Paidéia
jan-apr. 2014, Vol. 24, No. 57, 85-94. doi:10.1590/1982-43272457201411

Article

Executive Functions in Children and Adolescents With Autism Spectrum Disorder[1]

Fernanda Rasch Czermainski[2]
Rudimar dos Santos Riesgo
Universidade Federal do Rio Grande do Sul, Porto Alegre-RS, Brazil
Luciano Santos Pinto Guimarães
Hospital de Clínicas de Porto Alegre, Porto Alegre-RS, Brazil
Jerusa Fumagalli de Salles
Cleonice Alves Bosa
Universidade Federal do Rio Grande do Sul, Porto Alegre-RS, Brazil

Abstract: The literature has shown a strong relationship between executive dysfunction and Autism Spectrum Disorder (ASD), although there is no consensus on which subprocesses of executive functioning are impaired and/or preserved in this condition. This study aimed to investigate executive function and working memory in children and adolescents with ASD (n = 11) compared to children and adolescents with typical development (n = 19) matched by age, formal education, and nonverbal IQ. The tests used were: Raven's Colored Progressive Matrices, Stroop Test, Trail Making Test, Rey's Complex Figure Test, Digit span, Pseudowords span, Working memory, Verbal fluency (orthographic and semantic) and Go/no go. The results demonstrate impairment of executive function in the clinical group, especially in planning, flexibility, inhibition, and also visuospatial working memory.

Keywords: autism, neuropsychological assessment, cognition, neuropsychology

Funções Executivas em Crianças e Adolescentes com Transtorno do Espectro do Autismo

Resumo: A literatura tem demonstrado uma forte relação entre disfunções executivas e Transtorno do Espectro do Autismo (TEA), apesar de ainda não haver consenso sobre quais subprocessos do funcionamento executivo encontram-se prejudicados e/ou preservados nessa condição. Esse estudo teve por objetivo avaliar as funções executivas e a memória de trabalho em crianças/adolescentes com TEA (n = 11), comparadas a crianças/adolescentes com desenvolvimento típico (n = 19), equiparadas por idade, anos completos de estudo formal e QI não-verbal. Os testes usados foram: Matrizes Progressivas Coloridas de Raven, Teste Stroop, Teste de Trilhas, Figuras Complexas de Rey, Span de Dígitos, Span de Pseudopalavras, Memória de trabalho visuoespacial, Fluência verbal (ortográfica e semântica) e Go/no go. Os resultados demonstram prejuízos de funções executivas no grupo clínico, em especial na capacidade de planejamento, flexibilidade cognitiva, inibição, além do componente visuoespacial da memória de trabalho.

Palavras-chave: autismo, avaliação neuropsicológica, cognição, neuropsicologia

Funciones Ejecutivas en Niños y Adolescentes con Trastorno del Espectro Autista

Resumen: La literatura ha demostrado fuerte relación entre disfunciones ejecutivas y el Trastorno del Espectro Autista (TEA), aunque todavía no exista consenso acerca de los subprocesos del funcionamiento ejecutivo que se encuentran alterados y/o preservados en esta condición. El objetivo de este estudio fue evaluar las funciones ejecutivas y la memoria de trabajo en niños/adolescentes con TEA (n = 11), comparados a niños/adolescentes con un desarrollo típico (n = 19), equiparados por edad, años de escolaridad e inteligencia no verbal. Las pruebas utilizadas fueron: Test de Matrices Progresivas Coloreadas de Raven, Test de Stroop, Trail Making Test, Test de la Figura Compleja de Rey, Digit Span, Span de pseudopalabras, Memoria de trabajo visoespacial, Fluidez verbal (semántica y ortográfica) y Go/no Go. Los resultados demuestran alteraciones de las funciones ejecutivas en el grupo clínico, especialmente en la capacidad de planificación, flexibilidad, inhibición, así como en el componente visoespacial de la memoria de trabajo.

Palabras clave: autismo, evaluación neuropsicológica, cognición, neuropsicología

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition of unknown etiology, possibly with genetic and neurobiological factors associated, which compromises the overall development of the child (American Psychiatric Association [APA], 2012; Wing, Gould, & Gillberg, 2011). Individuals with ASD typically present qualitative impairments in the areas of social interaction, communication and behavior (APA, 2002), although there is wide variability in the manifestation of the symptoms that characterize the disorder. The neuropsychological evaluation has contributed to the comprehension of ASD by providing information about cognitive functioning in this population.

Neuropsychological studies have indicated the existence of a strong relationship between alterations in the executive functions (EF) and ASD, however, there is no

1 Support: Coordination for the Improvement of Higher Education Personnel (CAPES).

2 Correspondence address:
Fernanda Rasch Czermainski. Rua Gaston Englert, 785, apto 491. Vila Ipiranga. CEP 91360-210. Porto Alegre-RS, Brazil. E-mail: ferrasch@gmail.com

consensus regarding which executive subprocesses would be impaired and/or preserved in children and adolescents with this condition (Ambery, Russell, Perry, Morris, & Murphy, 2006; Hill & Bird, 2006; Landa & Goldberg, 2005; Lopez, Lincoln, Ozonoff, & Lai, 2005; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009; Sanders, Johnson, Gravan, Gill, & Gallagher, 2008). Furthermore, studies that examine in more detail which executives subcomponents are most affected in ASD are rarely found in the literature.

