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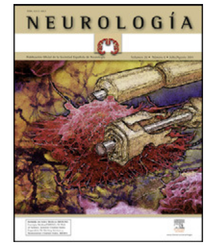

ORIGINAL ARTICLE

Spanish normative studies in young adults (*NEURONORMA* young adults project): Norms for Stroop Color—Word Interference and Tower of London-Drexel University tests☆

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KEYWORDS
Normative data;
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Abstract
Introduction: The Stroop Color—Word Interference Test (Stroop) measures cognitive flexibility, selective attention, cognitive inhibition and information processing speed. The Tower of London-Drexel University version test (TOL^{DX}) assesses higher-order problem solving and executive planning abilities.
Objective: In this study, as part of the Spanish normative studies project in young adults (*NEURONORMA* young adults), we present normative data for the Stroop and TOL^{DX} tests.
Material and methods: The sample consisted of 179 participants who are cognitively normal and range in age from 18 to 49 years. Tables are provided to convert raw scores to scaled scores. Scores adjusted for sociodemographic factors were obtained by applying linear regression techniques.
Results: No effects were found for age and sex in either test. Educational level impacted most of the Stroop test variables and some of the TOL^{DX} scores (total moves score and total initiation time score).
Conclusions: The norms obtained will be extremely useful in the clinical evaluation of young Spanish adults.

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PALABRAS CLAVE
Datos normativos;
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Estudios normativos españoles en población adulta joven (proyecto NEURONORMA jóvenes): normas para las pruebas *Stroop Color—Word Interference Test* y *Tower of London-Drexel University*

Resumen

Introducción: El *Stroop Color-Word Interference Test* (Stroop) se utiliza para explorar la flexibilidad mental, la atención selectiva, la inhibición cognitiva y la velocidad de procesamiento de la información. El test *Tower of London-Drexel University version* (TOL^{DX}) es útil para explorar la habilidad para resolver problemas y la planificación.

Objetivo: En el presente estudio, como parte de los estudios normativos españoles del proyecto NEURONORMA jóvenes, se presentan datos normativos para el Stroop y la TOL^{DX}.

Material y métodos: La muestra está formada por 179 participantes, cognitivamente normales, de entre 18 y 49 años de edad. Se aportan tablas para convertir las puntuaciones brutas en escalares. Se aplican regresiones lineales para calcular los ajustes por factores sociodemográficos.

Resultados: Se observó un efecto nulo de la edad y el género en ambas pruebas. La escolaridad influyó en la mayoría de variables del Stroop y en algunas medidas de la TOL^{DX} (movimientos totales y tiempo de latencia).

Conclusiones: Los datos normativos obtenidos son de gran utilidad clínica para la evaluación de población adulta joven española.

Introduction

Proper assessment of performances on any type of neuropsychological test requires access to normative data of reference. For these data of reference to be considered valid, they must be representative of the demographic and cultural context in which they are used. The NEURONORMA project (NN) was designed in order to remedy the lack of such data in Spain. Its aim is to obtain normative data from the Spanish population on some of the most common neuropsychological tests. Normative data have already been published for subjects older than 49 years[1] and an extension of the same project (NNy) is also being completed using younger subjects.

Within the framework of the NN Project, this article presents normative data for subjects aged between 18 and 49 years old. It employs 2 neuropsychological testing tools which evaluate executive capacities: Golden's version of the Stroop Color—Word Interference Test (Stroop),[2,3] and the Tower of London-Drexel University version test (TOL^{DX}).[4] The characteristics and methodology of the present study have already been described in detail in another article.[5]

The Stroop test measures cognitive flexibility, selective attention, cognitive inhibition, and information processing speed.[6,7] Different versions of the test have been developed (exhaustive reviews of the test may be found in certain compilations of neuropsychological tests).[8—10] Golden's version[2] is divided into 3 sections. In the first and second sections, researchers evaluate word reading speed and colour identification. The last section is a test of resistance to interference in which the subject is asked to name the ink colour of incongruously named colour words instead of reading the printed words. This test measures the executive function of cognitive inhibition, since it requires the controlled process of engaging in a new task while suppressing the automatic process of reading.[9,11] Factor analysis of test results suggests that the interference section has more in common with executive functions of time management such as verbal fluency and information processing speed, than with functions involving mental flexibility, divided attention, and working memory.[12]

