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# Brazilian norms and effects of age and education on the Hayling and Trail Making Tests

## Normas brasileiras e efeitos de idade e escolaridade no Teste Hayling e no Teste de Trilhas

Nicolle Zimmermann,<sup>1</sup> Caroline de Oliveira Cardoso,<sup>2</sup> Christian Haag Kristensen,<sup>3</sup> Rochele Paz Fonseca<sup>3</sup>

### Abstract

**Objectives:** To describe normative data for the Hayling Test and the Trail Making Test (TMT) in a sample of Brazilian adults, and to investigate the effects of age and education on test performance.

**Method:** A total of 313 (TMT) and 364 (Hayling) individuals with age ranges of 19-39, 40-59, and 60-75 years, and with at least 5 years of formal education, participated in this study. The tests were administered as part of a large battery of a normative project. Individuals were evaluated individually in silent, ventilated rooms at a university clinic. Instrument protocols were scored by trained research assistants and double-checked to ensure data reliability.

**Results:** There were major effects of age on the TMT (Time B, Errors B, B-A) and on the Hayling Test (Errors B/15, B/45), and major effects of education on the TMT (Time B, Errors B, B-A) and on the Hayling Test (Time A, Errors B/15, B/45). Interaction effects were found in Time B and B-A for the Hayling Test and in Time A for the TMT.

**Conclusions:** Age and education were critical for performance on both verbal and non-verbal executive functions.

**Keywords:** Executive functions, age, education, Trail Making Test, Hayling Test.

### Resumo

**Objetivos:** Descrever dados normativos do Teste Hayling e do Teste de Trilhas em uma amostra de adultos brasileiros e investigar os efeitos de idade e escolaridade no desempenho das tarefas.

**Método:** Participaram deste estudo um total de 313 (TMT) e 364 (Hayling) indivíduos com idades nos intervalos de 19-39, 40-59 e 60-75 anos e com pelo menos 5 anos de escolaridade formal. Os testes foram administrados como parte de uma bateria maior de um projeto de normatização. Os indivíduos foram avaliados individualmente em salas silenciosas e ventiladas em uma clínica universitária. As pontuações dos protocolos foram realizadas por assistentes de pesquisa treinados e foram checadas duplamente para garantir a fidedignidade dos dados.

**Resultados:** Foram encontrados efeitos principais de idade no TMT (Tempo B, Erros B e Tempo B-A) e no Teste Hayling (Erros B/15 e B/45), e efeitos principais de educação no TMT (Tempo B, Erros B e Tempo B-A) e no Teste Hayling (Tempo A, Erros B/15 e B/45). Foram encontrados efeitos de interação entre variáveis nos Tempos B e B-A do Teste Hayling e no Tempo A do TMT.

**Conclusões:** Idade e escolaridade foram fatores críticos para o desempenho em ambos os testes verbal e não-verbal de avaliação das funções executivas.

**Descritores:** Funções executivas, idade, escolaridade, Teste de Trilhas, Teste Hayling.

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## Introduction

Executive functions (EF) are critical for complex, goal-directed, adaptive behaviors, and they are related to important clinical and social behaviors throughout life.<sup>1</sup> Current updated cognitive EF models consider as major components the working memory (central executive), cognitive flexibility, and inhibitory control.<sup>2</sup> They are divided into subcomponents and also consider higher-order EF, such as planning, decision making, and fluid intelligence. EF are triggered when people need to accomplish tasks moving from their “automatic pilot” to a different way of thinking and acting.<sup>2</sup>

Neurological and psychiatric disorders are associated with EF dysfunctions, which lead to changes in the perspective of EF as frontal lobe-only functions, in spite of the evident special role of the frontal lobe.<sup>3</sup> Some examples of EF problems are difficulties in recognizing changes and applying feedback, giving repetitive responses, planning and organizing tasks or events, reasoning, controlling impulses, and initiating behavior.<sup>4</sup> The impacts of EF impairments on the individual’s daily life, quality of life, and psychosocial adjustment have been matter of investigation.<sup>5</sup> There is a consensus that the assessment of EF in clinical neuropsychology is essential for accurate diagnosis and intervention planning, as well as for follow-up of outcomes in different disorders.<sup>6</sup>

