The Symbol Digit Modalities Test - Oral version: Italian normative data

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Summary

In neuropsychological practice, the availability of effective and reliable tests is crucial. The Symbol Digit Modalities Test (SDMT) is widely used because it is easy to administer, reliable and also evaluates information processing speed.
We set out to obtain normative data (currently unavailable for the Italian population) for the oral version of this test.
Both age and education influenced performance on the SDMT; therefore, correction scores were obtained on the basis of these factors. The cut-off for normality was 34.2. The availability of Italian normative data for the SDMT will allow wider application of this test in clinical practice.

KEY WORDS: information processing speed, normative data, SDMT oral version.

Introduction

Among the various parameters to consider when evaluating a subject's ability to process information, the speed at which information is analysed and inserted into the patrimony of data available for other cognitive processes is crucial. Sustained attention and selective attention both help to determine information processing speed. The term "sustained attention" indicates "the ability to maintain a consistent behavioural response during continuous and repetitive activities" (1). This function comprises two sub-components: vigilance and working memory. "Working memory" (2) is a functional component of short-term memory; it is part of an integrated system that holds and processes information for brief periods of time during the performance of a complex cognitive task (3). The term "selective attention", on the other hand, refers to the ability to avoid distractions induced by other conflicting stimuli (1).
In neuropsychological practice, effective and reliable tests are necessary to assess the various aspects of cognitive functioning. The Symbol Digit Modalities Test (SDMT) (4), a modified version of the WAIS Digit Symbol sub-test (5), is a neuropsychological test used, in clinical settings, to assess information processing speed, which is possibly determined by attentional capacity (scanning and tracking in the visuo-spatial domain) (6) and working memory (7). Performance on the written version also depends on motor speed and agility (visuo-motor coordination) (7).
Aaron Smith developed this test to screen cognitive state. It was originally published in 1973 and subsequently revised in 1982. It consists of a sheet of paper with, at the top, a sequence of nine symbols and nine corresponding numbers (key). The task sequence consists of a series of symbols, each with a blank space underneath. Within a 90-second time limit the subject is required, consulting the key as necessary, to insert the numbers associated with the symbols. The test can be administered in both written and oral modalities.
In the Digit Symbol sub-test of the WAIS, the task sequence instead consists of a series of numbers, with which symbols must be associated. The test time is still 90 seconds, but the subject is required to complete 90 stimuli rather than the 110 of the SDMT.
By reversing the stimuli sequence (symbol-digit as opposed to digit-symbol), the SDMT maintains the basic characteristics of the Digit Symbol sub-test (8) but has the advantage of requiring the association of a more familiar number with each abstract symbol (7). However, the written version places subjects with motor and coordination difficulties at a disadvantage. Therefore, in these subjects, the oral modality is preferable.
Since standardised normative data for the SDMT are not available for the Italian population, the aim of this study was to obtain normative scores for the oral version, taking into account different demographic variables (sex, age and education). We restricted data collection to the oral version because this can be more widely used with patients suffering from focal and diffuse central nervous system (CNS) pathologies.

Materials and methods

Subjects

We randomly recruited 361 healthy subjects (162 males and 199 females) from the community. Their ages ranged from 20 to 80 years (mean 50.0, SD 16.9) and their education from 5 to 19 years (mean 11.3, SD 4.4). The participants' good health was ascertained during a brief interview. No subjects were suffering from pathologies liable to influence cognitive functioning, i.e., neurological or psychiatric illnesses, from medical pathologies (e.g., hypertension, diabetes) severe enough to interfere with nervous system functioning, from alcohol or drug abuse, or from significantly impaired auditory or visual perception. All the subjects took part in the study after giving their informed consent.

Materials

Smith's (4) oral version of the SDMT was administered. In this test procedure, the subject is given a sheet of paper at the top of which is printed the key (9 abstract symbols and 9 corresponding numbers). The key is available to the subject throughout the test. A sequence of 120 symbols, each printed in a square, is presented below the key. Empty squares are located below the squares containing the symbols. The key sequence and the first line of the test are reproduced in figure 1.

In the oral version, the examiner, on a copy of the test sheet, records in the empty squares the numbers the subject associates, orally, with the symbols.

In the first test phase, the subject has to make 10 trial symbol-number associations without a time limit; the examiner corrects the subject's errors.

After this initial learning phase, the test proper begins. The subject has to make as many associations as possible within the 90-sec time limit. If the subject is able to complete all 110 associations before the time runs out, the test is interrupted. The score is the number of correct associations made by the subject.