We examined the effect of sociodemographic factors, particularly those affecting the interference section. Most authors have detected a significant decrease in performance due to an age effect.[8,13—21] This effect appears to be more acute in subjects with a lower educational level.[20] Certain authors attribute this difference in interference to an overall slowing process as well as to a deficit in specific inhibitory control processes,[20,22,23] since the number of errors increases with age.[20,22] In addition to citing the slowing effect observed in the interference section, some authors have stated that ageing also influences colour naming speed.[6,17,20,24,25] However, studies with wider age ranges present inconclusive results, ranging from considerable[21] to low[15,19,26] or even insignificant levels of influence.[27]

Similarly, research on the influence of education provides no clear or conclusive data. Studies of older population segments show a relationship between education and the subject's score in the interference part of the test.[13,16,17,20,22,24,25,28,29] However, researchers have also detected isolated effects of this variable on all 3 parts of the test.[18] More recent studies, using other Stroop versions and including younger population segments, have described education as having a significant effect on scores,[26] mainly on the colour and interference sections.

The effect of sex on Stroop test performance has received less study. Researchers have observed that sex seems to have the least influence of any other factors on performance by subjects of all ages[30] and some even cite absence of influence due to sex.[13,16,17,20,31] Nevertheless, some researchers have found better performance by women[7,25] or by men.[32] In any case, any differences between these groups are very small and not relevant to clinical practice.

Some studies provide normative data from the Stroop test in different languages.[8–10] Torrealba et al.[33] completed the first Spanish pilot study with a wide age range (20—83 years). They observed that both age and educational level had a significant effect on scores. Artiola et al.[34] gathered normative data from 205 subjects living in Madrid and 185 subjects from the border region between Mexico and the USA with an age range of 18—65 years. They found both age and education effect on performance. López et al.[27] found significant differences in performance on the colour and interference parts of the test between groups with different educational levels.

Shallice[35] originally designed the Tower of London^{DX} test in order to assess problem-solving ability, and executive planning ability in particular, in subjects with frontal lobe lesions. There are several versions of the TOL tasks and each version has its own scoring and test administration protocols. Regardless of the version, these tasks have been traditionally used to measure planning and problem solving abilities.[36]

Some of the studies examine the influence of sociodemographic factors on TOL^{DX} performance. Research on the age effect provides ambiguous results. Some studies found no differences between younger and older subjects,[36] while others detected a small, but significant, negative correlation between age and performance.[6] Nevertheless, some of the studies suggest that age has a clear effect on performance.[5,17,37] For example, Andres et al.[38] found that subjects aged between 60 and 70 years did not perform as well as subjects aged between 20 and 30 years. Researchers have observed that young adults present optimal performance on the task since they are able to solve 92% of the problems correctly.[39]

We find less data regarding education and sex effects on TOL^{DX} test results. Some authors have concluded that neither education[40] nor sex[4] exert a significant influence on performing this task. Nevertheless, other authors have found significant effects of these variables on test performance.[17]

Most studies examining age and education effects on Stroop and TOL^{DX} test results were conducted in subjects older than 50.[8] Considering the impact of sociodemographic variables on the scores, we believe it is necessary to gather normative data from younger adults.[24] Some Spanish normative studies include Stroop test data for this age group,[8,34,41] but level of education was not taken into account in all cases.[42] Spanish literature contains no articles on the TOL^{DX} test. The previous study in the framework of the NN Project, which addressed subjects aged 50 and older,[17] was the first and only attempt at establishing normative data for the TOL^{DX} test in a Spanish population. The aim of our current article is to describe performance on the Stroop and TOL^{DX} tests in younger Spanish adults.

