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Demographically Adjusted Norms for the Trail Making Test in Native Spanish-speakers: Results from the Neuropsychological Norms for the US-Mexico Border Region in Spanish (NP-NUMBRS) Project

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Abstract

Objective: Despite the wide use of the Trail Making Test (TMT), there is a lack of normative data for Spanish-speakers living in the United States (US). Here we describe the development of regional norms for the TMT for native Spanish-speakers residing in the Southwest Mexico-Border Region of the US.

Method: Participants were 252 healthy native Spanish-speakers, 58% women, between the ages of 19 and 60, and ranging in education from 0–20 years, recruited in San Diego, CA and Tucson, AZ. All completed the TMT in Spanish along with a comprehensive neuropsychological test battery as part of their participation in the Neuropsychological Norms for the US-Mexico Border Region in Spanish (NP-NUMBRS) project. Univariable and interactive effects of demographics on test performance were examined. T-scores were calculated using fractional polynomial equations to account for linear and any non-linear effects of age, education, and sex.

Results: Older age and lower education were associated with worse scores on both TMT A and B. The newly derived T-scores showed no association with demographic variables and displayed the expected 16% rates of impairment using a −1 SD cut point based on a normal distribution. By comparison, published norms for English-speaking non-Hispanic Whites applied to the current data yielded significantly higher impairment for both TMT A and B with more comparable rates using non-Hispanic African Americans norms.

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Conclusions: Population-specific, demographically adjusted regional norms improve the utility and diagnostic accuracy of the TMT for use with native Spanish-speakers in the US-Mexico Border region.

Keywords

Demographic adjustments; Spanish-Speakers; Hispanic; Latino; Processing speed; Visual Scanning; Cognitive Set-Shifting

Introduction

By US Census estimates, approximately one in five people tested by a neuropsychologist in the Unites States will be of Latino descent, and an estimated 70% of those spoke Spanish at home in 2016 (U.S. Census, 2017). By these same estimates, in some larger cities in the southwestern US, such as Los Angeles, approximately 50% of the patient population is of Latino descent with greater numbers speaking Spanish as their first language (Census Reporter, 2017). These statistics highlight the need to develop norms for Spanish-speakers in the US. The Trail Making Test (TMT) was originally developed as part of the Army Individual Test Battery (Army Individual Test Battery, 1944) and later included in the Halstead-Reitan Battery (Halsted, 1947). The TMT is widely used to measure attention, processing speed and mental flexibility (Heaton, Miller, Taylor, & Grant, 2004). The TMT consists of two trials: the Trail Making Test-Part A (TMT-A) requires speeded visual search and psychomotor abilities to connect 25 encircled numbers in numerical order. The second trial, the Trail Making Test-Part B (TMT-B), requires connecting encircled numbers and letters by alternating between numerical and alphabetic sequences. As such, the TMT-B has an added switching component measuring cognitive flexibility. Normative studies in English-speaking samples have found that older age and lower education negatively impact performance, while sex has been found to have less of an effect (Heaton et al., 2004).

Despite the wide use of the TMT when assessing Spanish-speakers in the US, only one study has published norms that might be appropriate to use with Hispanics of Mexican-descent living in the U.S.-Mexico border region (O'Bryant et al., 2017) tested in either English and Spanish, the Texas Mexican American adult normative study (TMAANS). In this study, 797 Mexican Americans older than 40 years of age and with a mean education or 9.9 years (SD=4.6) were tested in both rural and urban communities as part of a multi-site effort. Participants in this study were tested in their preferred language resulting in 412 people who were administered a battery of tests in Spanish and the remainder in English. In this study, participants tested in Spanish were administered a Spanish version of the TMT based on a protocol previously developed by Acevedo and colleagues (2007), and those tested in English were administered the Reitan and Wolfson version (1993). Reitan's scoring strategy was utilized. Prior to the test administration, participants were asked to recite the alphabet out loud in order to ascertain knowledge and automaticity of the alphabet. In the overall sample including both English- and Spanish-speakers, no effects of sex were found for either TMT-A or TMT-B, while older age and less education were found to have a negative effect on performance for both subtests. Spanish-speaking participants were outperformed by their English-dominant counterparts on TMT-A. No group differences between Spanish- and English-speakers were reported for the TMT-B performance. Norms were developed in the combined group (English- and Spanish-speakers together) and were stratified using education ranges with corresponding midpoints (0–6, 3–9, 6–12, and above 12), with age ranges grouped as 40–60, and 61 and over.