Several paradigms have been developed to assess different components of EF. Bipartite tasks are highlighted in the literature for allowing the transition from an automatic or less complex activity to a more controlled or more difficult and complex way of thinking.<sup>7</sup> The Hayling Sentence Completion Test,<sup>8</sup> or Hayling Test, is a verbal EF paradigm that requires patients to complete sentences with words that match them (Part A) and do not match them at all (Part B). In Part A, the Hayling Test evaluates verbal initiation, planning, processing speed, and syntactic-semantic linguistic process. In Part B, it evaluates components of inhibition, cognitive flexibility, and processing speed. Those components are closely associated to the lexical-semantic system in the Hayling Test paradigm.<sup>9</sup> The utility of the Hayling Test for clinical neuropsychology is evidenced in studies with neurological and psychiatric adult samples.<sup>10</sup> Similarly, the Trail Making Test (TMT) assesses, in Part A, concentrated and focused visual attention and visual processing speed, and in Part B, alternated visual attention and cognitive flexibility. Also, qualitative analyses may provide evidence of inhibitory control functioning (for example, when a patient persists in connecting wrong sequences).<sup>11</sup> The applicability of the TMT has been demonstrated in

neurological adult samples, including people with mild cognitive impairment and dementia.<sup>12</sup>

The current study aims to present norms for the Hayling Test and the TMT for the Brazilian population. As far as we know, there are no adult normative studies employing the Hayling Test in a Brazilian sample, even though norms have been published for children.<sup>13,14</sup> The adapted task for Brazilian Portuguese was published by Fonseca et al.<sup>15</sup> With respect to the TMT, there are some studies published with adult samples from the Brazilian states of São Paulo<sup>16,17</sup> and Paraná.<sup>18</sup>

## Methods

### Participants

In the current study, community volunteers with ages ranging from 19 to 75 (mean=40.41; standard deviation=17.00) were recruited by convenience at universities, companies, and centers for activities (for example, painting or sports groups), or by word-of-mouth in the city of Porto Alegre, Brazil. For inclusion in the study, participants had to be native Brazilian speakers and have completed at least 5 years of formal education. A self-reported history of psychiatric or neurological disorder, uncorrected visual or hearing problems, abuse of cigarettes, illegal drugs, alcohol, or psychoactive medications were considered exclusion criteria. In addition, the Mini Mental State Examination<sup>19</sup> was applied to individuals who were  $\geq 40$  years old, in order to exclude abnormal cognitive performance. Furthermore, all participants had to score  $< 10$  on the Geriatric Depression Scale (GDS-15),<sup>20</sup> a 15-item scale that assesses depressive symptoms. A questionnaire from the Brazilian Association of Research Companies (Associação Brasileira de Empresas de Pesquisa, ABEP) was used to obtain the participants’ socioeconomic classification.

After a complete assessment of inclusion and exclusion criteria, 418 individuals performed the TMT, and 388 the Hayling Test. After a qualitative analysis of data, 46 individuals were excluded from the TMT sample, and 24 from the Hayling Test sample (due to administration errors, absence of sociodemographic or clinical data, lack of task comprehension or inability to minimally perform the task – which was the case of poorly educated individuals who did not have the alphabet as an automatic language skill). As a result, the TMT sample comprised 372 individuals, and the Hayling Test sample, 364. Table 1 presents sociodemographic and clinical data from both samples. Participants signed an informed consent form that was approved by the ethics committee of our institution (protocol no. 09/04908).