Materials and methods

Subjects

Recruitment methods and sample characteristics have already been thoroughly described in an earlier article[5] on NNy project methodology. To summarise, we recruited 179 subjects and stratified them by age and level of education. None of the subjects presented cognitive decline. All scores on the MMSE were equal to or higher than 24,[43,44] and scores on the Memory Impairment Screen were equal to or higher than 4.[45,46]

Neuropsychological measurements

We followed the neuropsychological protocol established for the NN project,[1] which included the Stroop and TOL^{DX}[17] tests.

Stroop Color—Word Interference Test

We used Golden's version[42] consisting of 3 cards with 100 items arranged in 5 columns. Subjects were allowed 45 seconds to complete each part and we recorded the last completed item on each of the 3 parts of the test. We therefore obtained 3 scores: Stroop-W (word reading): total number of completed items on card 1; Stroop-C (colour naming): total number of completed items on card 2; and Stroop-CW: (colour—word interference); total number of completed items on card 3. There was no penalty as such for errors, but if the subject gave a wrong answer, he had to rectify his answer while time was passing. This resulted in having fewer completed items at the end of the test.

Tower of London

Our study used the Drexel University version (TOL^{DX}).[4] The test includes 10 increasingly complex problems. The subject had a maximum of 2 minutes to solve the problem and was permitted a maximum of 20 moves for each problem. We took into account the 5 variables listed below. (a) Total correct answers: number of problems solved with the minimum number of moves. The highest possible score on the test was 10. (b) Total moves: number of moves the subject needed to solve all the problems. We considered a move to be the act of completely extracting the bead from the peg and placing it on another peg or the same peg (on the base or the last bead on the peg). The total score was the summation of excess moves for each item (number of moves completed minus the minimum number of possible moves); Scores ranged from 0 to 145. (c) Latency time: the time between displaying each problem and the onset of the first move for each problem. (d) Completion time: the time between beginning the first move and solving the problem. (e) Resolution time: the time between viewing the problem and solving it. For additional information about test administration protocols, see the manual.[4]

The variable of total latency time requires further comment due to its characteristics. The authors propose this variable as a relatively stable and potentially inhibitory measurement. In this sense, the time lapse before the first move is made reflects the subject's inhibitory processes, which may theoretically range from minimum response modulation (low control) to maximum response modulation (high control). Extremely low control is associated with rapid and impulsive response behaviour, while the opposite situation would indicate excessively inhibited behaviour. Both extremes may be accompanied by adaptation difficulties, since rapid response time increases the probability of errors and excessive inhibition can be a handicap in situations requiring rapid decision-making. As we will mention in a further section, the analysis of this variable should therefore be presented in a context with the rest of the tasks.

Statistical analysis

A standardised statistical analysis was carried out for all the neuropsychological tests included in the project. The procedure was as follows: (a) a normative data table was created for a single age group. Raw scores were converted into Neuronorma scaled scores (NSS) so as to guarantee a normal distribution. To do so, we generated an array of cumulative frequencies of raw scores and created percentile ranges for raw scores according to their positions within the distribution. Percentile ranges were then converted to scaled scores ranging from 2 to 18. This transformation of raw scores to NSS produced a normal distribution (mean $\pm$ standard deviation: 10 ± 3) to which linear regressions could be applied. (b) Next, we defined the effects of age, education and sex. SS correlation coefficients (r) and coefficients of determination (R^2) were determined for age, years of education, and sex for each of the variables on the Stroop and TOL^{DX} tests. (c) The regression coefficient (β) from this analysis was used as the basis for adjusting for age and education according to the following formula: $SS_{A\&E\&S} = SS - (\beta_1 \times [\text{age} - 35] + \beta_2 \times [\text{education} - 13] + \beta_3 \times \text{sex})$. The resulting value was truncated to the next lower integer. We only adjusted for sociodemographic variables accounting for more than 5% of the variance and presenting a significant regression coefficient. For more detailed information about methodology, see the NNy project's methodology article.

Results

Table 1 displays the array of frequencies of raw scores with the corresponding NSS and percentile ranks.