The executive functions consist of a broad construct that covers elaborate cognitive processes responsible for the control, integration, organization and maintenance of different cognitive skills, which, in turn, enable engagement in adaptive and self-organized behavior directed toward targets (Chan, Shum, Toulopoulou, & Chen, 2008; Hamdan & Pereira, 2009; Hill, 2004; Lezak, Howieson, & Loring, 2004). There are a variety of theoretical models that attempt to explain the overall executive functioning and that of its components, however, it is emphasized that there is still no gold standard model for this construct, with a battery of neuropsychological tests usually defined according to the executive components that need to be evaluated (Chan et al., 2008; Godefroy, 2003; Hamdan & Pereira, 2009; Testa, Bennett, & Ponsford, 2012). Some of the components usually evaluated are inhibitory control, planning, cognitive flexibility, and verbal fluency (Jurado & Rosselli, 2007). Furthermore, working memory, due to being a system closely related to the executive functioning, is usually also included in the evaluation of executive functions (Nee et al., 2012). The tests used in this study have been associated with different explanatory models of the executive functions: the model of a triple system of attentional and executive control (Stuss & Benson, 1986), the temporal integration model (Fuster, 2008), and the model of executive functions related to intelligence (Duncan, Burgess, & Emslie, 1995; Duncan, Emslie, Williams, Johnson, & Freer, 1996; Sternberg, 1984). The working memory tasks used were prepared according to the four components model of working memory (Baddeley, 2003; Repovs & Baddeley, 2006).

Accordingly, this study aimed to evaluate the executive functions and working memory in children/adolescents with ASD (n = 11), compared to children/adolescents with typical development (n = 19), matched by age, complete years of formal schooling, and non-verbal IQ. Regarding the hypothesis, it was expected that the children/adolescents with ASD would present lower performance in EF tasks when compared to the controls, demonstrating greater impairment in those involving planning, cognitive flexibility and inhibition, in addition to the visuospatial and phonological components of the working memory.

Method

Participants

Thirty children/adolescents, aged 9 to 15 years, participated in this study - 11 with ASD and 19 with typical development. The mean age of the clinical group was 11.73 years (SD = 1.90) and of the control group, 11.42 years (SD = 1.80). With regard to education, the mean for the clinical group was 4.18 years of completed schooling (SD = 1.16) and 4.32 years of completed schooling (SD = 1.29) for the control group. There were 9 boys in the clinical group and 17 boys in the control group. The clinical cases had diagnoses of ASD (5 with Autistic Disorder and 6 with Asperger's Disorder), according to the DSM-IV-TR (APA, 2002), and did not present associated mental retardation, according to Raven's Colored Progressive Matrices test - Special Scale (Angelini, Alves, Custódio, Duarte, & Duarte, 1999; Raven, Raven, & Court, 1988). Of the clinical group, only two participants attended an inclusive school, the others attended regular schools.

Instruments

Socioeconomic and development history questionnaire. Answer by parents or guardians of the participants in both groups, this questionnaire was formulated specifically for this study and consists of 60 questions that evaluate socioeconomic aspects, academic history and general health conditions. The version of the questionnaire for the parents of the participants with ASD included questions related to the diagnostic triad (impairments in communication; impairments in social interaction; and restricted interests and repetitive behavior).

Raven's Colored Progressive Matrices - Special Scale (Angelini et al., 1999; Raven et al., 1988). The instrument was used to evaluate the intellectual performance, serving as a measure for the nonverbal IQ criterion. The test consists of a notebook containing 36 figures, each of which has a part missing. The examinee must choose from six alternatives one of which correctly matches the part of the figure that is missing. The figures are divided into three series (A, Ab and B), with progressive levels of complexity. Individuals with Grade V (intellectually deficient) were excluded from the study.

Stroop test. This is a general measure instrument of cognitive flexibility, inhibition and attentional control, through the designation of words and colors (Golden, 1978). It evaluates the child's ability to alter the types of responses according to stimulus and to inhibit a habitual response with an uncommon one. The task consists of three stages (three pages), each one with a set of one hundred stimuli, distributed in five columns. On the first page the examinee is asked to read names of colors written in a black font (e.g. PINK, GREEN, BLUE), distributed randomly on the page. On the second page, sequences of stimuli are arranged - Letter 'X' (XXXX) - with the font colored in one of the three colors: pink, green and blue. The examinee is asked to name the colors of the Xs. These first two pages constitute the baselines, to investigate the processing speed (in reading and in naming). On the third page, condition of interference or color-word incongruence, again the words PINK, GREEN and BLUE are presented, however, this time printed in colors incongruent to the meaning represented (e.g., the word PINK can be printed in green or blue, but not in pink). The examinee must name the colors in which the words are written, inhibiting the reading of their meaning (meaning - font color incongruence). The total number of stimuli read or named on each page, during a period of 45 seconds (for each page) are considered. From these data, the interference effect (or Stroop effect) value is calculated, which indicates the level of cognitive effort made by the examinee to inhibit reading the words in favor of naming the colors. The interference is calculated from three major scores, relative to the first 45 seconds of duration for each of the three pages: number of words read correctly on page 1 (P); number of colors named correctly on page 2 (C); and number of colors named correctly on page 3 (PC). Thus, the interference value is provided by calculating: PC – (P. C) / (P + C) (Mourik, Oosterlaan, & Sergeant, 2005).

Trail Making Test (Capovilla, Assef, & Cozza, 2007; Espy & Cwik, 2004; Reitan, 1992). This test consists of two parts, A and B. The first part (A) refers to the evaluation of visual search speed, as a control for the interpretation of the performance in the second part (B). The latter involves measures of divided attention, speed of information processing and cognitive flexibility and alternation (Ashendorf et al., 2008). In the first part of the test (Part A) the examinee is required to connect, in ascending order, a sequence of numbers (1 to 25) arranged randomly on a sheet, as quickly as possible without lifting the pencil from the paper. In the second part (B), the examinee should follow the same instructions, however, alternately linking in ascending order numbers (1 to 13) and letters (A to L) randomly arranged (A-1, A-2, B-2, B-3, 3-C, etc.). The examinee has five minutes to complete each part of the test. After this period, the test should be stopped. Each part of the test is preceded by a short training, which checks whether the examinee understood the instructions. For the analysis, the time (in seconds) and number of errors in the implementation of Parts A and B are considered. The maximum test score is 24 points.