## Instruments

The TMT and the Hayling Test were administered as part of a large battery of a normative project, comprised of the following tests: Digit Span (administration time: ~8 minutes), Stroop Color and Word Test (administration time: ~7 minutes), and Modified Wisconsin Card Sorting Test (administration time: ~15 minutes).<sup>21</sup> Individuals were evaluated individually in silent, ventilated rooms at a university clinic. The administration order of the test battery was counterbalanced among participants, and oral and visual paradigms were administered alternately. Instrument protocols were scored by trained research assistants and double-checked to ensure data reliability. Test instructions and scoring norms are currently being prepared for publication by the authors. Briefly, the authors suggest that the test be applied in individuals with enough educational experience to appropriately understand and perform the tasks. For example, individuals who are not aware of alphabetical order will not present valid responses on TMT Part B.

The TMT<sup>22</sup> assesses visual search strategy and speed, praxis processing speed, visual attention, and cognitive flexibility. In Part A, individuals were required to connect numbers randomly distributed in an A4 paper sheet, as fast as they could. After that, in Part B, individuals had to connect alternating numbers and letters (for example: 1-A, 2-B, 3-C), also as fast as possible. In both parts, the maximum time allowed was 5 minutes. Time, accuracy (maximum of 24) and errors were considered for scoring. Adaptation procedures and instructions for this Brazilian version are currently being prepared for publication by the authors. Total administration time was around 10 minutes.

The Hayling Sentence Completion Test<sup>15,23</sup> is a verbal instrument developed to assess initiation and inhibition of verbal stimuli, based on the Supervisory Attentional System model. The task requires the subject to complete sentences in Parts A and B. In Part A, individuals had to complete general sentences with words that would fit properly; in Part B, they had to complete other sentences with random unrelated words. Participants were required to evoke the words as fast as they could. Each part comprised 15 items. Error scores and total time to complete each item were calculated separately for each task part. Particularly, in Part B, a qualitative-quantitative error score was proposed: each answer type received different scores. The higher the score, the lower the qualitative performance. Fonseca et al.<sup>15</sup> provide complete data on adaptation, rapport and scoring procedures. Total administration time was around 10 minutes.

## Data analysis

After verifying data normality and sample homogeneity (Kolmogorov-Smirnov and Levene tests), instrument scores were analyzed using univariate analysis of variance for age, years of study (education), and sex variables. Significant results were followed by Bonferroni post-hoc procedure. Means and standard deviations were provided by descriptive statistical methods. All analyses were performed using the Statistical Package for the Social Sciences (SPSS), with significance set at  $p \leq 0.05$ .

## Results

Descriptive statistics (means and standard deviations) obtained in the TMT and the Hayling Test are shown in Tables 2 and 3, respectively. Age and education effects analyses are presented in Table 4.

Sex did not have any effect on performance in both tasks. In the TMT, results were as follows: Time A,  $F=1.514$ ,  $p=0.219$ ; Errors A,  $F=1.354$ ,  $p=0.245$ ; Time B,  $F=0.974$ ,  $p=0.331$ ; Errors B,  $F=2.225$ ,  $p=0.134$ ; Time B-A,  $F=2.490$ ,  $p=0.115$ . A similar pattern regarding sex was found in the Hayling Test: Time A,  $F=0.000$ ,  $p=0.991$ ; Errors A,  $F=0.287$ ,  $p=0.592$ ; Time B,  $F=1.824$ ,  $p=0.178$ ; Errors B/15,  $F=0.011$ ,  $p=0.917$ ; Errors B/45,  $F=0.095$ ,  $p=0.758$ ; Time B-A,  $F=2.038$ ,  $p=0.154$ .

According to Table 4, the effects of age and education were similar for Time B, Errors B, and Time B-A in the TMT. Conversely, Hayling Test analyses indicated that the education effect was slightly more frequent than age effects. Interaction effects were found in the TMT for Time A (Figure 1), and in the Hayling Test for Time B (Figure 2) and Time B-A (Figure 3).

