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Hayling Test – adult version: applicability in the assessment of executive functions in children

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Abstract

Childhood neuropsychology is a growing scientific area in Brazil. Regarding cognitive function in infancy, executive function (EF) has been the main focus of several studies because of its importance for and complexity in human cognition and behavior. Executive functions can be considered a set of cognitive processes related to control and integration devoted to the execution of goal-directed behaviors. Research has shown that these abilities begin in infancy and progressively develop until adulthood. Although some studies on EF development in children have already been conducted, our knowledge on this topic is still incipient. Because of the relevant role of age in cognition and EF development, the present study investigated whether differences exist between children aged 6 to 12 years concerning their performance on the Hayling test–adult version, an instrument that assesses the EF components of initiation and inhibition. Pilot data are presented that verify the applicability of this test to children. Significant differences were found between comparable age groups only in three of the seven main Hayling test scores, suggesting that the adult version may not be appropriate for children, and an adaptation of the test for child assessment is necessary. The study may lead to an initial reflection on the development of these components and thus contribute to improvements in the field of child neuropsychology. **Keywords:** executive function, child neuropsychological assessment, Hayling test, cognitive development.

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Introduction

Despite the scientific and clinical advances in neuropsychology in Brazil, the number of neuropsychological instruments developed to assess the infant population is still low. To lessen this gap, one option is the use and adaptation of tests widely administered to the adult population, accompanied by standardization. However, infancy presents peculiar features in terms of cognitive and emotional development, and neuropsychological tests for adults demand precaution and the formulation of specific criteria for interpreting the results in infants (Ardila, 1996; Rosselli & Ardila, 2003). Executive functions (EF) have increasingly become the focus of many studies because of their importance for cognition, human behavior, and the complexity of their interaction with other cognitive functions (Marcovitch & Zelazo, 2009; Matute, Chamorro, Inozemtseva, Rosselli, & Ardila, 2008).

In addition, EF can be considered a set of higher-order cognitive processes that organize and adjust human behavior and cognition to fit into a context and the subject's aims (Bielak, Mansueti, Strauss, & Dixon, 2006). These executive components must rely on the contribution of several components and subprocesses, such as attention, planning, initiation and inhibition of processes and information, cognitive flexibility, multiple task monitoring, working memory, and verbal fluency control. All of these processes are targeted to solve problems and are directly related to thought and behavior management (Chan, Shum, Toulopoulou, & Chen, 2008).

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Studies have shown that EF emerge in infancy and continue to develop in adolescence (Sun, Mohay, & O'Callaghan, 2009). The ages of 5-8 years and 11-12 years appear to be milestones in the development of executive components. Moreover, age, schooling, socioeconomic level, and other factors play important roles in the development of these cognitive functions (Ardila, 1996; Rosselli & Ardila, 2003).

The literature refers to the relationship between EF and the frontal lobe, concluding that the assessment of cognitive components in infancy and adolescence is related to the maturation of this cortical region. However, new findings have related EF to other brain regions, such as more posterior areas (Tamnes et al., 2010). Some authors suggest that EF reach maturity later compared with other cognitive functions. According to Romine and Reynolds (2005), for example, these processes develop intensively between 6 and 8 years of age and continue to develop until the end of adolescence and the beginning of adulthood.

Concerning EF component assessment in clinical practice, different standardized instruments have been used to complement clinical observations (for review, see Chan et al., 2008; Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006). Among the most widely adopted are the Wisconsin Card Sorting Test, Stroop Test, Trail Making Test, and measures of verbal fluency. Several tests that evaluate EF should be seen as tools with which to assess specific EF components and not the construct as a whole. Because of the multidimensionality of EF, some instruments predominantly measure the planning component, such as the Tower of London Test, whereas another instrument may measure inhibition (Stroop Test) and so on (Andres & Van der Linden, 2000).

The Hayling test (Burgess & Shallice, 1997) is an instrument that asks the subject to complete sentences by saying a final word to complete the sentence. The aim of Part A of the test is evaluate the preprogrammed organizing process because in this phase the constructs to be examined are concentrated attention, verbal initiation, processing speed, and the strategy of a well-succeeded search for automated words related to the preactivation of semantic networks. Part B assesses more complex EF components, such as verbal inhibition and planning, because the subject must inhibit the content of the sentence (semantics) and develop alternative strategies in his lexical search to complete the syntactic stimulus (Chan et al., 2008).