Rey's Complex Figures (Oliveira & Rigoni, 2010; Rey, 1999). This instrument evaluates the visual perception (involved in the organization of elements that form a whole), the planning and the development of task execution strategies, as well as the ability of visual memorization and constructive praxis. Composed of two complex, geometric and abstract figures, the test is divided into two application phases: reproduction by copying and reproduction by immediate memory (3 minutes after exposure to the stimulus). In this study Figure A was used and reproductions by copying and immediate memory (3 minutes). The reproductions are evaluated regarding the type of copy/design from memory and each part of the figure reproduced is scored (0; 0.5; 1; or 2) depending on the location and accuracy. The total scores of copying and memory are transformed into percentages, guided by the rules of the manual (Oliveira & Rigoni, 2010).

Executive function and working memory subtests of the Child Neuropsychological Brief Assessment Instrument - NEUPSILIN-INF (Salles et al., 2011, in press). This instrument covers eight neuropsychological functions: orientation, perception, attention, memory, language, visuo-constructive abilities, executive functions, and arithmetic skills. The psychometric studies of the instrument have already been finalized. The following executive function and working memory subtests were used in this study:

1. Digit Span (reverse order): four sequences of two to five digits are presented orally, which should then be repeated by the examinee in reverse order, with two trials for each sequence. The evaluator says a sequence of digits (from two to five digits), which should then be repeated backwards by the examinee. The total score is 28 points. The test also provides the score for the longer sequence of digits scored by the examinee (*span*).

2. Pseudoword span: a sequences of pseudowords (of 1 to 4 stimuli) are presented orally and should then be repeated by the child, in the same order presented. The number of pseudowords increases progressively, from 1 to 4 items. The total score is 20 points. The test also provides the score for the longer sequence of pseudowords scored by the examinee (*span*).

3. Visuospatial working memory: the examiner indicates a progressive sequences of stimuli (squares randomly arranged on a blank page) ranging from 2 to 5, and the child is asked to repeat, indicating the stimuli of the page in reverse order to that presented, immediately after the examiner's model. The total score is 28 points. The test also provides the score for the longer sequence of stimuli scored by the examinee (*span*).

4. Orthographic or phonemic verbal fluency: the child is asked to evoke words that begin with the letter M for one minute. Words repeated or derived from the same root are not considered. The score is the number of words correctly evoked.

5. Semantic verbal fluency: the child is asked to evoke names of animals also for one minute. Repeated animal names are not considered. The score is the number of words correctly evoked.

6. Auditory go/no go: Numbers from 0 to 9 are presented from an audio recording, at the rate of one number per second. The child should answer yes every time he/she hears a number, except when hearing the number 8, when he/she should remain silent. The score is calculated by the difference between the errors (answer yes to the number 8) and omissions, with the maximum number of correct responses being 60 points.

Procedure

Data collection. The participants of the clinical group were selected from the database of a public university hospital or by indication by specialists. The children and adolescents were evaluated individually in a single session, of one hour average duration, in an appropriate room considering lighting and silence, at the Institute of Psychology of UFRGS. The participants of the control group were selected and evaluated in (public and private) elementary education institutions.

At first, the control candidates were selected according to the criteria of equivalence to the clinical group (gender, age, education, and type of school), answering Raven's Colored Progressive Matrices - Special Scale, in its collective form (in small groups of up to eight participants). The control participants were defined from the scores of this test, and were individually evaluated using the other instruments, with the evaluation conducted at their school. There were no statistically significant differences between the groups in any of the equivalence variables - age, completed years of formal study, type of school (public or private), and IQ performance (nonverbal), according to Student's t-test.

The evaluation of the components of the EF and the working memory followed a fixed order of application for both groups, in function of the logistics of the times of each application and intervals of those subtests involving delayed memory. The verbal fluency tasks were administered in the interval between the reproductions by copying and memory of Rey's Complex Figures. The order of the instruments was as follows: Trail Making Test, Stroop Test, Rey's Complex Figures (Figure A, copy), Phonemic verbal fluency, Semantic verbal fluency, Rey's Complex Figures (Figure A, memory), Digit span (reverse order), Pseudoword span, Visuospatial working memory, and Auditory go/no go.

Data analysis. The comparison between groups was made through the Generalized Linear Models analysis (Nelder & Wedderburn, 1972; Paula, 2010), with the covariates age and IQ performance included in the model. The effect size of the comparison was calculated using Cohen's d. From the finding of atypical cases (outliers) in some tasks, a new comparison of the groups was performed (Generalized Linear Model), this time excluding these cases, and the differences between the groups remained statistically significant.

Ethical Considerations

This study was approved by the Research Ethics Committee linked to the Institute of Psychology of the Universidade Federal do Rio Grande do Sul (UFRGS), under protocol number 2011031. The participation of children/adolescents was voluntary, having been authorized by their parents or guardians, through the signing of the Terms of Free Prior Informed Consent (TFPIC).

Results

There were significant differences between the groups in various measures of EF and working memory, as shown in Table 1. In the Stroop test, the clinical group were slower compared to the control group in relation to the two control conditions: word reading (page 1) and color naming (page 2), with an interval of 45 seconds. The calculation of the interference (stroop effect) indicated that the clinical group suffered more interference in the color-word incongruence (needed greater cognitive effort) than the control group to perform the task on page 3 (font color and meaning of the word incongruence), the experimental condition of the test that required inhibitory control. In the Trail Making Test, the clinical group presented inferior performance in Part B, which requires cognitive flexibility from the examinee through the ability to switch sequences of stimuli (letters and numbers).

In the execution of Rey's Complex Figure (Figure A), the clinical group showed performance significantly inferior to that of the control group both in the reproduction by copying and in the reproduction by immediate memory. There were no significant differences between the groups with respect to the execution speed for the copying and memory tasks. Thus, the groups presented differences in accuracy, however, not in execution speed. Furthermore, there was no identifiable strategy pattern for the reproductions of the figure in the clinical group.