Before this important study was published in the US for use with Spanish- speakers of Mexican descent, Peña Casanova and colleagues in 2009 published norms for a Spanish version of the TMT specifically with a Spaniard population between 50 to 90 years of age. Age and education were found to affect performance on both TMT-A and TMT-B. In 2012, the same group published norms for ages 18 to 49. While Peña Casanova et al. (2009) reported education and age effects for TMT-A, TMT-B performance was only affected by education. No sex effects were found for either study (Tamayo et al., 2012). Later, efforts by Arango-Lasprilla and colleagues (2015) yielded normative data for Spanish-speakers derived from a sample of healthy adults living in 11 Latin American countries. This sample of healthy individuals with at least one year of education (no maximum reported) ranged in age from 18 to 95. Across countries, speeded performance declined as a function of older age and lower education (dichotomized as 1–12 vs >12 years), but the sex effect varied by country, with Mexico being one country where women were outperformed by men. Norms were derived using a multiple linear regression model adjusting for age and sex and provided for each country based on (Arango-Lasprilla et al., 2015). More recently, norms for individuals 55 years or older, and with low (between 9 and 12) or high level of education (more than 12 years of education) were developed as part of a study of cardiovascular risk factors in Spain (N = 1,923). In this study, both TMT-A and TMT-B were found to have effects of age, sex, and education using stepwise multiple linear regression (Llinas-Regla et al., 2017).

While the TMT is one of the most widely used neuropsychological tests to detect brain damage, even among Spanish-speakers in the United States, normative data for this specific population is sorely lacking. However, irrespective of language or country of administration, the limited number of normative data published for a Spanish version of the TMT has consistently found effects of age and education, and inconsistent small effects of sex. The one study to date which provided norms for use with Spanish- speakers residing in the US offered stratified data for adults older than 40 years old with various levels of education in a combined group of Spanish and English-speaking Hispanics (O'Bryant et al., 2017). In this article, we describe the development of regression-based norms for the TMT with a younger adult sample of native Spanish- speakers from the U.S.–Mexico border regions of San Diego, California and Tucson, Arizona. The TMT norms were generated with the added benefit of co-norming with a larger, comprehensive battery of tests (presented in this TCN Special Issue) based upon the *Neuropsychological Norms for the U.S.-Mexico Border Region in Spanish* (NP- NUMBRS) project, which covers eight domains including verbal fluency (phomenic and semantic category fluency; Marquine et al., Under Review); processing speed (Trail Making Test-Part A [TMT-A]; Wechsler Adult Intelligence Scale-III [WAIS-III] Digit Symbol Coding and Symbol Search subtests; Rivera Mindt et al., 2020 and Suarez et al., This Issue); attention/working memory (Paced Auditory Serial Addition Test [PASAT], Wechsler Adult Intelligence Scale-Third Edition [WAIS-III] Letter Number Sequencing Test [LNS], and Wechsler Adult Intelligence Scale-Revised [WAIS-R]

Arithmetic subtest; Gooding et al., 2020; and Scott et al., 2020); executive function ([Halstead Category Test [HCT], Trail Making Test-Part B [TMT-B], Wisconsin Card Sorting Test-64 Item [WCST-64]; Marquine et al., 2020; Morlett Paredes et al., 2020; and Suarez et al., 2020); learning and delayed recall (Hopkins Verbal Learning Test- Revised [HVLT-R] and Brief Visuospatial Memory Test-Revised [BVMT-R]; Diaz-Santos et al., This Issue); visuospatial construction (WAIS-R Block Design subtest; Scott et al., 2020); and fine motor skills (Finger Tapping Test and Grooved Pegboard Test; Heaton et al., 2020). We derived T-scores adjusted for demographics for each test via fractional polynomial regression equations based on an overall sample of 252 Spanish-speaking adults. See Cherner, Marquine and colleagues, 2020 for details on methodology.

Methods

Participants

Participants were 252 healthy adults with valid data for the TMT as part of the larger NP-NUMBRS project, which included two recruitment cohorts (Cohort 1 [n=182] from San Diego, CA and Tucson, AZ areas; 1998–2000; Cohort 2 [n=70], from San Diego only; 2006–2009). Participants were carefully screened to ensure that they had no significant history of medical, psychiatric, developmental, or substance abuse disorders that could confound neuropsychological performance. As part of the larger normative studies, efforts were made to recruit a sample with equal representation of men and women across pre-set age and education ranges. Our final sample consisted of 105 men and 147 women ranging in age from 19 to 60 years (M = 37.2, SD = 10.2) with educational attainment between 0 and 20 years (M = 10.7, SD = 4.3; see Table 1).