While using the same structure to present the stimuli, the two test conditions (Parts A and B) allow the comparative evaluation of the functioning of two EF components (initiation and inhibition) related to a single symbolic form (verbal). This specificity generates a valuable clinical tool for the detection of modifications that are potentially useful for the diagnosis and treatment of patients with executive dysfunction. Supervisory Attentional System theory, developed by Norman and Shallice (1986), is the most accepted theory for explaining the cognitive processes that underlie the solution of Parts A and B of the Hayling test (Chan et al., 2008).

From an information processing perspective, Norman and Shallice (1986) made a distinction between the automatic and controlled processing required during daily cognitive processing and problem solving situations. Supervisory Attentional System theory is a theoretical model of the cognitive processes that underlie behavior presumably directed to the aims that are necessary in non-ordinary situations. It represents a set of cognitive processes that involve initiation, strategy generation toward a target, and performance evaluation required to execute complex cognitive, non-ordinary and unlearned tasks. It is involved whenever action and thinking schemas, which represent routines capable of effectively accomplishing an aim, cannot be selected by means of automatic triggering provided by learned cues. This system plays a vital role in problem solving situations in which well-learned behaviors or sequential reasoning are insufficient or inadequate and when new behaviors need to be planned and monitored to reach satisfactory performance in the task.

Considering this cognitive neuropsychological relationship, the Hayling test generates a measure of an individual's capacity to develop strategies targeted to the fulfillment of task demands. According to Burgess and Shallice (1996), the inability to generate adequate strategies may lead to low performance in the test and contribute to errors.

The Hayling test has been used internationally for several age groups but mainly with adults (Frias, Dixon, & Strauss, 2009), both in the assessment of EF inhibitory components in neurological syndromes, such as traumatic brain injury (Draper & Ponsford, 2008), and in psychiatric syndromes, such as the examination of EF in schizophrenia (Chan et al., 2010). Because of the fact of being theoretically and experimentally well grounded, this instrument has been used as a tool in neuroimaging studies that seek a deeper understanding of the neural correlates of verbal inhibitory processes (Allen et al., 2008; Nathaniel-James, Fletcher, & Frith, 1997).

However, a review of the literature yields few studies on EF processing with a developmental neuropsychological perspective using this accurate instrument for measuring verbal initiation and inhibition. Studies with children and adolescents have been conducted (Herba, Tranah, Rubia, & Yule, 2006; Robinson, Goddarb, Dritschel, Wisley, & Howlin, 2009; Shallice et al., 2002) but only with clinical populations. No studies have focused on healthy children with the goal of delimiting a developmental performance standard. In Brazil, the Hayling test was adapted for the neuropsychological assessment of adults (Fonseca, Oliveira, Gindri, Zimmermann, & Reppold, 2010) and has been used to assess EF components in adults with right cerebrovascular lesion (Gindri, Zibetti & Fonseca, 2008). However, it has not yet been used for infant neuropsychological assessment in Brazil. In this context, the present article presents data on the performance of school-aged children as a pilot study for the verification of the applicability of the adult version of the Hayling test (Fonseca et al., 2010) in child neuropsychological assessment to verify the presence or absence of differences in performance between children aged 6 and 12 years.

Methods

Participants

Twenty-four children participated in this study (n = 12, 6-year-olds, all in the first year of Fundamental Course; n = 12, 12-year-olds, three of whom were in the fifth grade and nine of whom were in the sixth grade). The subjects were regularly enrolled at public schools in the city of Porto Alegre, RS, Brazil. The groups were paired by gender, with four boys in the 6-year-old group and three in the 12-year old group. No differences were found in this variable between groups ($\chi^2[1] = 0.756$, $p = .385$). Regarding socioeconomic status according to the 2008 Associação Brasileira de Empresas e Pesquisa economic classification criteria in Brazil, the majority of the children's families belonged to the B2 socioeconomic class.

