectly in school performance.

Indeed, academic performance has been linked to low-level attention process such as sustained attention (Stern & Shalev, 2013) and this link has also been considered in developmental disorders (Kirk, Gray, Riby, Taffe & Cornish, 2016) as well as in ASD (May et al. 2013). For instance, May et al. (2013), identified an association between attention switching and math performance in children with ASD. Since atypical attention features heavily in the ASD literature (Keehn et al., 2017; Spaniol, 2018), it is possible that in ASD problems in academic attainment may be driven by fluid intelligence, by attention atypicalities or by both. Importantly, if academic performance is not only explained by intelligence but also independently related to attention capacity in ASD, this provides a possible avenue for intervention that will target attention in this population. In fact, an attention training program has shown improvements in academic skills of children with ASD (Spaniol, Shalev, Kossyvaki & Mevorach, 2018), thus the role of attention on school performance should be further explored. While previous research investigated the relation between attention and school performance, it is mainly in typical developing children or Attention Deficit Hyperactivity Disorder, in which attention plays a main role. Research on this topic in ASD is still scarce, particularly the relationship between nonverbal intelligence, attention and school performance. In the present study we assessed the link between attention, nonverbal fluid intelligence and school performance in math, reading and writing in a group of children with autism from a middle-income developing country and from a public health context in Brazil, to verify whether attention capacity contributes to academic performance irrespective of nonverbal intelligence.

2. Material and Methods

2.1. Participants and procedure

The study was conducted with children and adolescents, with regular attendance at the ASD Reference Unit linked to the Brazilian public health system - Dr Marcos T Mercadante, CAISM Vila Mariana, São Paulo - Brazil. To be invited to participate in the study patients of the centre had to be between 8-14 years old and have a formal diagnosis of ASD according to the DSM 5 (American Psychiatric Association 2013). At CAISM each patient is diagnosed by a specialist together with a multidisciplinary assessment based on standardized instruments, including screening assessment, functional skills, communication, neuropsychological and treatment assessment. Of the 97 eligible children and adolescents, 34 parents/guardians agreed for their child to participate in the study. Two of these 34 participants exhibited severe behavioural problems, which led to their exclusion from the study (as data collection was not possible). Thus, the final sample consisted of 32 children and adolescents aged 8-14 years (mean 11.4; SD 1.7), 81.2% were male, and 65.6% were between the 2nd - 4th grade (regular or special schools). The school year of 10 children was estimated according to their age group as they frequented special schools in which there is no division by school year (special school: 9 children; regular school: 23 children). The assessment instruments were applied individually in 2-3 sessions lasting approximately 45 minutes each. The study was approved by the Research Ethics Council of Santa Casa de Misericórdia Hospital 72809517.3.0000.5479. Informed consent was obtained from all participants and their parents.

2.2. Measures

Three instruments were used to separately assess nonverbal fluid intelligence, attention capacity and academic performance as follows:

Raven's Coloured Progressive Matrices Test (CPM): a cognitive assessment which evaluates nonverbal *fluid intelligence* measuring the ability to reason and solve problems from prior information (Raven, 2000). The CPM consists of 36 items divided into 3 categories, each containing 12 items. The test has no application time limit - average application time ranged from 15 to 30 minutes. The CPM was adapted and validated to Brazilian Portuguese (Pasquali et al., 2002). The standardized scores were calculated according to the test manual.

Cancellation Attention Test (CAT): this test assesses *attention*: sustained, selective and attention switching/alternating (Montiel & Seabra, 2012). The CAT is a Brazilian version of an Attention Cancelation Test, used in typical and clinical populations, such as in Matier, Wolf & Halperin (1994). It has been used and validated in Brazil for children from primary schools (Hazin et al., 2012) and pre-school children (Dias, Trevisan & Prado, 2011). This test has also been used in children with ASD (Passos, 2020) and other neurodevelopmental conditions, for example, children born preterm at risk for developmental problems (Nobre et al., 2020). It consists of three parts; each one contains a matrix with different stimuli (geometric shapes). The task is to identify all stimuli that are the same as the target. In the first part, the target stimulus is a single figure; in the second part, the target is composed by two figures. Parts 1 and 2 assess selective attention. The third part evaluates selective and alternating attention as the target changes every line. Each subtest has 3 variables of interest: accuracy, omission and commission errors (Capovilla & Dias, 2008). The omission and commission errors are measures considered essential for the evaluation of attentional skills, for example the Conners' Continuous Performance Test/CPT evaluates the same measures, and the CPT is a gold standard test to evaluate ADHD. The administration time is one minute for each part. However, as the standardized test is used with neurotypical children and adults, given our clinical sample are children with ASD, in this research an adaptation was performed according to the profile of the children, allowing the sample two minutes to perform each subtest. Raw scores were standardised according to the test manual to characterize the sample. As such the standardised score reflects an overestimate of the attention capacity in this cohort compared to neurotypicals. The number of correct answers and errors for each subtest and overall score were used for data analysis (number of targets correctly marked; Montiel & Seabra, 2012).