## Discussion

In this article, we aimed to investigate age and education effects on TMT and Hayling Test performance in a healthy Brazilian sample, searching for reference normative data for Brazilian Portuguese. The main characteristics of the sample were age range from 19 to 75 years and 5 or more years of formal education. There were major effects of age on the TMT (Time B, Errors B, Time B-A, and Time B/A) and on the Hayling Test (Errors B/15 and B/45), and also major effects of education on the TMT (Time B, Errors B, Time B-A, and Time B/A) and on the Hayling Test (Time A, Errors B/15 and B/45). Interaction effects were found on Time B and Time B-A for the Hayling Test and on Time A for the TMT.

**Table 1 -** Sociodemographic and clinical characteristics of the samples

	19-39 years of age		40-59 years of age		60-75 years of age	
	5-8 years of education (n=35)	9-11 years of education (n=76)	≥12 years of education (n=104)	5-8 years of education (n=9)	9-11 years of education (n=33)	≥12 years of education (n=44)
<b>Trail Making Test</b>						
Age (years)	29.54 (6.58)	26.50 (6.86)	25.98 (5.21)	49.44 (4.97)	46.97 (4.81)	49.84 (5.70)
Education (years)	6.91 (1.14)	10.79 (0.49)	15.62 (2.56)	6.11 (1.36)	10.91 (0.39)	16.65 (2.73)
Sex						
Male	17	33	50	5	9	14
Female	18	43	54	4	24	30
Reading and writing habits	10.53 (4.92)	15.50 (5.24)	18.20 (5.34)	11.56 (4.55)	15.42 (6.13)	17.63 (4.61)
MMSE score	27.05 (1.91)	28.90 (1.45)	29.10 (1.30)	27.67 (2.23)	28.81 (1.42)	28.85 (1.55)
GDS-30 score	12.31 (3.83)	10.50 (4.90)	5.88 (3.66)	9.50 (6.60)	8.73 (5.42)	8.71 (3.98)
GDS-15 score	5.92 (1.84)	4.92 (2.50)	2.63 (1.92)	4.60 (2.88)	4.18 (2.76)	4.33 (1.93)
<b>Hayling Test sample</b>						
5-8 years of education (n=37)	9-11 years of education (n=73)	≥12 years of education (n=90)	5-8 years of education (n=18)	9-11 years of education (n=30)	≥12 years of education (n=41)	5-8 years of education (n=19)
Age (years)	29.08 (7.15)	26.64 (6.74)	26.34 (5.29)	47.89 (5.89)	47.07 (4.73)	50.41 (5.56)
Education (years)	7.00 (1.10)	10.84 (0.40)	15.78 (2.46)	6.56 (1.19)	10.90 (0.40)	16.57 (2.39)
Sex						
Male	16	30	41	7	8	13
Female	21	43	49	11	22	28
Reading and writing habits	11.08 (4.54)	15.97 (5.18)	18.02 (5.54)	11.18 (3.55)	15.13 (6.05)	17.54 (4.51)
MMSE	27.30 (2.05)	28.98 (1.43)	29.14 (1.25)	27.00 (1.78)	28.70 (1.68)	28.76 (1.60)
GDS 30 score	11.29 (4.32)	10.00 (4.81)	5.63 (3.54)	6.00 (3.74)	9.20 (5.47)	8.78 (3.49)
GDS 15 score	5.43 (2.01)	4.64 (2.42)	2.47 (1.86)	3.00 (1.93)	4.40 (2.71)	4.36 (1.74)

Data presented as mean (standard deviation).

MMSE = Mini Mental State Examination; GDS = Geriatric Depression Scale.

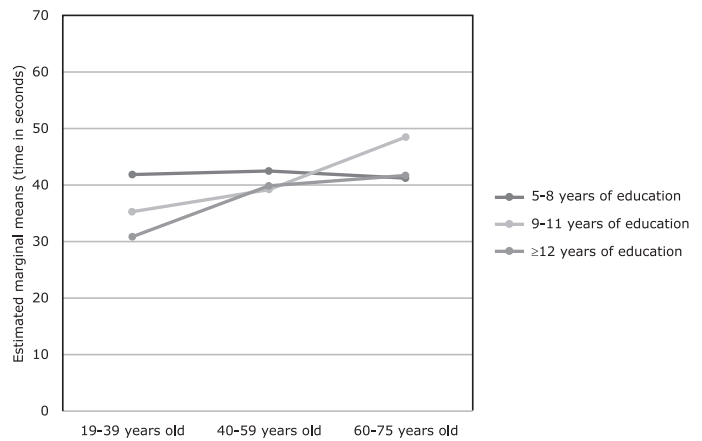
**Table 2 -** Descriptive data of each group for the Trail Making Test