In the Digit span task (reverse order) there was a tendency for the clinical group to present performance slightly below the control group in the total score, however, the differences were not significant. In terms of ability to span (longer sequence of digits correctly repeated), again there were no significant differences between the means of the groups. In the clinical group, 30% of the participants scored the maximum sequence of correct responses (span = 5), 20% correctly repeated four items (span = 4) and 50% three items (span = 3). In the control group, 26% achieved the maximum span score for the instrument (span = 5), 47% correctly repeated four items (span = 4), 15% three items (span = 3) and 10% two items (span = 2). Variability in performance was observed in both groups.

In the Pseudoword span task (total score), the clinical group presented performance slightly below that of the controls, however, this difference was not statistically significant. The clinical group was statistically lower than the control in terms of the mean of the longer sequence of correctly repeated pseudowords (pseudoword span). Neither group scored the maximum sequence of correct responses (span = 5) in this subtest. In the clinical group, 18% correctly presented sequences of four items (span = 4), 63% of three items (span = 3), and 18% of two items (span = 2). In the control group, 42% correctly presented sequences of four items (span = 4) and 57% of three items (span = 3). The results of the two tasks suggest greater difficulties in the phonological component of working memory, for the clinical group compared to the control group.

In the Visuospacial Working Memory task, the clinical group presented performance significantly below that of the control group, in terms of total score and visuospatial span scores (more visuospatial sequences repeated correctly), suggesting the presence of impairments in the visuospatial component and central executive of the working memory. In the clinical group, 20% of the participants achieved the maximum sequence of correct responses in the task (span = 5), 40% correctly presented sequences of four items (span = 4), 20% of three items (span = 3) and 20% of two items (span = 2). In the control group, 78% of the participants

Table 1
Performance (Mean and Standard Deviation) of the Clinical and Control Groups in the Executive Functions and Working Memory Tests, Adjusted for the Covariates Age and IQ

Instruments	Control Group $n = 19$	Clinical Group $n = 11$	*p* value	b	EP	Cohen's *d*	95%CI	
							Lower	Upper
Stroop (Number of Stimuli)	M (SD)	M (SD)						
Reading Words[2]	78.1 (13.3)	59.6 (13.4)[a]	.001**	-18.47	5.10	1.38	0.44	2.11
Naming Colors[2]	54.5 (12.7)	40.0 (12.7)[a]	.003**	-14.50	4.85	1.14	0.24	1.87
Color-Word[2]	32.4 (7.9)	26.8 (7.9)[a]	.067	-5.54	3.02	0.70	-0.14	1.43
Interference score[2]	0.7 (3.8)	4.9 (3.8)[a]	.004**	4.19	1.46	1.09	0.20	1.82
Trail Making Test								
Part A (Time)[2]	52.4 (16.4)	62.1 (16.5)	.123	9.69	6.28	0.59	-0.21	1.30
Part B (Time)[2]	117.9 (46.3)	170.7 (46.5)	.003**	52.84	17.72	1.14	0.26	1.84
Rey's Complex Figures								
Figure A (Copy)[2]	27.5 (5.9)	16.4 (5.9)	.001**	-11.11	2.26	1.88	0.87	2.60
Copy Time	3.62 (0.4)	4.34 (0.6)	.319	0.18	0.18	1.48	2.19	1.84
Figure A (Memory)[2]	14.1(5.8)	2.7 (5.8)	.001**	-11.35	2.21	1.96	0.94	2.68
Memory Time	2.26 (0.3)	2.13 (0.3)	.795	-0.06	0.23	0.40	1.12	0.35
NEUPSILIN-INF								
Sequence of Indirect Order Digits[2]	19.2 (4.9)	18.4 (5.1)[a]	.69	-0.75	1.91	0.15	-0.63	0.91
Sequence of Digits (Span)	3.9 (0.2)	3.7 (0.2)[a]	.68	-0.03	0.09	0.61	1.32	0.52
Pseudoword Span[2]	14.0 (3.2)	11.9 (3.2)	.08	-2.09	1.21	0.66	-0.15	1.37
Pseudoword Sequence (Span)	3.4 (0.1)	3.0 (0.1)	.05*	-0.12	0.06	2.86	3.64	2.61
Visuospatial working memory[1]	23.8 (8.6)	16.1 (6.1)[a]	.005**	-0.39	0.14	0.99	0.11	1.71
Visuospatial Sequence (Span)	4.7 (0.6)	3.6 (1.1)[a]	.001**	-0.26	0.07	1.48	0.52	2.21
Working Memory Total[1]	56.9 (12.7)	46.9 (11.0)[a]	.02*	-0.19	0.09	0.83	-0.03	1.55
Verbal Orthographic Fluency[2]	9.0 (3.3)	6.0 (3.3)	.016*	-3.01	1.25	0.92	0.07	1.62
Semantic Verbal Fluency[2]	16.6 (4.3)	12.9 (4.3)	.023*	-3.69	1.63	0.87	0.03	1.57

Note. [a]n = 10; [o]n = 8; [1]Gamma distribution function with logarithmic link function; [2]normal distribution function with identity link function.
*p < .05. **p < .01.

achieved the maximum span for the task (span = 5), 15% correctly presented sequences of four items (span = 4) and 5% of three items (span = 3).

In the orthographic and semantic verbal fluency task, statistically significant differences were also observed between the groups, indicating impairments among the clinical group in the evocation of words with orthographical-phonological and semantic criteria. On average, the clinical group evoked three words less than the control group in the tasks with phonological/orthographic and semantic criteria. In the Auditory go/no go task, the clinical group also presented significantly poorer performance than the control group, making more mistakes and omissions, indicating attentional and inhibitory control impairments, concerning auditory information.

Discussion

The results of this study indicated that the ASD group presented lower performance than the control group in all the tasks used, with the majority of these differences being statistically significant (Table 1). The main EF impairments of the clinical group involved multiple aspects of these functions, with performance indicative of impairments in the visuospatial component of the working memory also observed. These results are discussed below.