Study participants responded to flyers or direct contact with recruiters in community settings. All participants had reason to spent time in the United States (e.g., for work, school, place of residence). We used a language questionnaire to confirm that Spanish was their preferred language and all participants expressed a desire to be tested in Spanish. As suggested by Artiola i Fortuny, Hermosillo, Heaton, and Pardee (1999), the Controlled Oral Word Association Test (COWAT) (Benton & Hamsher, 1989) was administered in both English (F-A-S) and Spanish (P-M-R) to provide an objective measure of the degree of verbal fluency in each language. Please refer to Cherner, Marquine et al. (this issue) for additional participant recruitment details as well as demographic characteristics of the overall NP-NUMBRS sample, the cohort by years when the data were collected (Cohort 1 and Cohort 2) and study site (Arizona and California).

Procedures

This study was approved by the UCSD Human Research Protections Program. Participants completed self-report questionnaires of education, social and language background, and a Spanish translation of the TMT as part of a larger battery of neuropsychological tests. Testing was performed by trained bilingual psychometrists using standardized procedures based on the administration and scoring instructions in the expanded Halstead-Reitan battery (see Appendix 1 for instructions in Spanish) (Heaton, Grant, & Matthews, 1991). Participants were asked to recite the alphabet prior to the administration to ensure that they had sufficient knowledge to complete the TMT- B. If participants included the sound “ch” between C and D, which is common among people who received their education in Spanish speaking countries, they received a TMT-B version that included “Ch.” As described by Cherner et al, 2008, this version is otherwise identical in pattern and total number of circles as the standard version. Per the standard administration, each trial included a practice sample to ensure that instructions were understood. Each trial was scored as the time to completion, with discontinuation at 180 seconds for TMT-A and 301 seconds for TMT-B. For the TMT-A, the examinee was asked to rapidly draw lines connecting encircled numbers from 1 to 25. The examiner kept track of the performance to instruct the participants in the event of a sequencing error. For the TMT-B, the examinee was asked to rapidly draw lines alternating between connecting numbers in numerical sequence, and letters in alphabetic order. All errors were recorded and the examinee was required to correct the error before moving on with the task. Time to completion, therefore, includes time spent to correct error(s).

Statistical Analysis

Descriptive characteristics and distribution of raw scores.—We computed descriptive statistics of raw scores on the TMT-A and TMT-B: Time and Errors. We examined the distribution of TMT-A and TMT-B time and errors raw scores via Shapiro-Wilk tests. We then examined the linear and non-linear association of age and education with TMT-A and TMT-B raw scores via a series of univariable linear regression analyses, and the association between sex and raw scores via independent sample *t*-tests (or Wilcoxon Rank sum tests for variables with skewed distributions). We also ran a series of separate linear regression models of TMT-A and TMT-B raw scores (time and errors) to quantify the potential two-way interactions between demographic variables (age, education, sex). Note that these analyses were limited by the restricted range in error scores. For TMT-A and TMT-B raw scores that met sensitivity criteria we report Scale Scores and demographically-adjusted T-scores, and for raw scores with limited range of scores or very skewed raw score distribution, we report percentile ranges.

Generation of T-scores and Norms Comparisons.—Time to completion raw scores for the TMT-A and TMT-B were converted into normal quantiles and standardized. These scores were converted into scaled scores with a mean of 10 and standard deviation of 3. The influence of education, age, and sex on scaled scores was calculated using fractional polynomial regression equations with the residuals from the models converted into T-scores with a mean of 50 and a standard deviation of 10 with significant, as well as non-significant predictors included. This was the case to ensure that T-scores derived for all measures included weights for all demographic variables. See Cherner, Marquine et al. (2020) for more details on participants and methodology. We also examined the descriptive characteristics of the resulting T-scores and their distributions via Shapiro-Wilk tests, and investigated the association of age and education with the newly developed T-scores via Pearson product moment correlation coefficients, and the association of sex with T-scores via independent sample *t*-tests. We also compared T-scores based on the newly developed norms by testing site (Arizona and California) and study wave (Cohorts 1 and 2) via a series of independent sample t-tests. Once the newly derived T-scores were obtained, participants with a T- score of 39 or lower were deemed as “impaired” and rates of impairment were compared to those expected in the general population, with 15–16% of the sample expected to fall in the impaired range.