Groups by age and/or education	Time A	Correct answers A	Errors A	Time B	Correct answers B	Errors B	Time B-A	Time B/A
Age groups								
19-39 years (n=215)	34.27 (12.16)	24.00 (0.00)	0.06 (0.23)	79.59 (34.50)	24.00 (0.00)	0.43 (0.75)	45.32 (30.53)	2.42 (1.00)
40-59 years (n=86)	39.91 (13.50)	24.00 (0.00)	0.07 (0.26)	100.91 (37.01)	24.00 (0.00)	0.62 (0.91)	61.01 (33.36)	2.65 (0.96)
60-75 years (n=71)	43.62 (12.96)	24.00 (0.00)	0.10 (0.30)	108.56 (39.61)	24.00 (0.00)	0.72 (0.88)	64.94 (35.26)	2.57 (0.94)
Education groups								
5-8 years of education (n=56)	41.85 (12.49)	24.00 (0.00)	0.05 (0.23)	119.92 (36.19)	24.00 (0.00)	1.04 (1.06)	78.08 (36.56)	3.07 (1.21)
9-11 years of education (n=129)	38.40 (12.45)	24.00 (0.00)	0.07 (0.26)	91.49 (35.67)	24.00 (0.00)	0.55 (0.81)	53.09 (31.43)	2.47 (0.92)
≥12 years of education (n=187)	35.30 (13.49)	24.00 (0.00)	0.07 (0.26)	80.11 (35.57)	24.00 (0.00)	0.36 (0.68)	44.81 (29.49)	2.36 (0.88)

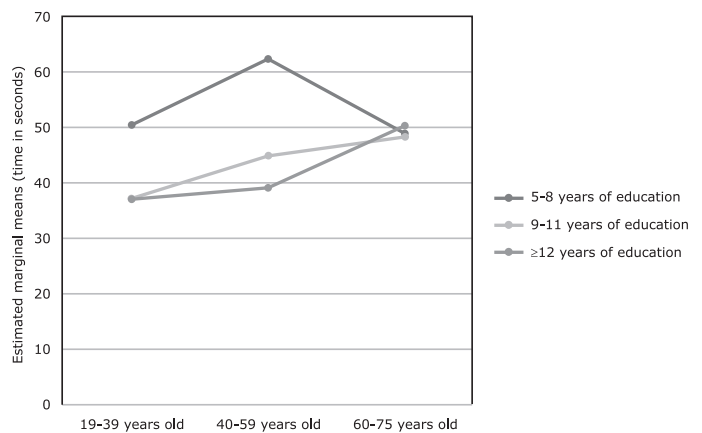
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Groups by age and/or education	Correct answers A		Correct answers B		Errors B		Time B-A		Time B/A	
	Time A	Errors A	Time B	Errors B	Time B	Errors B	Time B-A	Time B/A	Time B-A	Time B/A
Age and education groups										
19-39 years of age										
5-8 years of education (n=35)	41.93 (12.85)	0.06 (0.24)	112.67 (35.03)	0.91 (1.01)	70.74 (35.52)	2.90 (1.21)				
9-11 years of education (n=76)	35.33 (11.61)	0.05 (0.23)	80.06 (32.09)	0.42 (0.74)	44.73 (27.99)	2.35 (0.87)				
≥12 years of education (n=104)	30.91 (11.06)	0.06 (0.23)	68.12 (28.51)	0.28 (0.58)	37.20 (25.75)	2.31 (0.97)				
40-59 years of age										
5-8 years of education (n=9)	42.21 (14.54)	0.00 (0.00)	137.08 (38.24)	0.89 (1.27)	94.87 (38.72)	3.46 (1.21)				
9-11 years of education (n=33)	39.29 (10.46)	0.06 (0.24)	102.18 (32.68)	0.88 (0.96)	62.89 (29.82)	2.69 (0.90)				
≥12 years of education (n=44)	39.90 (15.44)	0.09 (0.29)	92.57 (35.98)	0.36 (0.72)	52.67 (30.76)	2.46 (0.87)				
60-75 years of age										
5-8 years of education (n=12)	41.32 (10.71)	0.08 (0.29)	128.21 (34.78)	1.50 (1.00)	86.89 (34.70)	3.26 (1.19)				
9-11 years of education (n=20)	48.56 (13.42)	0.15 (0.37)	117.27 (35.90)	0.50 (0.69)	68.70 (36.91)	2.58 (1.11)				
≥12 years of education (n=39)	41.80 (12.97)	0.08 (0.28)	98.05 (40.25)	0.59 (0.82)	56.25 (31.98)	2.36 (0.63)				