School Performance Test (SPT): a widely used Brazilian standardized test to measure school performance (Knijnik et al., 2013), it evaluates *academic performance* in three categories: 1. Math – problem solving and written math calculations. 2. Writing – 34 dictated words, which were also presented visually (copying); and 3. Reading – recognition of words isolated from context. The difficulty level in each subtest increases gradually. Children had 10 minutes to complete each subtest. Performance scores (number of correct responses) were also standardized according to the test manual. The test provides a classification according to school year and age for each subtest and total scores (sum of scores from all subtests) as an overall measure of school performance. Mean scores vary for each school year, and for age. Overall, mean scores irrespective of age/school year are: writing: 24.9, STDV:8.9; reading: 60.2, STDV:17.3; math: 17 STDV:7.7; total: 102.1, STDV:31.5. (Stein, 1994).

The Autism Behavior Checklist (ABC autism; Krug et al., 1980) was used to measure autistic symptoms and severity. The ABC evaluates 57 atypical behaviors that are organized into five areas: sensory, relational, body concept, language, social and self-care. It is used to aid in the diagnosis and severity of autism. Final scores lower than 47 indicate typical development, 47-53 indicate a slight probability for an ASD diagnosis, between 54-67 indicates moderate probability for an ASD diagnosis, while final scores higher than 68 are indicative of children with ASD. The Portuguese – Brazilian version showed good sensitivity and specificity (.93; Marteleto et al., 2005).

2.3. Data analysis

Initially, standardised scores were calculated and reported (means and standard deviations). Then correct answers were analysed using Pearson's correlation to verify possible associations between Cancellation Attention Test (CAT) and Raven's Coloured Progressive Matrices (CPM) scores in relation to School Performance Test (SPT), as well as CPM scores in relation to those obtained in CAT. Next, multiple linear regression was utilized to test whether attention capacity significantly predicts academic performance even when controlling for the contribution of nonverbal fluid intelligence. Collinearity statistics were also evaluated to ascertain that multicollinearity between the variables would not affect the results from the regression, considering the cut-off value of 3 used in more conservative approaches (Midi, Bagheri & Imon, 2010). Partial correlations between the variables tested in the regression were also added to corroborate the results from the regression. The probability level adopted was 95% ($p < 0.05$).

3. Results

Overall, in the CAT standard score, performance of the sample was within the average range (91.9, SD=31.8) in comparison to neurotypical children of the same mean age. Performance was also within the average range across the three subtests (92.9, 94.2, and 94.8, for set 1, set 2 and set 3, respectively), in which the normal range is between 85 - 114, according to the test manual. Note however, that since we extended the time allowed to complete the test, these scores are likely an overestimate of the attention capacity in our group. For the CPM, mean performance indicated a borderline level approaching low average (78.0, SD=21.4). For the SPT overall score (total number of correct answers), performance was within the low range

(54.7, SD=35.9). This was evident across the three subtests with all indicating performance in the lower level (5.9, 15.1, and 34.7 for math, writing and reading, respectively), see Table 1. Age did not correlate to overall school performance (r=.105; p=.569), and type of school (special or regular) did not influence school performance (t(30) =-.881, p =.385).

[Insert Table 1 here]

3.1. Exploratory correlations

In all correlations, the raw test scores (correct responses) were used. Overall, we found significant and positive correlations across the three tests. As expected, both the attention capacity (CAT) and nonverbal fluid intelligence measures (CPM), were positively correlated with academic performance (SPT/Table 2).

[Insert Table 2 here]

The specific correlations between each subtest of these measures followed the same pattern (e.g., set 1, 2 and 3 from the CAT all correlated positively with the math, reading and writing sub-test of the SPT). We also found significant and positive correlations between the attention measure (CAT) and nonverbal fluid intelligence (Raven CPM; Table 2), and the same link was evident for each of the attention subtests.