Comparison between published/existing norms with newly derived.—T-scores were first calculated for the TMT-A and TMT-B time to completion based on published norms for English-speaking non-Hispanic Whites and non-Hispanic (NH) Blacks/African Americans in the U.S (Heaton, Miller, Taylor & Grant, 2004; Norman et al, 2011). Same impairment criteria of T-scores lower than 39 were applied. Rates of "impairment" were statistically compared between the existing English-speaking norms and the newly developed Spanish-speaking norms using McNemar's test. In order to investigate whether the T-scores derived from applying demographically-adjusted norms based on English-speaking non-Hispanics adequately controlled for demographic factors in the present Spanish-speaking sample, we ran a series of univariable analyses (Pearson product moment correlation coefficients for age and education, and independent sample *t*-tests for gender) on these T-scores. Details on the statistical analyses for the NP-NUMBRS project are provided in the overall statistical approach for co-norming the battery of tests presented in this Special Issue (Cherner, Marquine et al., this issue)

Results

Sample Characteristics

Two-hundred and fifty-two healthy adults between the ages of 19–60, with 0–20 years of schooling, completed both the TMT-A and TMT-B. Table 2 summarizes the sample's educational, social and language background based on a self-report questionnaire. Based on their own responses, approximately 85% of the population completed more years of education in their country of origin than in the U.S. (8 years on average), and almost 30% of the sample stopped attending school to work. Years of education completed by their mothers was 5.8 on average and for their fathers was 6.8 on average. Participants lived the majority of their lives in their country of origin. Most participants described their childhood socioeconomic status as middle class, with nearly 30% reporting having been poor. Fifty percent of participants reported working for money during childhood, and 40% of those stated they did so to help their families financially. Approximately 70% of the participants were gainfully employed at the time of their participation in the present study. All but 4 participants reported that Spanish was the first language they learned. Almost two-thirds of the sample was monolingual Spanish-speaking or strongly Spanish dominant, with the remaining third being bilingual. Average ratings of language used in various everyday activities indicated that Spanish was the predominant language used in daily life.

Table 3 shows the mean, standard deviation, and range of both TMT-A and TMT-B raw scores (time and errors) for the sample. Table 4 illustrates participants by study cohort (Cohort 1 recruitment between 1998 and 2000; Cohort 2 recruitment between 2006 and 2009) and study site (Tucson, Arizona [AZ]; San Diego, California [CA]).

Raw scores and demographic characteristics and scale score conversions.

Table 5 shows the association of raw scores with demographic variables (age, sex, education), based on Spearman *p* (for age and education) and Wilcoxon-ran sum tests (for sex). There were medium effects of age on TMT-A and TMT-B Time. Education had an effect on time to complete TMT- A. A small effect of education on TM- B Time was found. There were no significant effects of age on TMT-A or TMT-B number of errors, but there were medium to large effects of education on both TMT-A and TMT-B errors. There were no significant main effects of sex on any of the TMT-A and TMT-B raw scores. There were no significant two-way interaction effects of demographic characteristics on the TMT-A or TMT-B scores (time or errors).

Table 6 shows the raw-to-scale score conversions for the TMT-A and TMT-B Time scores. Given the skewness of the distribution and the limited range of scores of TMT-A and TMT-B errors, percentile scores are presented in Table 7.

Table 8 shows the T-score equations used to compute individual T-scores (please see online supplement for digital calculator).

As expected, the resulting T-scores had a mean of 50 and a SD of 10. T- scores ranged from 29 to 74 for TMT-A Time and from 22 to 80 for TMT-B Time. Pearson product moment correlation coefficients showed no significant effect of age or education on any of the T-scores and there were no significant sex differences. No significant differences were found between cohorts based on recruitment period or study site.

Application of existing norms.

As shown in Figure 1, published demographically- adjusted norms for English-speaking non-Hispanic whites (Heaton et al., 2004) yielded significantly higher impairment rates of 28% for TMT-A and 35% for TMT-B ($ps < .0001$), while norms for English-speaking non-Hispanic African Americans (Norman et al., 2011) resulted in 18% impairment for TMT-A and 20% impairment for TMT-B, not statistically different than our current norms ($ps > .05$).

Univariable analyses investigating the association of demographic variables (age, education and gender) with TS derived from norms for non-Hispanic whites (Heaton et all, 2004) showed a small but significant effect of education on TMT-B ($r = 0.16$, $p = .01$) with no other significant demographic effects. Comparable analyses on TS derived from norms for non-Hispanic African Americans showed that men had significantly higher T-Scores on TMT-A ($M = 50.5$, $SD = 9.4$) than women ($M = 47.6$, $SD = 9.9$; $p = .02$), and higher education was significantly associated with higher T-Scores on TMT-A ($r = 0.19$, $p < .01$) and TMT-B ($r = 0.30$, $p < .001$).