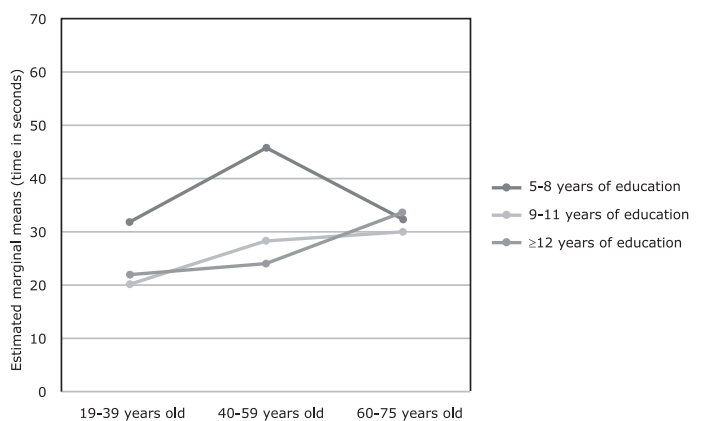
Data presented as mean (standard deviation).



**Figure 1** - Interaction effect between age and education in the Trail Making Test - Time A.



**Figure 2** - Interaction effect between age and education in the Hayling Test - Time B.



**Figure 3** - Interaction effect between age and education groups in the Hayling Test - Time B-A.

**Table 3** - Descriptive data of each group for the Hayling Test

Groups by age and/or education	Time A	Errors A	Time B	Errors B/15	Errors B/45	Time B-A
Age groups						
19-39 years (n=200)	16.22 (6.08)	0.20 (0.43)	39.49 (20.18)	2.44 (2.02)	10.26 (6.66)	23.27 (18.43)
40-59 years (n=89)	15.73 (6.07)	0.17 (0.41)	45.76 (21.43)	2.62 (2.23)	11.53 (6.99)	30.03 (20.72)
60-75 years (n=75)	17.02 (4.91)	0.24 (0.49)	49.49 (17.36)	3.65 (2.28)	13.91 (6.79)	32.46 (16.93)
Education groups						
5-8 years of education (n=74)	17.56 (5.58)	0.19 (0.39)	52.95 (19.21)	4.01 (2.28)	15.28 (6.60)	35.39 (18.97)
9-11 years of education (n=122)	16.92 (7.19)	0.25 (0.47)	40.80 (19.18)	2.39 (1.93)	9.75 (6.53)	23.88 (17.24)
≥12 years of education (n=168)	15.22 (4.63)	0.17 (0.42)	40.39 (20.40)	2.42 (2.11)	10.71 (6.66)	25.18 (19.46)
Age and education groups						
19-39 years of age						
5-8 years of education (n=37)	18.49 (4.88)	0.24 (0.43)	50.40 (17.86)	3.68 (1.78)	13.78 (5.24)	31.91 (17.29)
9-11 years of education (n=73)	16.83 (7.74)	0.26 (0.50)	37.16 (18.44)	2.12 (1.91)	8.82 (6.64)	20.33 (15.50)
≥12 years of education (n=90)	14.79 (4.48)	0.13 (0.34)	36.89 (21.11)	2.19 (2.03)	9.97 (6.74)	22.10 (20.13)
40-59 years of age						
5-8 years of education (n=18)	16.61 (7.30)	0.17 (0.38)	62.38 (20.18)	4.56 (2.66)	17.17 (7.92)	45.77 (21.20)
9-11 years of education (n=30)	16.36 (7.05)	0.10 (0.31)	44.88 (21.50)	2.27 (1.80)	9.60 (6.10)	28.52 (20.48)
≥12 years of education (n=41)	14.88 (4.58)	0.22 (0.47)	39.11 (18.22)	2.02 (1.86)	10.46 (5.97)	24.23 (17.37)