Planning is a complex and dynamic operation in which a sequence of planned actions needs to be constantly monitored, reviewed and updated so that the individual can achieve the proposed objective (Jurado & Rosselli, 2007). It is the ability to establish the best way to achieve a defined objective. The performance obtained by the ASD group in Rey's Complex Figure test (reproduction of Figure A by copying and memory) indicated the presence of impairments in planning ability, visual perception and immediate memory (visual component). Previous studies have found planning impairments in ASD subjects (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Landa & Goldberg, 2005; Luppi, Tamanaha, & Perissinoto, 2005; Robinson et al., 2009). Aspects associated with inhibitory control were evidenced through the repeated reproduction of parts of the figure (perseverations), as well as difficulties in finalizing this reproduction, although there was no time limit for the completion of the test.

The working memory, a functional system for temporary storage and manipulation of information, consists of four subsystems: the phonological loop, visuospatial sketchpad, episodic buffer, and central executive (Baddeley, 2012; Repovs & Baddeley, 2006). Visuospatial working memory tasks involve storing, processing and manipulating information and additionally require the central executive resources, due to the increased demand for attention and control processes (Rosenthal, Riccio, Gsanger, & Jarratt, 2006).

The visuospatial working memory task used also indicated performance below that expected in the ASD group, reinforcing the results found in Rey's Complex Figure test. Both instruments involve the visuospatial component of the working memory, through retrieval and reproduction of complex visual stimuli in a short period. These results corroborate other studies that also found impairments involving the visuospatial working memory in ASD subjects (Geurts et al., 2004; Landa & Goldberg, 2005).

Mental or cognitive flexibility is the ability to alternate different thoughts or action, in accordance with changes in the environment or the context (Lezak et al., 2004). The Trail Making Test involves motor planning, visual searches and alternation between stimuli. The alternation paradigm (task-switching) involves the ability to flexibly change from one activity to another, requiring both working memory as well as inhibition. The extra time required to complete Part B of the Trail Making Test (compared to Part A) reflects the cost of switching from numbers to letters and vice versa (switching-cost). It is expected that performing Part B of the test will be more time consuming, however, excessively slow performance in Part B relative to Part A is assumed to be indicative of impaired executive functioning (Ashendorf et al., 2008; Davidson, Amso, Anderson, & Diamond, 2006). The ASD group spent on average more than twice as long to perform Part B of the test. Impairments of cognitive flexibility in ASD subjects were also described by Geurts et al. (2004) and Van Eylen et al. (2011).

In the inhibitory control, the executive component related to the ability to inhibit stimuli, irrelevant impulses or distractors (Barkley, 2001), there is also evidence of significant impairments when individuals with ASD are compared to those with typical development (Chan et al., 2009; Christ, Holt, White, & Green, 2007; Christ, Kester, Bodner, & Miles, 2011; Robinson et al., 2009). In this study, impairments in inhibitory control were observed in the ASD group, in the Stroop Test (score of color-word interference), in the Auditory go/no go task, in the verbal fluency tasks (inhibition of all words of the lexicon that comes to mind and that do not fulfilling the criterion requested by the examiner), and in Part B of the Trail Making Test.

Verbal fluency involves the ability to emit a series of behaviors within a structure of specific rules. It is related to the ability to spontaneously generate new ideas and behaviors (Strauss, Sherman, & Spreen, 2006; Tombaugh, Kozak, & Rees, 1999). The ASD group had significantly poorer performance than the control group in the verbal fluency tasks with phonological-orthographic and semantic criteria, evoking fewer words. Previous studies have indicated the presence of verbal fluency deficits in ASD subjects (Geurts et al., 2004; Kilinçaslan, Mukaddes, Küçükyazici, & Gürvit, 2010), a process that requires organization skills, self-regulation and working memory from the individual (Rueda, Posner, & Rothbart, 2005).

The ASD group presented impairments in two other tasks that also assess language skills: Pseudoword span (phonological processing of language ability) and verbal fluency (lexical evocation or lexical access). It is possible that the deficits in language known to be found in children/adolescents with ASD are also interfering with these results (Landa & Goldberg, 2005).

Interestingly, in all the tasks in which some kind of time constraint existed or that the instructions involved responding as quickly as possible, the ASD group performed below the control group (Stroop test, Trail making test, Verbal fluency and Auditory go/no go). Time is indicated by Ardila (2005) as an underlying variable in the cognitive assessment, which can influence the results. The observed performance could be related to a slower processing of information, and also to increased anxiety resulting from the timing. In this case, anxiety can exacerbate the obsessive aspects of the behavior (e.g. perfectionism, attention to detail at the expense of the whole), often reported as a comorbidity of the ASD (Fonseca, Campos, & Arras López, 2007). It is noteworthy, however, that the lower performance of the clinical group was observed in other measures (such as in Rey's Figure test) and not only in those where there was some kind of time constraint, which suggests that the impairments observed in the clinical group went beyond the issues relative to the execution time of the tasks.

Given these findings, children/adolescents with ASD appear to present impairments involving various EF processes, such as planning, cognitive flexibility, inhibitory control, verbal fluency, and also impairments in the visuospatial component of working memory. As the EF tasks are not isolated, but involve other processes, the results suggest changes in the speed of information processing and attentional processes in the ASD group. These impairments appear to be implicated in the deficits observed in the three domains that make up the diagnostic triad of ASD: impairments in social interaction; impairments in communication; and restricted interests and repetitive behavior.

In the social interaction domain, impairments of the EF (inflexibility, planning, and inhibition) may be reflected, for example, in difficulties of initiative and spontaneity in social interactions. These compromises affect the engagement in actions, such as playing together, which are performed during the social interaction between the child and a partner. These activities require planning and goal-directed behavior, therefore, the more initiatives there are (such as seeking a partner to play), the greater the demand for these skills. These compromises, in turn, hinder the development of more complex social skills, as they provide the basis for them (Tomasello, Carpenter, Call, Behne, & Moll, 2005).

Thus, this set of social cognitive impairments presented at early ages by autistic children is possibly related to the atypical development of EF (such as planning, inhibition, and cognitive flexibility), affecting the initiative and self-regulatory skills, essential in the more complex forms of social interaction (Martins-Junior, Sanvicente-Vieira, Grassi-Oliveira, & Brietzke, 2011).