Discussion

Our newly derived norms for a Spanish version of the TMT are consistent with previous normative studies that found effects of age and education, but no sex effects. Older age and lower education are associated with worse raw scores on both TMT-A and TMT-B. With respect to number of errors, there were no significant effects of age or sex on TMT-A or

TMT-B, but there were medium to large effects of education on both trials. In our sample, while age had a similar effect on TMT-A and TMT-B time raw scores, the effect of education was larger for TMT-B than it was for TMT-B. The newly derived demographically adjusted T-scores showed no association with demographic variables and displayed the expected 16% rates of impairment using a <1 SD cut-point based on a normal distribution, which is what would be expected in the general population of “normal” individuals. By comparison, published norms for English-speaking non-Hispanic Whites yielded impairment rates of 28% for TMT-A and 35% for TMT-B while norms for English-speaking non-Hispanic African Americans resulted in 18% impairment for TMT-A and 20% impairment for TMT-B.

When compared to demographic effects on both the TMT among Spanish- speakers tested in their native countries (Arango-Lasprilla et al., 2015) and among Spanish-speakers residing in Texas (O’Bryant and colleagues, 2017), our results show similar effects of education and age. Unique to this study is that our sample demonstrated differences in degrees of English fluency, which has been found to facilitate performance in TMT-B (see Suarez et al., this issue), and not in TMT-A. That is, those with higher relative English fluency outperformed participants with lower relative English fluency and these effects were not best accounted by the higher levels of education alone. With this in mind, we would presume the same findings from the Texas norming sample (O’Bryant et al., 2017), but participants were tested in both English and Spanish and scores for TMT-B were jointly reported for the English and Spanish administrations in the TMAANS study.

The current study may be limited in generalizability, and caution should be used when applying these norms to other groups of native Spanish-speakers who are not of Mexican-descent and living in the Southwest US-Mexico border region, given the heterogeneity of the Latino population. Similarly, our normative equations should not be used to extrapolate values for older Spanish-speaking adults, given that our sample was limited to age 60, and effects at older ages may have different mathematical properties (e.g., nonlinear). Notably, the current norms should be interpreted with caution in individuals who are bilingual given the effects of bilingualism (i.e., higher relative English fluency) found on tests of controlled-switching. These results were discussed in a separate article in this same issue (see Suarez et al, this issue). There may be other demographic characteristics not accounted for by this normative study that may also need to be considered when interpreting performance, as well as in future studies when developing normative data (e.g., test familiarity, socio-economic status, measures of acculturation, etc.). Regarding test familiarity and cognitive styles, for example, the education system in the United States uses musical mnemonics for children to learn the alphabet (Good, Russo, & Sullivan, 2015). This educational strategy is not typical in Spanish-speaking countries (Escamilla, 1999) and could account for slower speed when patients of lower education are tasked with completing the TMT B portion of this test. In our current study, we found that healthy individuals with less than 6 years of education were slower in completing TMT-A and B. Clinicians are encouraged to ask Spanish-speaking individuals to recite the alphabet out loud in their preferred language (O’Bryant et al., 2017) to gauge (1) their knowledge of the alphabet and (2) the letter automaticity, both of which could represent confounding factors reducing test sensitivity. Additionally, another confounding factor is the inclusion of “ch” in the Spanish alphabet. If clinicians encounter

Spanish-speaking adults who include the "ch" while reciting the alphabet, the clinician ought to administer the "ch" version of the Trail Making Test since Cherner et al. (2008) demonstrated equivalency between these two versions.

This normative effort is significant in that no norms for use with U.S.-dwelling native Spanish-speakers of Mexican-descent had previously been published for individuals younger than 40 years of age. The current study provides norms for use with a U.S.-dwelling native Spanish-speaking population of Mexican-descent that adjust for age, sex, and level of education. Future work ought to focus on identifying additional sources of variance in test performance that can explain normative differences observed in rates of impairment with greater granularity when using non-Hispanic White and African American English norms compared to Spanish-norms.

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APPENDIX 1

Trail Making Test- Form A & B Instructions

TMT-A:

Sample: "En esta página hay unos números (point). **Comience con el número 1** (point to 1) **y dibuje una línea del 1 al 2**, (point to 2) **del 2 al 3**, (point to 3) **del 3 al 4**, (point to 4) **y así sucesivamente, en orden, hasta llegar al final** (point to the circle marked "Fin"). **Dibuje las líneas lo más rápido que pueda. ¿Listo/a? Adelante."**

"Bien. Intentemos el siguiente."

If the subject makes a mistake on sample A, point out the error and explain it. The following explanations of mistakes serve as illustrations:

"Empezó en el círculo equivocado. Aquí es donde debe empezar" (point to number 1). **"Aquí se brincó este círculo** (point to the circle omitted)." **"Debe dibujar la línea del número 1** (point) **al 2** (point), **del 2 al 3** (point), **"y así sucesivamente, hasta llegar al círculo que dice FIN"** (point).