3.2. Multiple Linear Regression

Since the exploratory correlation suggested that both attention and nonverbal fluid intelligence are associated with academic performance in our cohort, we conducted a multiple linear regression analysis to test if attention and nonverbal fluid intelligence still significantly predicted academic performance even when controlling for the contribution of the other. The regression model was significant and explained 34.1% of the variance, although the residual Standard Error is relatively high (R^2 =.34, F[2,29]=7.52, p=.002). Interestingly, attention was significantly (and positively) predicting academic performance (β = .552, p=.010), but not nonverbal fluid intelligence (β=.048, p=.811). Thus, the model suggest that attention may contribute to academic performance in our sample over and above the contribution of nonverbal fluid intelligence (Table 3). In addition, we conducted the regression in two steps, adding the nonverbal intelligence measure as a predictor for school performance in the first step, then both intelligence and CAT as predictors for school performance in the second step of the linear regression. Results are the same as in our original analysis, whereas in the second model (step 2), delta R-squared and delta F (.184; 8.15, respectively) are significant (p=.008).

[Insert Table 3 here]

Collinearity statistics shows no multicollinearity issues between the variables affecting the outcomes of the regression, as the variance inflation factor between CAT and CPM was 1.712, which is below the suggested cut-off. Nevertheless, we also checked Partial Correlation between attention and academic performance controlling for intelligence. The correlation between attention and academic performance is significant even after controlling for nonverbal fluid intelligence scores (r=.468, p=.008). The same partial correlation between academic performance and nonverbal fluid intelligence, this time controlling for attention is not significant (r=.038, p=.840), which corroborates results from the regression.

4. Discussion

This study focused on testing associations between attentional performance and nonverbal fluid intelligence in relation to school performance of children with ASD. Our findings highlight positive correlations between both attention and intelligence and academic performance in the cohort of children and adolescents with ASD. Participants with better attention capacity and better nonverbal fluid intelligence demonstrated better academic attainment, in the overall test scores and for each subtest. These correlations fit with previous findings showing similar associations between attention performance and math in children with ASD (e.g., May et al. 2013) as well as correlation between nonverbal fluid intelligence and school performance (e.g., Brandt, Lechner, Tetzner & Rammstedt, 2019), although nonverbal fluid intelligence scores in our sample were slightly lower in comparison to previous studies with children with ASD (Bodner, Williams, Engelhardt & Minshew, 2014). While our findings from the simple correlations point to a link between attention and academic attainment it is still not clear whether this link is driven by nonverbal fluid intelligence (which was also correlated with attention capacity in our sample) or whether attention contributes to academic attainment in ASD irrespective of intelligence. To test this, we run a multiple linear regression analysis in which attention and intelligence were entered together as predictors of academic attainment. Results revealed attention as having a substantial association with academic performance over and above the contribution of nonverbal fluid intelligence. Furthermore, partial correlations showed that while attention was correlated to academic performance after controlling for the contribution of nonverbal fluid intelligence, the relationship between school performance and nonverbal fluid intelligence was not significant after controlling for attention. These findings are in accordance to research showing that intelligence did not correlate to executive functions in children with ASD (Merchán-Naranjo et al. 2016). Furthermore, academic performance was mediated by attention, but was not directly associated with nonverbal fluid intelligence in children with ADHD (Costa et. al. 2014). Thus, our findings point to the important contribution of attention capacity in ASD to academic performance as an independent source (irrespective of intelligence).

Our findings are therefore of particular interest when considering barriers as well as possible interventions to academic success in ASD. First, if attention capacity contributes to academic achievement in this cohort independently of other cognitive capacities then it may be beneficial to assess attention in ASD in more detail. This way, the specific difficulties can be better understood, if for instance a specific reduction in the capacity for spatial selective attention contributes to impaired reading and literacy (Kirk et al. 2016). Second, attention functions can be boosted through training and practice (Kerns, Macoun, MacSween, Pei & Hutchison, 2017), and so a possible route for improved academic attainment in ASD could utilise attention training as a means to improve academic attainment. Indeed, a recent pilot study (Spaniol et al. 2018) highlighted the potential of such an approach within the school system, where attention training using the Computerised Progressive Attention Training - CPAT (Shalev, Tsal & Mevorach, 2007) improved performance in academic tests of reading comprehension, math and text copying.

Since previous research established the link between nonverbal fluid intelligence and academic attainment, our findings, where attention plays a more substantial role, should be considered for alternative explanations. For instance, it is possible that the academic tasks we have used here are relatively simple (especially the writing or copying subtest) and are therefore more closely related to low-level attention measures than higher level cognition. There is evidence to suggest that the role of intelligence may vary across different school subjects and academic level (Vedel & Poropat, 2017). This implies that across distinct learning contexts the associations with intelligence can vary systematically (Brandt et al. 2019). However, since our findings hold across the different academic subtests this argument is not very likely. Another possibility is that since our cohort was relatively low in terms of both academic attainment and nonverbal fluid intelligence (although standard scores on CPM ranged from extremely low [55] to superior [125]), but average in terms of attention capacity, we have underestimated the link between intelligence and academic performance. While this is possible, it still points to the critical role attention capacity plays in academic performance when nonverbal fluid intelligence is at the borderline low/average range. It should also be noted that the attention capacity here is likely overestimated given the extra time we allowed for task completion. Finally, it could also be argued that the writing sub-tasks we have used has a close similarity with the attention task (which were timed tasks requiring participants to strike out letter-like symbols). However, this argument still does not hold for the reading and math sub-test which also showed significant correlation with the attention task.