Regarding the verbal and non-verbal (pragmatic) communication impairments evidenced by the presence of idiosyncrasies, jargon and verbal rituals, these appear to be partially related to executive dysfunctions, as impairments in inhibition, flexibility and working memory (phonological loop) may be implicated in the difficulty in spontaneously adapting the speech and gesture to the sociocultural context (Eigsti, Marchena, Schuh, & Kelley, 2011; Repovs & Baddeley, 2006). Similarly, the occurrence of motor mannerisms and repetitive and stereotyped behaviors seem to be partially related to difficulties of inhibition and cognitive inflexibility (Hill, 2004; Sucksmith, Roth, & Hoekstra, 2011; Wing et al., 2011). Behaviorally, this translates into rigidity and excessive repetition of actions, in a compulsive and impulsive way, which is beyond the voluntary control of the person with ASD.

It is important to highlight that the executive functioning problems are not specific to ASD, and have also been reported in children and adolescents with various disorders, such as Attention Deficit Hyperactivity Disorder (ADHD), Obsessive Compulsive Disorder (OCD), learning disabilities (dyslexia, dyscalculia), specific language disturbances, and Down syndrome (Dias, Menezes, & Seabra, 2010; Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010; Rowe, Avender, & Turk, 2006). In the literature, there is a lack of comparative studies of executive functioning, with different clinical groups in childhood, which aim to identify distinct patterns of executive dysfunction in the different disorders (Pureza, Jacobsen, Oliveira, & Fonseca, 2011). Thus, it is not possible to affirm that the EF and working memory difficulties found in the present study are typical of children/adolescents with ASD, nor whether they fully explain the difficulties that form the core of the compromises characteristic to this group. However, it seems difficult to ignore the role that these functions play in explaining at least some of the symptoms observed in ASD.

Conclusions

The results of this study indicate the presence of significant impairments in the EF and working memory subprocesses of the ASD subjects, especially regarding planning, cognitive flexibility, inhibition, verbal fluency, and visuospatial working memory. However, these findings should be interpreted with caution, considering the small sample size of the study, especially of the clinical group. Furthermore, no instruments were used to confirm the diagnosis, however, the selection of clinical participants was careful, through centers specialized in the care of people with ASD. Aspects related to the diagnosis and the absence of psychiatric and neurological diseases were also checked through the socioeconomic and development history questionnaire, completed by the parents or guardians of the participants.

Another limitation of this study refers to the measure of intelligence employed, in which only the nonverbal area was assessed. However, this brief evaluation of the intelligence procedure is in line with other studies in the area (Christ et al., 2011; Geurts et al., 2004). This choice is justified by the fact that a full IQ evaluation battery substantially increases the time taken to make the evaluation, with possible implications for the performance of the clinical group, such as fatigue and stress. Therefore the emphasis is on a more extensive evaluation of the focus of the study, the executive functions.

Some contributions of this study for the comprehension of the EF in children and adolescents with ASD were the use of an extensive neuropsychological evaluation battery (including internationally used tests), the use of well-defined inclusion criteria, and the control of the IQ and age variables. Also, the division of the EF into different domains allowed the examination of its subprocesses. This profile has implications for a more detailed comprehension of the cognitive and behavioral functioning of ASD, which can be useful both in the therapeutic planning and in the guidance for the families, such as in the design of interventions, and education and training for healthcare professionals.

Future studies are suggested that use diagnostic confirmation scales/protocols and include the evaluation of possible comorbidities in the individuals with ASD, as well as the complementary use of EF functional assessment instruments (scales or questionnaires) and case studies, in order to obtain multiple information sources regarding the neuropsychological function of this population. The importance of studies involving a larger number of participants and including a second clinical group with other psychiatric and/or developmental conditions should be emphasized, allowing advances in the comprehension of the ASD executive dysfunctions.

References

Ambery, F. Z., Russell, A. J., Perry, K., Morris, R., & Murphy, D. G. M. (2006). Neuropsychological functioning in adults with Asperger Syndrome. *Autism, 10*(6), 551-564. doi:10.1177/1362361306068507

American Psychiatric Association. (2012). *DSM-5 proposed criteria for autism spectrum disorder designed to provide more accurate diagnosis and treatment*. Retrieved from http://www.dsm5.org/Documents/12-03%20Autism%20Spectrum%20Disorders%20-%20DSM5.pdf

American Psychiatric Association. (2002). *DSM-IV: Manual diagnóstico e estatístico de transtornos mentais* (C. Dorneles, Trad., 4th ed.). Porto Alegre, RS: Artes Médicas.

Angelini, A. L., Alves, I. C. B., Custódio, E. M., Duarte, W. F., & Duarte, J. L. M. (1999). *Matrizes Progressivas Coloridas de Raven: Escala especial. Manual*. São Paulo, SP: CETEPP.

Ardila, A. (2005). Cultural values underlying psychometric cognitive testing. *Neuropsychology Review, 15*(4), 185-195. doi:10.1007/s11065-005-9180-y

Ashendorf, L., Jefferson, A. L., O'Connor, M. K., Chaisson, C., Green, R. C., & Stern, R. A. (2008). Trail making test errors in normal aging, mild cognitive impairment, and dementia. *Archives of Clinical Neuropsychology, 23*(2), 129-137. doi:10.1016/j.acn.2007.11.005

Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4*(10), 829-839. doi:10.1038/nrn1201

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology, 63*, 1-29. doi:10.1146/annurev-psych-120710-100422

Barkley, R. A. (2001). The executive functions and self-regulation: An evolutionary neuropsychological perspective. *Neuropsychology Review, 11*(1), 1-29. doi:10.1023/A:1009085417776

Capovilla, A. G. S., Assef, E. C. S., & Cozza, H. F. P. (2007). Avaliação neuropsicológica das funções executivas e relação com desatenção e hiperatividade. *Avaliação Psicológica, 6*(1), 56-60.