If the subject still cannot complete sample A, take his/her hand and guide his pencil (eraser end down) through the trail. Then say:

"Ahora inténtelo usted. Recuerde, comience con el número 1 (point), **y dibuje una línea del 1 al 2** (point to 2), **del 2 al 3** (point to 3), **del 3 al 4** (point to 4), **etc., en orden, hasta llegar al círculo que dice 'FIN'** (point). **No se brinque ninguno y proceda de un número al siguiente en orden. Recuerde, dibuje las líneas lo más rápido que pueda. ¿Listo/a? Adelante."**

Test: "En esta página hay unos números. Haga esta página de la misma manera. Comience con el número 1 (point to 1) **y dibuje una línea del 1 al 2** (point to 2), **del 2 al 3** (point to 3), **del 3 al 4** (point to 4), **y así sucesivamente, en orden, hasta llegar al final** (point to the circle marked FIN). **Recuerde, dibuje lo más rápido que pueda. ¿Listo/a? Adelante."**

If the subject makes an error, call it to his/her attention immediately and have him /her proceed from the point the mistake occurred. Cue:

"Se brincó un círculo. Regrese al número ____." (The last correct circle)

"Muy bien. Ahora intente otro."

TMT-B:

"En esta página hay números y letras. Comiece con el número 1 (point to 1), **y dibuje una línea del número 1 a la letra A** (point to A), **de la letra A al número 2** (point to 2), **del número 2 a la letra B** (point to B), **de la letra B al número 3** (point to 3), **del número 3 a la letra C** (point to C), **y así sucesivamente, en orden, hasta llegar al final** (point to circle marked "FIN"). **Recuerde, primero hay un número** (point to 1), **seguido por una letra** (point to A), **seguido por un número** (point to 2), **seguido por una letra** (point to B), **y así sucesivamente. Dibuje las líneas lo más rápido que pueda. ¿Listo/a? Adelante."**

If the subject completes the sample correctly, say:

"Bien. Intentemos el siguiente."

If the subject makes a mistake on Sample B, point it out and explain it. The following explanations of mistakes serve as illustrations:

"Empezó en el círculo equivocado. Aquí es donde debe empezar." (Point to number 1.) **"Se brincó este círculo** (Point to the circle omitted). **Debe dibujar la línea del número 1** (point), **a la letra A** (point), **de la letra A al número 2** (point), **del número 2 a la letra B** (point), **de la letra B al número 3** (point), **y así sucesivamente hasta llegar al círculo que dice FIN"** (point).

If the subject cannot complete Sample B, take his/her hand and guide the pencil (eraser end down) through the circles, step by step, as in part A.

Test: "En esta página hay números y letras. Haga esta página de la misma manera. Comience con el número 1 (point to 1), **y dibuje una línea del número 1 al la letra A** (point to A), **de la letra A al número 2** (point to 2), **del número 2 al la letra B** (point to B), **de la letra B al número 3** (point to 3), **del número 3 a la letra C** (point to C), **y así sucesivamente, en orden, hasta llegar al final** (point to circle marked "FIN"). **Recuerde, primero hay un número** (point to 1), **seguido por una letra** (point to A), **seguido por un número** (point to 2), **seguido por una letra** (point to B), **y así sucesivamente. No se brinque ninguno, proceda de un círculo al siguiente en orden. Recuerde, dibuje las líneas los más rápido que pueda. ¿Listo/a? Adelante."**

If the subject makes an error, call it to his attention immediately and have him/her proceed from the point the mistake occurred. Cue:

"Se brincó un círculo. Regrese al número/la letra_________." (the last correct circle)

Do not stop timing.