The inclusion criteria were the following: (*i*) in the first year of school (for the 6-year-old children), (*ii*) the presence of self-report capacity, (*iii*) the absence of repetition of school years, (*iv*) the absence of reports of generalized deficits in learning and oral language, (*v*) the absence of non-corrected sensory difficulties (visual or auditory), neurological impairments, and self-reported psychiatric syndromes, and (*vi*) Brazilian Portuguese as the native language. To verify the sample's characterization and inclusion criteria, a questionnaire was administered to the children's parents or guardians that included demographic, cultural, and health condition questions, with the latter considering aspects related to pregnancy, birth, and biopsychosocial development. The Raven Progressive Matrices Test (Angelini, Alves, Custódio, Duarte, & Duarte, 1999) was administered to exclude children with evidence of intellectual difficulties, and the Conners Questionnaire (Barbosa & Gouveia, 1993) was answered by the subjects' teachers to exclude subjects with suggestive signs of attention deficit and hyperactivity disorder.

Procedures and instruments

The study procedures were approved by the Ethics Committee in Research of Pontifícia Universidade Católica do Rio Grande do Sul (protocol 09/04864). All children were selected according to the inclusion criteria and evaluated using the adult version of the Hayling test (Fonseca et al., 2010). The assessment occurred in the school where the children were enrolled, in a quiet place with no influence of external factors. The test consists of two parts, with a mean duration of 15 min. In Part A, the subject must say a word that coherently completes a sentence read by the examiner. In Part B, the subject must produce a word that does not present any logical or meaningful relation with the sentence. In Part A, the stimulus syntactic and semantic context (sentence) leads to the activation of a word that is coherent with the semantic context of the clause. In Part B, the subject must inhibit the dominant answer, one that would be logical and coherent, and search for a word that is not related to the syntactic and semantic context required by the clause.

The assessment was audio-recorded, and the time measure was collected, following the instructions for administration and registration of the test. The only adaptation done for the administration of the Hayling test in children was in the examples so that they were more accessible and more easily comprehended.

Regarding the scores, the Hayling test can generate scores concerning response time, correct answers, and errors in both parts. The main scores that were the most sensitive were the following: Part A (the addition of errors related to the number of sentences in which the answers were not inhibited; maximum = 15), Part B (the error score was calculated as a function of the values referring to qualitative classifications according to the answers given by the children, with the worst error scored 3; maximum = 45). A more general error score in Part B was also calculated, with a maximum of 15 (i.e., the number of possible incorrect answers). The total times were also scored from the addition of the time between the stimulus and the beginning of the answer in each part. The total time of execution for each part is used to compare the speed of processing and performance inhibition between Parts A and B. Two calculations were made: a subtraction (Time B - Time A) and a quotient (Time B / Time A).

Data analysis

In addition to the descriptive analysis of the quantitative scores of accuracy and time in Parts A and B of the Hayling test, the Independent Samples t-test was used for the comparison of pilot data in 6- and 12-year-old children. The significance level was set to $p \leq .05$. All data were parametric according to the one-sample Kolmogorov-Smirnov test. Data were analyzed using SPSS version 18.0 software.

Results

Table 1 shows the performance on the Hayling test for the two age groups. Significant differences were found between groups in this comparative pilot study only in the scores representing time and errors in Part

Table 1. Descriptive and inferential statistical comparative data of the age groups in the Hayling test. Each group was composed by 12 subjects. SD = standard deviation.

Measurement	GROUP				*p*-value
	6-year-olds		12-year-olds		
	Mean	SD	Mean	SD	
Time (s)—Part A	40.70	14.70	20.58	7.43	$p < .001$
Errors—Part A	2.67	1.43	0.17	0.38	$p < .001$
Time (s)—Part B	62.49	28.43	43.53	28.08	$p = .115$
Errors/15—Part B	6.42	3.60	3.75	1.91	$p = .034$
Errors/45—Part B	15.83	10.67	9.75	5.52	$p = .094$
Time B – Time A	21.79	26.33	22.95	24.00	$p = .911$
Time B / Time A	1.63	0.69	1.96	1.08	$p = .379$

A of the instrument and in the number of sentences erroneously completed in Part B (p = .034; maximum score = 15 points). A difference was found in the least representative score in Part B, which was the number of incorrect sentences, but not in the score that considered error severity (score of 45) or in the time score. The 12-year-old group appeared to have greater heterogeneity in their results compared with the 6-year-old group.