The correlation coefficient (r) and coefficient of determination (R^2) are shown in Table 2. Education was the variable with the greatest effect on performance on both tests. The effect on all variables was discrete. In the Stroop test, education accounted for a percentage of variance ranging from 4% to 10%. The age and sex variables had no effect on any of the 3 variables. In the TOL^{DX} test, the variable 'years of education' had a significant effect on all the variables, except for the completion time variable. The variables 'total moves' (8.9%) and 'latency time' (7.3%) were the only ones to have percentages of explained variance exceeding 5%. Therefore, adjustments were applied to these measures only. As on the Stroop test, the age and sex effects were not significant for any of the variables.

Table 3 shows education adjustments obtained from multiple regression coefficients. The adjustment is applied by adding or subtracting scores corresponding to the variable 'years of education' to or from the SS shown in Table 1.

Discussion

Within the context of the NN project in the group of subjects younger than 50, the current article provides normative data from younger Spanish adults gathered from 2 executive function tests, the Stroop Color—Word Interference Test and the Tower of London test. We studied the effect of sociodemographic variables on the tests and created adjustment tables in order to correct the scores.

Stroop Color—Word Interference Test

The current study revealed no significant age effects on any of the 3 study variables. These results contrast with those published in prior studies in which researchers found a clear age effect on performance,[6,7,15,17,19,24,25,34] especially in the interference section (Stroop-CW).[13–21] This difference is attributable to the distinct characteristics of the samples. The inclusion of elderly subjects in other studies, whether in order to analyse changes longitudinally or to provide normative data for elderly subjects, explains the appearance of the age effect. Results suggest that age effect is only marked after a certain age threshold. The absence of this effect in our sample leads us to think that it may appear in subjects older than 50.

Education effect was significant in the interference section (Stroop-CW). These results are similar to those from previous studies including younger population segments.[21,26,27,33] In our study, the education effect was slightly greater for the word reading section than for the colour naming section, contrary to the effect observed in other studies.[21]

The studied sample presented no significant sex effects on any of the 3 parts of the Stroop test, which is true of studies of either younger or older populations.[13,16,17,20,31]

Tower of London

Data from the present study showed no significant age effects on the scores obtained on the TOL^{DX} test. These results coincide with those published in the original manual, which only described an age effect in subjects older than 60.[4] Central scores of subjects aged between 18 and 49 in the original data were similar to those of our sample.

Education had a clear effect on subjects' performance, and mainly affected 2 of the variables on the TOL^{DX} test: total moves and latency time. The total number of moves, that is, the sum of excess moves for each problem, is the main testing variable. For this variable, the percentage of variation explained by education was 9%, which is very similar to the percentage obtained in adults older than 49 (10%).[17] We can therefore conclude that educational level may have a linear effect on the subject's test performance throughout his or her lifetime. As stated previously, the variable of latency time may be difficult to interpret and therefore deserves special mention. Since requiring more time before starting the task may be indicative of loss of speed or a greater degree of cognitive control (that is, inhibition of excessively impulsive responses that may lead to errors), we suggest that this measure should be always be analysed in the context of the other testing variables.

Table 1 Education-adjusted table for TOL^{DX} and Stroop tests.

SS	Percentile ranges	Stroop			TOL^{DX}				
		W	C	CW	Total correct	Total moves	Latency time	Completion time	Resolution time
2	<1	≤71	≤48	≤24	–	≥83	≥209	≥498	≥556
3	1	72–77	49–50	25–26	–	78–82	185–208	463–497	507–555
4	2	78–87	51–54	27–29	–	66–77	166–184	444–462	480–506
5	3–5	88–93	55–60	30–33	0	58–65	144–165	327–443	429–479
6	6–10	94–98	61–62	34–38	1	50–57	112–143	297–326	372–428
7	11–18	99–101	63–66	39–40	–	45–49	95–111	248–296	325–371
8	19–28	102–104	67–70	41–43	2	38–44	81–94	229–247	294–324
9	29–40	105–108	71–73	44–45	3	30–37	59–80	196–228	269–293
10	41–59	109–114	74–78	46–50	4	23–29	39–58	167–195	224–268
11	60–71	115–118	79–83	51–53	5	20–22	33–38	147–166	198–223
12	72–81	119–122	84–86	54–56	–	14–19	26–32	129–146	180–197
13	82–89	123–126	87–90	57–59	6–7	10–13	22–25	108–128	157–179
14	90–94	127–133	91–93	60–62	–	8–9	19–21	91–107	134–156
15	95–97	134–141	94–98	63–68	8	5–7	17–18	83–90	123–133
16	98	142–144	99–101	69–71	–	3–4	14–16	57–82	119–122
17	99	145–153	102–103	72–77	9	1–2	13	23–56	104–118
18	>99	≥154	≥104	≥78	10	0	≤12	≤22	≤103
Number of subjects	175	175	175	179	179	179	179	179	

SS: scaled scores; TOL^{DX}: Tower of London Drexel University version.