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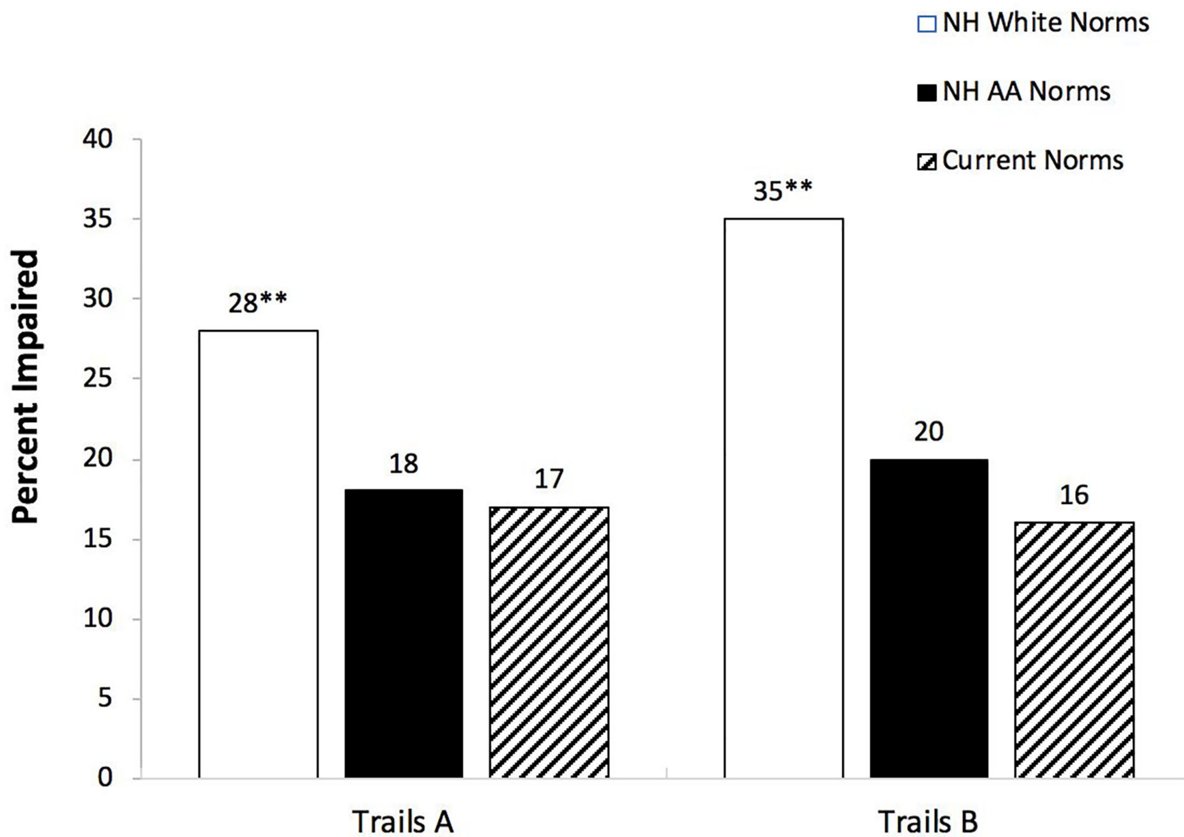

Figure 1.

Rates of impairment based on published norms for non-Hispanic (NH) Whites and NH African Americans (Heaton et al., 2004), and newly developed norms for the Trial Making Test A and B (TMT- A, TMT-B) Time Scores. Impairment was defined as T-Score <40 (−1 SD). Asterisks denote significant difference based on McNemar's tests compared to currently developed norms: **p<.0001.

Table 1.

Demographic characteristics of the normative sample stratified by years of education for those who completed The Trail Making Test (TMT; *N* = 252).

	ALL (N=252)
Age (years), M (SD)	37.2 (10.2)
Education (years), M (SD)	10.7, (4.3)
% Female	58.33

Note. M: mean; *SD*: standard deviation.

Table 2.

Educational, social, and language background characteristics of NP-NUMBRS participants with data on the Trail Making Test (TMT, *N*=252)

Characteristics	Descriptives	
	***M* (SD), %**	***n***
Educational Background		
Years of education in country of origin	8.53 (4.80)	226
Years of education in the U.S.	2.54 (4.74)	226
Proportion of education by country	--	226
More years of education in country of origin	84.07%	190
More years of education in the U.S.	15.04%	34
Equal number of years of education in both countries	0.89%	2
Type of school attended[a]	--	241
Large	55.19%	133
Regular	40.25%	97
Small	4.57%	11
Number of students in the class	--	245
Less than 21	15.10%	37
21 to 30	39.59%	97
31 to 40	24.08%	59
40+	21.22%	52
Had to stop attending school to work	--	223
Yes	28.70	64
Social Background		
Mother’s years of education	5.78 (3.65)	179
Father’s years of education	6.79 (5.06)	163
Years lived in country of origin	26.37 (12.47)	243
Years living in the U.S.	10.68 (10.87)	243
Childhood SES[b]	--	249
Very poor	5.22%	13
Poor	27.31%	68
Middle class	58.64%	146
Upper class	8.84%	22
Worked as a child	--	246
Yes	52.44%	129
Reason to work	--	129
Help family financially	38.76%	50
Own benefit	61.24%	79
Age started working as a child	12.96 (3.19)	125
Currently Gainfully Employed	--	223
Yes	69.06%	154

Characteristics	Descriptives	
	***M* (SD), %**	***n***
Language		
First Language	--	248
Spanish	98.39%	244
English	0.40%	1
Both	1.21%	3
Current Language Use Rating[c]		
Radio or TV	2.38 (1.04)	249
Reading	2.24 (1.19)	249
Math	1.54 (1.05)	247
Praying	1.26 (0.72)	238
With family	1.56 (0.89)	244
Performance-based language fluency	--	201
Spanish dominant	61.69%	124
English dominant	0.00%	0
Bilingual	38.31%	77

Note. M: mean; *SD*: standard deviation; SES = socioeconomic status

[a]Type of school attended: 'large' refers to large school that had many classrooms and room to play); 'regular' refers to a school with at least one classroom per grade and room to play; and small school refers to a small school with less than one classroom per grade.