Discussion

Despite the fact that the sample consisted of 24 participants, this pilot study found significant differences between the two groups (6- and 12-year-old children) in the time and error scores in Part A, demonstrating that age appears to influence performance in the test, particularly in Part A. Although no significant age difference was found in the execution time of Part B, the results showed a significant difference in the execution time of Part A, demonstrating that the 12-year-old children exhibited higher speed accompanied by higher accuracy in correctly completing the test compared with the 6-year-old participants.

These results may reflect characteristics of immaturity in the development of EF in 6-year-old children, such as sustained attention, processing speed, and initiation, which are known to be predictors of inhibition development (Reck & Hund, 2010). A possible explanation for the difference between groups in Part A of the test is that the difficulty in initiation in the 6-year-old children may be related to lexical and semantic development, causing them to make more mistakes and need more time in the search for a word to complete the sentences. In Part B, the child does not necessarily need to utilize semantic networks, and completing the sentences with words that do not require contextualized lexical access is easier for the child.

Part B of the Hayling test-adult version may not be an efficient instrument for evaluating EF in children aged 6 and 12 years because the stimuli in this part could have been difficult to solve by both groups when considering the complex language stimuli that must be inhibited, making their final responses easier to achieve by chance. Despite the significant differences among groups in Part A of the instrument, more prominent differences could be expected in Part B, which were not found in this study. Thus, this finding appears to reflect the need to develop an adapted version of the tool for infants, with less complex sentences and within a semantic and syntactic format that should be more related to the vocabulary and syntactic structures to which children are exposed and use in their daily life.

The use of strategies that favor retrieval of non-related words (e.g., using as a response to a stimuli objects found in the assessment environment) was not investigated in this study. However, the clinical observation of these occurrences may justify the results presented by the groups in their performance in Part B of the Hayling test.

The younger children showed a tendency toward lower performance when the test required higher inhibitory demand, with an increase in the number of completely wrong sentences. Thus, the lower performance in younger children in Part B may reflect difficulties in inhibiting automatic responses or a strategy to complete each sentence according to the instructions given.

This comparative pilot study was based on a relatively reduced sample of participants and was an important phase in the pre-adaptation of the instrument of EF examination for children aged 6 to 12 years. Additionally, some children demonstrated difficulties comprehending some stimuli of the test, demonstrating that instruments designed for adults must be adapted for children because of the complex stimuli. With the Hayling test, some sentences may not have activated some semantic-syntactic networks in the children, which may have aided accuracy and inhibitory speed.

The results of this study suggest a lack of success in finding age-related differences in the groups' performance in a task that analyzes the executive component of inhibition, suggesting that the nature of EF development remains stable during the second infancy period. Moreover, the results suggest that the adult version of the Hayling test appears to not have discriminated the most important clinical scores (i.e., deficits in the inhibitory process), indicating the necessity to adapt the test to children. Such a version will be developed based on the results found in the present study and the existing child versions of other instruments, such as the Junior Hayling test (Shallice et al., 2002).

Studies on autistic disorders already use a version of the Hayling test adapted to children for EF assessment (Robinson et al, 2009). These studies report a significant correlation between age and performance in Part A of the instrument in children with a diagnosis of Asperger Syndrome or autism. As suggested by Anderson (1998), developing valid and well-standardized assessment measures specifically for children is important and should be based on a deep comprehension of brain and cognitive development in childhood. The need to adapt tests for infant neuropsychological assessment, even in children younger than 6 years old, was suggested by Argolo et al. (2009).

The Hayling test is an efficient instrument for diagnosing executive dysfunction involving components of initiation and inhibition of verbal content. However, this instrument must be adapted to the infant population to verify performance with regard to age and years of schooling and increase our understanding of typical and atypical EF development in childhood. The study of EF in the second infancy period, in addition to contributing to our knowledge about the processes involved in these functions, will allow researchers and clinicians to attain a better comprehension of the correlations and development of these components, thus contributing to advances in the field of infant neuropsychology.

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