Chan, A. S., Cheung, M.-C., Han, Y. M. Y., Sze, S. L., Leung, W. W., Man, H. S., & To, C. Y. (2009). Executive function deficits and neural discordance in children with autism spectrum disorders. *Clinical Neurophysiology, 120*(6), 1107-1115. doi:10.1016/j.clinph.2009.04.002

Chan, R. C. K., Shum, D., Toulopoulou, T., & Chen, E. Y. H. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology, 23*(2), 201-216. doi:10.1016/j.acn.2007.08.010

Christ, S. E., Holt, D. D., White, D. A., & Green, L. (2007). Inhibitory control in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 37*(6), 1155-1165. doi:10.1007/s10803-006-0259-y

Christ, S. E., Kester, L. E., Bodner, K. E., & Miles, J. H. (2011). Evidence of selective inhibitory impairment in individuals with autism spectrum disorder. *Neuropsychology, 25*(6), 690-701. doi:10.1037/a0024256

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence of manipulations of memory, inhibition and task-switching. *Neuropsychologia, 44*(11), 2037-2078. doi:10.1016/j.neuropsychologia.2006.02.006

Dias, N. M., Menezes, A., & Seabra, A. G. (2010). Alterações das funções executivas em crianças e adolescentes. *Estudos Interdisciplinares em Psicologia, 1*(1), 80-95.

Duncan, J., Burgess, P., & Emslie, H. (1995). Fluid intelligence after frontal lobe lesions. *Neuropsychologia, 33*(3), 261-268. doi:10.1016/0028-3932(94)00124-8

Duncan, J., Emslei, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: The organization of goal-directed behavior. *Cognitive Psychology, 30*(3), 257-303. doi:10.1006/cogp.1996.0008

Eigsti, I.-M., Marchena, A. B., Schuh, J. M., & Kelley, E. (2011). Language acquisition in autism spectrum disorders: A developmental review. *Research in Autism Spectrum Disorders, 5*(2)*,* 681-691. doi:10.1016/j.rasd.2010.09.001

Espy, K. A., & Cwik, M. F. (2004). The development of a Trail Making Test in young children: THE TRAILS-P. *The Clinical Neuropsychologist, 18*(3), 411-422. doi:10.1080/138540409052416

Fonseca, J. M. A., Campos, A. L. M., & Arras López, J. R. R. (2007). Síndrome de Asperger e TOC: Comorbidade ou unidade? *Jornal Brasileiro de Psiquiatria, 56*(4), 287-289. doi:10.1590/S0047-20852007000400008

Fuster, J. M. (2008). *The prefrontal cortex* (4th ed.). Amsterdam, Netherlands: Elsevier.

Geurts, H. M., Verté, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2004). How specific are executive functioning deficits in attention deficit hyperactivity disorder and autism? *Journal of Child Psychology and Psychiatry, 45*(4), 836-854. doi:10.1111/j.1469-7610.2004.00276.x

Godefroy, O. (2003). Frontal syndrome and disorders of executive functions. *Journal of Neurology,* 250, 1-6.

Golden, C. J. (1978). *Stroop colour and word test*. Wood Dale, IL: Stoelting.

Hamdan, A. C. & Pereira, A. P. A. (2009). Avaliação neuropsicológica das funções executivas: considerações metodológicas. *Psicologia Reflexão e Crítica, 22*(3), 386-393.

Hill, E. L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review, 24*(2), 189-233. doi:10.1016/j.dr.2004.01.001

Hill, E. L., & Bird, C. M. (2006). Executive processes in Asperger syndrome: Patterns of performance in a multiple case series. *Neuropsychologia, 44*(14), 2822-2835. doi:10.1016/j.neuropsychologia.2006.06.007

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review, 17*(3), 213-233. doi:10.1007/s11065-007-9040-z

Kilinçaslan, A., Mukaddes, N. M., Küçükyazici, G. S., & Gürvit, H. (2010). Assessment of executive/attentional performance in Asperger's disorder. *Turkish Journal of Psychiatry, 21*(4), 289-299.

Landa, R. J., & Goldberg, M. C. (2005). Language, social and executive functions in high functioning autism: A continuum of performance. *Journal of Autism and Developmental Disorders, 35*(5), 557-573. doi:10.1007/s10803-005-0001-1

Lanfranchi, S., Jerman, O., Dal Pont, E., Alberti, A., & Vianello, R. (2010). Executive function in adolescents with Down syndrome. *Journal of Intellectual Disability Research, 54*(4), 308-319. doi:10.1111/j.1365-2788.2010.01262.x

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment* (4th ed.). New York, NY: Oxford University Press.

Lopez, B. R., Lincoln, A. J., Ozonoff, S., & Lai, Z. (2005). Examining the relationship between executive functions and restricted, repetitive symptoms of autistic disorder. *Journal of Autism and Developmental Disorders, 35(*4), 445-460.

Luppi, G. S., Tamanaha, A. C., & Perissinoto, J. (2005). A análise das funções executivas no autismo infantil: Um estudo preliminar. *Temas em Desenvolvimento, 14*(79), 32-36.

Martins-Junior, F. E., Sanvicente-Vieira, B., Grassi-Oliveira, R., & Brietzke, E. (2011). Social cognition and theory of mind: Controversies and promises for understanding major psychiatric disorders. *Psychology and Neuroscience, 4*(3), 347-351. doi:10.3922/j.psns.2011.3.008

Mourik, R. V., Oosterlaan, J., & Sergeant, J. A. (2005). The Stroop revisited: a meta-analysis of interference control in AD/HD. *Journal of Child Psychology and Psychiatry, 46*(2), 150-165.

Nee, D. E., Brown, J. W., Askren, M. K., Berman, M. G., Demiralp, E., Krawitz, A., & Jonides, J. (2012). A meta-analysis of executive components of working memory. *Cerebral Cortex, 23*(2), 264-282. doi:10.1093/cercor/bhs007

Nelder, J. A., & Wedderburn, R. W. M. (1972). Generalized linear models. *Journal of the Royal Statistical Society. Series A, 135*(3), 370-384.