[b]Childhood SES was assessed by the following question and response options: "As a child, your family was: (1) Very Poor; (2) Poor; (3) Middle Class); (4) Upper Class".

[c]Ratings for each activity ranged from 1 "Always in Spanish" to 5 "Always in English", with 3 being "similarly in English and Spanish").

Table 3.

Mean, standard deviation, and range of the Trial Making Test A and B (TMT-A, TMT-B) raw scores (time and errors; $N = 252$)

	Mean (SD)	Range
TMT-A Time	33.27 (13.8)	12 – 98
TMT-A Errors	0.22 (0.45	0 – 2
TMT-B Time	100.58 (65.9)	26 – 309
TMT-B Errors	0.91 (1.5)	0 – 9

Note. SD: standard deviation.

Table 4.

Number of participants with data on Trails Making Test-A and/or Trail Making Test-B by study cohort and site

Domain	Test	Total	Study Cohort		Study Site	
		N	Cohort 1	Cohort 2	AZ	CA
			n	*n*	*n*	*n*
Processing Speed	TMT-A	251	182	69	102	149
Executive Functioning	TMT-B	246	176	70	99	147

Note. AZ = Arizona; CA=California

Table 5.

Association between raw scores and demographic characteristics for the Trial Making Test A and B (TMT-A, TMT-B; *N* = 252).

	Age[a]	Education[a]	Sex[b]		
			Male (*n*=105)	Female (*n*=146)	p
TMT-A Time	0.29***	−0.42***	32.0 (13.2)	34.2 (14.2)	NS
TMT-A Errors	0.12	−0.17	0.3 (0.5)	0.19 (0.5)	NS
TMT-B Time	0.24***	−0.57**	99.0 (69.7)	101.68 (63.2)	NS
TMT-B Errors	0.08	−0.39***	0.98 (1.6)	0.86 (1.4)	NS

Note. Based on results from Spearman ρ[a] and Wilcoxon rank-sum tests[b].

* $p<.05$

** $p<.01$

*** $p<.001$

Table 6.

Raw-to-scale score conversions of the Trial Making Test (TMT): TMT- A and TMT-B (Time; *N* = 252).

Scaled	TMT-A Time	TMT- B Time
19	0 – 5	0 – 12
18	6 – 13	13 – 28
17	14 – 15	29 – 34
16	16 – 17	35 – 39
15	18	40 – 42
14	19 – 20	43 – 49
13	21 – 22	50 – 55
12	23 – 25	56 – 62
11	26 – 28	63 – 70
10	29 – 31	71 – 83
9	32 – 35	84 – 98
8	36 – 41	99 – 128
7	42 – 48	129 – 175
6	49 – 57	176 – 268
5	58 – 63	269 – 276
4	64 – 78	277 – 278
3	79 – 88	279 – 282
2	89 – 135	283 – 301
1	136 – 166	--

Table 7.

Raw-to-percentiles of the Trial Making Test A and B (TMT-A, TMT-B; *N* = 252) errors

Percentile	TMT-A (errors)	TMT-B (errors)
100	2	9
99.5	2	8.6
97.5	2	5.9
90.0	1	3
75.0	0	1
≤50	0	0

Table 8.

Demographically adjusted T-Score equations for the Trial Making Test A and B (TMT-A, TMT-B) Time Score (N= 252).

Measure	Equation
TMT-A Time	$10 \times \left(\frac{SS\ Trails\ A\ Time - \left(12.74112 - 8.03021 * \frac{age}{100} + 2.892902 * log\frac{(edu + 1)}{10} + 0.17253 * gender\right)}{2.5439} \right) + 50$
TMT-B Time	$10 \times \left(\frac{SS\ Trails\ B\ Time - \left(7.9068 - 6.29789 * \frac{age}{100} + 3.75062 * log\frac{(edu + 1)}{10} + 0.06026 * gender\right)}{2.37373} \right) + 50$

Note. These formulas should be applied to education level ranges from 0–20 and age 19–60. Using values outside these ranges might result in extrapolation errors. Gender: Male=1; Female=0

Edu=years of education

Age= years of age