Table 2 Correlation coefficients (r) and coefficients of determination (R^2) of the scaled scores by age, education, and sex.

	Age (years)		Education (years)		Sex	
	r	R^2	r	R^2	r	R^2
Stroop						
W	0.108	0.012	0.265[a]	0.070[b]	−0.080	0.006
C	−0.017	0.000	0.207[a]	0.043	0.018	0.000
CW	−0.126	0.016	0.327[a]	0.107[b]	0.082	0.007
TOL^{DX}						
Total moves	0.050	0.003	0.298[a]	0.089[b]	−0.100	0.010
Total correct	0.131	0.017	0.218[a]	0.047	−0.055	0.003
Latency time	−0.019	0.000	−0.270[a]	0.073[b]	0.025	0.001
Completion time	0.085	0.007	0.214[a]	0.046	−0.092	0.008
Resolution time	0.035	0.001	0.077	0.006	−0.116	0.013

TOL^{DX}: Tower of London Drexel University version.
[a] Correlation significant at a level of .01 (bilateral).
[b] $R^2 \geq 0.05$.

Table 3 Education-adjusted table for TOL^{DX} and Stroop tests.

	Education												
	8	9	10	11	12	13	14	15	16	17	18	19	20
Stroop													
W[a]	+1	0	0	0	0	0	0	0	0	0	−1	−1	−1
CW[b]	+1	+1	0	0	0	0	0	0	0	−1	−1	−1	−1
TOL^{DX}													
Total moves[c]	+1	0	0	0	0	0	0	0	0	0	−1	−1	−1
Latency time[d]	−1	0	0	0	0	0	0	0	0	0	+1	+1	+1

TOL^{DX}: Tower of London Drexel University version.
[a] $\beta = 0.215$.
[b] $\beta = 0.260$.
[c] $\beta = 0.245$.
[d] $\beta = -0.217$.

We should also be mindful of the fact that either extreme may be indicative of poor cognitive function. The study sample showed a negative relationship between education and the scaled score corresponding to that variable. As we mentioned before, a higher educational level is related to a lower number of excess moves. Therefore, a longer time lapse before starting the task in more educated subjects may be indicative of greater inhibitory control and superior planning ability. Such a relationship between education and latency time was not found in the NN project sample of older subjects.[17] This could be due to the fact that elderly subjects are usually more reflective, regardless of their educational level. Other studies including subjects with a wide age range such as the one by Zook et al.,[40] do not report a different relationship between the TOL^{DX} score and education in young and older subjects. The wide age range found in the study by Zook et al. could be masking that difference, although data interpretation is not conclusive since they only included subjects with 12 or more years of education.

As in the Stroop test, our data showed no age effect on any of the TOL^{DX} test variables, which concurs with findings from the original normative sample.[4]

The present study, an extension of the NNy project, provides normative data from the Stroop Color—Word Interference Test and the Tower of London test in a Spanish population segment aged between 18 and 49. This study corroborates the effect of education on some of the variables in the Stroop and TOL^{DX} tests, so we propose applying the appropriate adjustments. In addition, we show that age and sex had no effect on performance of these tasks. It should be stated that these normative data for the TOL^{DX} test are the first that may be applied to a younger Spanish population.

In conclusion, the normative data and the adjustments for education presented in this study are helpful for raising the quality of neuropsychological examinations of executive functions in younger Spanish subjects. Likewise, the NN project methodology allows us to directly compare performances between tests measuring different cognitive areas.

Conflicts of interest

The authors have no conflicts of interest to declare.

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