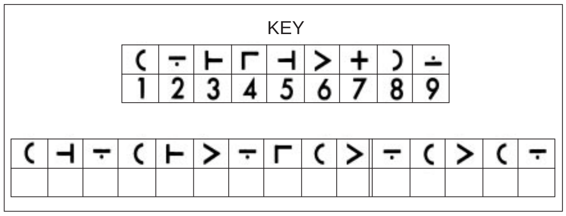

Figure 1 - Key sequence and first line of the Symbol Digit Modalities Test.

Results

Table I reports the distribution of the sample according to sex, age and education.

Considering the whole sample, the SDMT mean score was 50.7 (SD 14.1; min. 13, max. 87). None of the sub-

Table I - Distribution of the sample according to sex, age and education.

		Education (years)				
	Age	5-7	8-12	13-15	16+	Total
F	20-29	0	5	19	9	33
	30-39	1	8	9	13	31
	40-49	1	15	8	12	36
	50-59	8	8	11	11	38
	60-69	7	16	7	6	36
	70-80	17	5	3	0	25
	Total	34	57	57	51	199
M	20-29	0	4	16	6	26
	30-39	0	9	4	8	21
	40-49	0	11	6	5	22
	50-59	3	12	9	4	28
	60-69	11	6	10	8	35
	70-80	13	3	4	10	30
	Total	27	45	49	41	162
M+F	20-29	0	9	35	15	59
	30-39	1	17	13	21	52
	40-49	1	26	14	17	58
	50-59	11	20	20	15	66
	60-69	18	22	17	14	71
	70-80	30	8	7	10	55
	Total	61	102	106	92	361

Abbreviations: F=females; M=males. The table reports the number of subjects for each combination of age range and years of education.

jects reached either the ceiling (=110) or the floor (=0) of the score range.

The scores obtained by the 361 subjects on the SDMT had an interpolated distribution frequency with good approximation to the Gaussian curve, as shown by the histogram and the Q-Q plot in figure 2.

This fit to Gaussian distribution was further improved after taking into account age and education, allowing the application of regression procedures without the need for mathematical transformations of data, and in general guaranteeing greater robustness of the estimated model.

When age and education were used as explicative variables of the score (no gender effect was found), multiple linear regression provided a multiple R value of 0.744 with a corresponding R^2 determination index of 0.55, indicating that 55% of the score variance was explained by the combination of age and education. The model equation was:

$$SDMT\ score = 59.41 - 0.44 \times Age + 1.17 \times Education$$

This indicates that for each progressive year of age, the SDMT score decreased, on average, by 0.44 and increased by 1.17 for each additional year of education. These coefficients allowed us to calculate the correction scores to apply to individual subjects in order to consider the “physiological” effects of age and education.

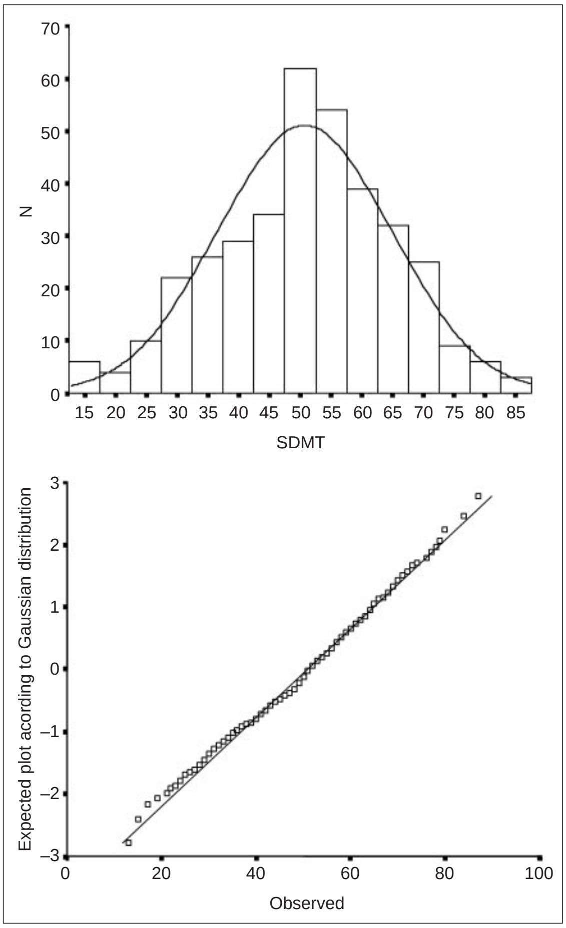

Figure 2 - Histogram of SDMT distribution (upper) and corresponding Q-Q plot (lower).