60-75 years of age						
5-8 years of education (n=19)	16.65 (4.96)	0.11 (0.32)	48.98 (18.85)	4.16 (2.73)	16.42 (7.27)	32.33 (17.16)
9-11 years of education (n=19)	18.14 (5.00)	0.42 (0.51)	48.33 (15.06)	3.63 (1.77)	13.58 (5.55)	30.19 (15.24)
≥12 years of education (n=37)	16.64 (4.89)	0.22 (0.53)	50.35 (18.07)	3.41 (2.28)	12.78 (6.95)	33.70 (17.92)

Data presented as mean (standard deviation).

**Table 4** - Main effects, interactions, and post-hoc Bonferroni results

	Age			Education			Interaction			Post-hoc	
	F	p	Partial $\eta^2$	F	p	Partial $\eta^2$	F	p	Partial $\eta^2$	Age	Education
Trail Making Test											
Time A	9.600	<b>&lt;0.001</b>	0.050	3.430	<b>0.036</b>	0.019	2.791	<b>0.026</b>	0.030		*
Errors A	0.862	0.423	0.005	0.375	0.688	0.002	0.506	0.731	0.006		
Time B	22.028	<b>&lt;0.001</b>	0.101	23.592	<b>&lt;0.001</b>	0.115	0.692	0.598	0.008	19-39<40-59 19-39<60-75	5-8>9-11 5-8>12 or more 9-11>12 or more
Errors B	4.046	<b>0.018</b>	0.022	12.696	<b>&lt;0.001</b>	0.065	2.016	0.092	0.022	19-39<60-75	5-8>9-11 5-8>12 or more
Time B-A	14.281	<b>&lt;0.001</b>	0.073	22.477	<b>&lt;0.001</b>	0.110	0.263	0.902	0.003	19-39<40-59 19-39<60-75	5-8>9-11 5-8>12 or more 9-11>12 or more
Time B/A	3.234	<b>0.041</b>	0.018	12.207	<b>&lt;0.001</b>	0.063	0.418	0.795	0.005	NS	5-8>9-11 5-8>12 or more
Hayling Test											
Time A	0.828	0.438	0.005	3.379	<b>0.035</b>	0.019	0.940	0.441	0.010		NS
Errors A	0.743	0.477	0.004	1.030	0.358	0.006	2.070	0.084	0.023		
Time B	6.074	<b>0.003</b>	0.033	9.052	<b>&lt;0.001</b>	0.049	2.714	<b>0.030</b>	0.030		*
Errors B/15	6.715	<b>0.001</b>	0.036	14.862	<b>&lt;0.001</b>	0.077	1.420	0.227	0.016	19-39<60-75	5-8>9-11 5-8>12 or more
Errors B/45	6.941	<b>0.001</b>	0.038	14.664	<b>&lt;0.001</b>	0.076	0.852	0.493	0.010	19-39<60-75	5-8>9-11 5-8>12 or more
Time B-A	7.219	<b>0.001</b>	0.039	8.059	<b>&lt;0.001</b>	0.043	2.574	<b>0.038</b>	0.028		*

NS = non-significant differences.