The present study also has some limitations, such as the lack of analysis of comorbidities, which may influence our measures of attention, nonverbal fluid intelligence or school performance. Future studies should expand the assessment battery, with typical and clinical samples, considering gender and age differences to determine if the association is specific to the tasks or a broad attention impairment, and whether the association between attention and academic performance is modulated by age. We also had to adapt the time to perform the CAT which was changed to 2 minutes in this sample, and consequently may have benefited their performance. In addition, and most importantly, our sample size is relatively small for this type of study and therefore our results should be interpreted with caution. In future studies we not only suggest to include a larger, more variable sample from different locations, but also to include a control group with neurotypical participants to assess whether the association between attention and school performance is unique to children with ASD or also holds in neurotypical children or different disorders. Nevertheless, the associations between attention and school performance of children with ASD points to a need to monitor attentional aspects of these children, so that future interventions in health and educational systems could utilise this information. Considering the importance of attention skills in academic performance, intervention programs for children and adolescents with ASD should include attention training.

5. Conclusions

There is a diversity of factors that can influence school performance, that go beyond intelligence and/or attention, such as educational opportunity, socio-economic status, social aptitudes and personality traits (Wentzel, 2017). Although it is important to consider these multiple factors, our findings support the important role low-level attention skills play irrespective of other more high-level cognitive processes. Since such basic cognitive skills are amenable and can possibly be improved with practice it opens a potential avenue for intervention in ASD, which can aim to improve academic performance.

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Table 1

Classification, mean, minimum and maximum scores and standard deviation of the sample age, sex, ASD severity from the Autism Behavior Checklist - ABC; and performance in the subtests of the cancellation attention test – CAT; and subtests of the school performance test – SPT; and Raven CPM (N = 32).

	Average	**Min. - Max.**	**Standard Dev.**
Sex	6F, 26M	---	---
Age	11.4	8 - 14	1.72
ABC **Classification**	54.3 Moderate probability of autism	8 - 115	22.1
CAT 1: accuracy/error **Classification**	39.8/1.6	6-50/0-40 Extremely low- Superior	12.7/7.1
CAT 2: accuracy/errors **Classification**	3.5/5.15	1-7/0-25 Extremely low- Superior	1.8/5.9
CAT 3: accuracy/errors **Classification**	28.6/5	5-51/0-39 Extremely low- Superior	13.1/8.3
SPT: Total score **Classification**	54.8 Low	0 – 113 Low - Superior	36
SPT: Math (correct responses) **Classification**	6 Low	0 – 19 Low - Superior	4.7
SPT: writing (correct responses) **Classification**	15.2 Low	0 – 34 Low - Superior	10.5
SPT: reading (correct responses) **Classification**	34.7 Low	0 – 67 Low - Superior	25
CPM standard **Classification**	78.3 Borderline	<60 – 125 Extremely low - Superior	21.3

Table 2

Correlation between test scores, using the rate of correct answers for all measures (n=32). CPM - Raven's Coloured Progressive Matrices; CAT - Cancellation Attention Test; SPT - School Performance Test.

		SPT Total	**SPT Writing**	**SPT Reading**	**SPT Math**	**CPM**
CAT Total	*r*	0.583	0.557	0.513	0.629	0.724
	p	<0.001	0.001	0.003	<0.001	<0.001
CAT **Set 1**	*r*	0.521	0.544	0.442	0.518	0.643
	p	0.002	0.001	0.011	0.002	<0.001
CAT **Set 2**	*r*	0.590	0.637	0.559	0.601	0.684
	p	<0.001	<0.001	0.001	<0.001	<0.001
CAT **Set 3**	*r*	0.510	0.432	0.459	0.599	0.644
	p	0.003	0.013	0.008	<0.001	<0.001
CPM	*r*	0.528	0.614	0.445	0.687	-
	p	0.002	<0.001	0.011	<0.001	-

Table 3

Regression analysis, with CAT and CPM as predictors, and SPT as dependent variable, showing model summary and coefficients. CPM - Raven's Coloured Progressive Matrices; CAT - Cancellation Attention Test; SPT - School Performance Test.

	R, R^2	**Std. Error**	**t, p**	**B, beta**
Model Summary	.588, .345	30.12877	-	-
Predictors				
CAT	-	.287	2.854, .008	.819, .561
CPM	-	.332	.203, .840	.067, .040