These values are reported in Table II, subdivided by decades of age and cycles of formal education (elementary, junior, high school, and university).

Table II - Correction scores computed for years (in bold) of age and education.

	Education			
Age	**5 (5-7)**	**8 (8-12)**	**13 (13-15)**	**16 (16+)**
25 (20-29)	–3.6	–7.1	–13.0	–16.5
35 (30-39)	+0.8	–2.7	–8.6	–12.1
45 (40-49)	+5.2	+1.7	–4.2	–7.7
55 (50-59)	+9.6	+6.1	+0.2	–3.3
65 (60-69)	+14.0	+10.5	+4.6	+1.1
75 (70-80)	+18.4	+14.9	+9.0	+5.5

Note: The correction scores can be considered approximately valid for the ranges reported in parentheses.

We calculated the cut-off scores after the raw scores had been corrected. Since the distribution of corrected scores was almost a perfect Gaussian distribution, the 5th percentile (35.5) was very close to the mean

$$- z_{1-0.05} \times SD\ (50.6-1.645*9.35=35.2).$$

The use of parametric tolerance limits in this sample (9) enabled us to determine that at least 95% of the population was above a threshold of 34.2 (lower one-sided tolerance “outer” limit). Therefore, a score lower than 34.2 had to be taken as pathological. It is worth noting that we were able to use parametric tolerance limits thanks to the Gaussian distribution and the distance of the raw scores from the floor and the ceiling of the scale. In particular, the latter feature of the SDMT scores should make indeterminacy of the position of corrected scores unlikely after adjustment for age and education. Furthermore, parametric procedures allow narrower limits, which should ensure greater sensitivity.

Discussion

Often a clinical examination is not sufficient to assess the association between cerebral damage, diffuse or focal, and impaired cognitive functioning. In this regard, detailed information can be obtained through the use of neuropsychological tests. These tests must be simple to administer, but they must have good sensitivity and specificity. Also, reliable normative data are necessary in order to classify a brain-damaged subject’s performance on a specific test as normal or pathological.

In the oral version, in particular, the SDMT (4) is easy to administer and remarkably sensitive for identifying deficits due to the presence of cerebral dysfunction (4, 6). It is not surprising, therefore, that this test is widely used in both clinical and research areas. Smith’s normative data are undoubtedly very robust due to the large size of his normal subject sample. However, these data refer to populations in the United States. Furthermore, as regards sample distribution by years of education, in Smith’s study a dichotomous distinction was made between subjects with 12 or fewer years of education and those with 13 or more years of education.

Moreover, because of socio-cultural differences in the United States and Italy, Smith's normative data should not be used to classify Italian patients' performances. Therefore, since we consider the SDMT a useful test for clinical practice as well as for experimental research, we set out to gather normative data on a sample of normal subjects demographically representative of the Italian population. We gathered data only on the oral version of the SDMT because this is the version most frequently used with brain-damaged patients.

Our normal subjects' score distribution on the oral version of the SDMT was very close to the Gaussian curve distribution. This supports the idea that the variables associated with normal subjects influence test performances in a regular fashion, and also allows the application of classical statistical methods, thus guaranteeing greater robustness of the estimated model.

Of the three demographic variables considered, gender did not significantly influence performance; therefore, as in the case of Smith's (4) normative data, in our study there was no need to separate the data for men and women. Age and education explained 55% of the score variance, making it necessary to consider both of these variables and to calculate the correction scores and then the cut-off for normality.

However, we could not compare the normative data obtained in this way with Smith's data because we had to use different age ranges and a greater distribution of educational levels in order to reflect more closely the current Italian situation. For the same reason, young subjects with low levels of education and older subjects with high levels of education were less represented in our sample. Moreover, the educational levels of subjects with acquired CNS pathologies were obviously similar to those of the normal subjects.

The normative data obtained in this study have the advantage of including a wider spectrum of ages and educational levels than Smith's data (4), facilitating the application of the SDMT in clinical and experimental settings, and allowing Italian clinicians to use this classical and useful neuropsychological tool with increased confidence. The SDMT has a very broad field of application. Since it can be administered relatively quickly, it is suitable as a screening tool or, alternatively, it can be used with other tests in many situations in which a dysfunction of attention or of working memory and information processing speed is suspected. For example, it can be used to evaluate the consequences of traumatic head injury (10,11), brain damage in children (12), ageing and dementia (13) and of other pathologies directly or indirectly involving frontal lobe functions, e.g., extra-pyramidal disorders (14,15) and multiple sclerosis (16,17), to name just a few of the main conditions.

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