Oliveira, M., & Rigoni, M. (2010). *Figuras Complexas de Rey – Teste de cópia e de reprodução de memória de figuras geométricas complexas. Adaptação brasileira*. São Paulo, SP: Casa do Psicólogo.

Paula, G. A. (2010). *Modelos de regressão com apoio computacional*. São Paulo, SP: IME-USP. Recuperado de http://people.ufpr.br/~lucambio/CE225/2S2011/texto_2010.pdf

Pureza, J. R., Jacobsen, G. M., Oliveira, R. G., & Fonseca, R. P. (2011). Relationships between executive functions tasks in late childhood. *Psychology & Neuroscience, 4*(3), 369-376. doi:10.3922/j.psns.2011.3.010

Raven, J. C., Raven, J., & Court, J. H. (1988). *Matrizes Progressivas Coloridas de Raven. Manual* (CETEPP). São Paulo, SP: Casa do Psicólogo.

Reitan, R. M. (1992). *Trail Making Test: Manual for administration and scoring*. Tucson, AZ: Reitan Neuropsychological Laboratory.

Repovs, G., & Baddeley, A. (2006). The multi-component model of working memory: Explorations in experimental cognitive psychology. *Neuroscience, 139*(1), 5-21. doi:10.1016/j.neuroscience.2005.12.061

Rey, A. (1999). *Teste de cópia e de reprodução de memória de figuras geométricas complexas: Manual* (Margareth da Silva Oliveira, Adaptação Brasileira). São Paulo, SP: Casa do Psicólogo.

Robinson, S., Goddard, L., Dritschel, B., Wisley, M., & Howlin, P. (2009). Executive functions in children with autism spectrum disorders. *Brain and Cognition, 71*(3), 362-368. doi:10.1016/j.bandc.2009.06.007

Rosenthal, E. N., Riccio, C. A., Gsanger, K. M., & Jarratt, K. P. (2006). Digit span components as predictors of attention problems and executive functioning in children. *Archives of Clinical Neuropsychology, 21*(2), 131-139. doi:10.1016/j.acn.2005.08.004

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28*(2), 573-594. doi:10.1207/s15326942dn2802_2

Rowe, J., Lavender, A., & Turk, V. (2006). Cognitive executive function in Down's syndrome. *British Journal of Clinical Psychology, 45*(1), 5-17. doi:10.1348/014466505X29594

Salles, J. F., Fonseca, R. P., Cruz-Rodrigues, C., Mello, C. B., Barbosa, T., & Miranda, M. C. (2011). Desenvolvimento do Instrumento de Avaliação Neuropsicológica Breve Infantil NEUPSILIN-INF. *Psico-USF, 16*(3), 297-305. doi:10.1590/S1413-82712011000300006

Salles, J. F., Fonseca, R., Miranda, M., Berlin, C., Rodrigues, C., & Barbosa, T. (no prelo). *Instrumento de avaliação neuropsicológica breve infantil*. Porto Alegre, RS: UFRGS.

Sanders, J.; Johnons, K. A.; Garavan, H., Gill, M. & Gallagher, L. (2008). A review of neuropsychological and neuroimaging research in autistic spectrum disorders: attention, inhibition and cognitive flexibility. *Research in Autism Spectrum Disorders, 2*, 1-16.

Sternberg, R. J. (1984). Toward a triarchic theory of human intelligence. *Behavioral an Brain Sciences, 7*(2)*,* 269-315. doi:10.1017/S0140525X00044629

Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms and commentary* (3rd ed.). New York, NY: Oxford University Press.

Stuss, D. T., & Benson, D. F. (1986). *The frontal lobes*. New York, NY: Raven.

Sucksmith, E., Roth, I., & Hoekstra, R. A. (2011). Autistic traits below the clinical threshold: re-examining the broader autism phenotype in the 21st century. *Neuropsychological Review, 21*, 360-389.

Testa, R., Bennett, P., & Ponsford, J. (2012). Factor analysis of nineteen executive function tests in healthy adult population. *Archives of Clinical Neuropsychology, 27*, 1-12.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences, 28*(5), 675-735. doi:10.1017/S0140525X05000129

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology, 14*(2), 167-177. doi:10.1016/S0887-6177(97)00095-4

Van Eylen, L., Boets, B., Steyaert, J., Evers, K., Wagemans, J., & Noens, I. (2011). Cognitive flexibility in autism spectrum disorder: Explaining the inconsistencies? *Research in Autism Spectrum Disorders, 5*(4), 1390-1401. doi:10.1016/j.rasd.2011.01.025

Wing, L., Gould, J., & Gillberg, C. (2011). Autism spectrum disorders in the DSM-V: Better or worse than the DSM-IV? *Research in Developmental Disabilities, 32*(2), 768-773. doi:10.1016/j.ridd.2010.11.003

Fernanda is Czermainski Rasch is a Ph.D. candidate of the Graduate Program in Psychology of the Universidade Federal do Rio Grande do Sul.

Rudimar dos Santos Riesgo is a Professor of the Faculdade de Medicina of the Universidade Federal do Rio Grande do Sul and Head of Neuropediatrics of the Hospital de Clínicas de Porto Alegre.

Luciano Santos Pinto Guimarães is a Statistician of the Hospital de Clínicas de Porto Alegre.

Jerusha Fumagalli de Salles is an Associate Professor of the Institute of Psychology of the Universidade Federal do Rio Grande do Sul.

Cleonice Alves Bosa is an Associate Professor of the Institute of Psychology of the Universidade Federal do Rio Grande do Sul.

Received: Oct. 9th, 2012
1st Revision: Oct. 7th, 2013
Approved: Nov. 6th, 2013

How to cite this article:

Czermainski, F. R., Riesgo, R. S., Guimarães, L. S. P., Salles, J. F., & Bosa, C. A. (2014). Executive functions in children and adolescents with autism spectrum disorder. *Paidéia (Ribeirão Preto), 24*(57), 85-94. doi:10.1590/1982-43272457201411