Correct answers A and B from TMT did not present standard deviation values, therefore inferential analyses are not available.

\* See Figures 1, 2, and 3 for interpretation of interactions among groups.

Bold font indicates significant results ( $p \leq 0.05$ ).



With regards to the age effect on the Hayling Test, a previous study from Borella et al.,<sup>24</sup> with a sample from Switzerland, found that older age decreases the inhibition capacity required Part B. In the same study, this was observed with Errors, but not with Time. Those authors also failed to find effects of age on any other task variable. Another study assessing a Canadian and Belgian sample<sup>7</sup> found the opposite, i.e., age effects were observed on Time B, but not on Errors B. Yet another study found age effects on Time B and on Errors B,<sup>25</sup> but not on Time A. Our hypothesis for the unexpected lack of effects of age on Time<sup>26</sup> variables in the Hayling Test is that the measurement of time in a relatively large interval (60 seconds) caused important interindividual variability. In spite of not using the same method as Borella et al.,<sup>24</sup> but rather the same method as Belleville et al.,<sup>7</sup> for time measurement, age effect may have had less impact on time measurement in our study for cultural reasons. A previous study showed that different cultures may present different performances on timed measures, but not in other types of measures, such as errors or accuracy.<sup>27</sup> An Argentinian study by Abusamra et al. demonstrated education effects on Time A and B and on Errors of Part B.<sup>28</sup>

The influence of age on TMT variables has been largely reported. Most studies found the same effects (or correlations) on Time B,<sup>17,29</sup> Errors B, and Errors B-A.<sup>30</sup> Some research studies also found an effect of age on Time A.<sup>17,29</sup> Our results indicate that age effects may be found in conditions with increased executive demands, such as in Part B of the task. The effect of education has also been reported in previous studies on the TMT A and B.<sup>17,29</sup> These variable results may be attributed to differences in groups' age ranges, task application methods, and cultural aspects that were not analyzed in the present study.

When comparing the effects of both age and education on the TMT and Hayling Test in Part A, the TMT showed interaction effects (education had less impact on groups with age ranges 40-59 and 60-75 years), while in the Hayling Test only education had an effect on the first part. The variable Errors of Part A did not show any effect of age or education in any task, probably because the occurrence of errors in an automatic paradigm is uncommon regardless of age range or education level. Most studies do not present norms or analyses of these variables; however, we strongly believe that the analysis of errors may be an important feature for the appropriate diagnosis of dysexecutive symptoms.<sup>30</sup> In Part B, the TMT showed major effects of age and education, while the Hayling Test presented interaction on time of

execution (the 60-75-year old group did not present education effects regardless of education group; the 19-39-year old group did not present differences between the 5-8 and 9-11 years of education groups). Regarding the occurrence of errors in Part B, both tasks presented effects of age and education, which suggests that verbal and non-verbal EF tasks are affected by these factors.<sup>31</sup> The Hayling formulae B-A presented similar interaction effects than those obtained for Time B.

Observing the effects of age and education on neuropsychological assessment results is critical for valid clinical interpretation, since it may prevent false-negative and false-positive results. Therefore, these two tasks can be considered complementary to assess dissociations and discrepancies among predominant verbal and non-verbal executive processing, being applicable mainly to patients with at least 5 years of education. Limitations of the present study include the recruitment method, exclusion of clinical symptoms or diagnosis by self-report, exclusion of individuals *a posteriori* because of administration errors or missing sociodemographic or clinical data, limited sample size and the large amplitude of educational level groups. Even though the main aim of this paper was to verify age and educational differences, both variables may be treated or studied as continuous factors in future studies. We also suggest that future studies increase sample size and include other relevant factors associated with education, such as frequency of reading and writing habits and quality of education. Also, future studies are warranted to investigate sensitivity and specificity of these versions of the TMT and the Hayling Test in different Brazilian clinical populations.

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## Disclosure

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