Neuropsychological Trends

29
April 2021

The Paced Auditory Serial Addition Task (PASAT): normative data for the Italian population

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DOI: https://dx.doi.org/10.7358/neur-2021-029-saet

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ABSTRACT

The Paced Auditory Serial Addition Task (PASAT) is a neuropsychological instrument designed to measure attention, working memory and speed of information processing in a complex manner. It is currently used to evaluate different neurological diseases. The purpose of this study was to establish PASAT normative data for the healthy Italian population using the standardized methodology of Equivalents Scores. The brief PASAT auditory version included in the Multiple Sclerosis Functional Composite was administered to 146 healthy Italian participants, distributed for gender (70 men; 76 women), age (range 18-83) and education (8-19). We found that age and education, but not gender, were significant PASAT score predictors. PASAT normative Italian data may represent a useful application for clinicians and researchers to document mild executive deficits in different neurological populations.

Keywords: PASAT; attention; executive functions; normative data

1. Introduction

The Paced Auditory Serial Addition Task (PASAT) is a well-known neuropsychological test introduced by Gronwall (1977) to evaluate the determinants of traumatic brain injury on speed of information processing and to validate rehabilitation programs. In the original version, a set of digits is presented in a sequential random order and subjects have to add the next digit to the previous one. The result of each sum has to be vocalized before each next digit is presented (Gronwall, 1977). PASAT is a complex test able to highlight slight cognitive deficits in neurological patients. Its sensitivity could depend on its multifactorial nature (Madigan et al., 2000), requiring the interpolation of several cognitive functions for a successful performance. Attentional processes are the most involved abilities in PASAT (Spikman et al., 1996): focal attention allows the distinction between the two digits-target and distractors; sustained attention aids concentration and reduces lapses; alertness influences the speed of response to each digit presentation. The relationship between PASAT and attentional processes has been confirmed by the correlation between the patient's performance on PASAT and on other attentional tests such as Digit Span Backward, Trail Making Test part B and Symbol Digit (Royan et al., 2004; Tombaugh, 2006). The central executive system (Baddeley, 2003) also plays a prominent role during PASAT administration, as it allows for retention of digits while performing the test. Several studies suggested that PASAT scores are also likely to be influenced by mental arithmetic ability (Chronicle & MacGregor, 1998), speed of information processing (Gronwall, 1977; Fos et al., 2000) and emotional states such as anxiety (Tombaugh, 2006). Functional neuroimaging confirmed the multifactorial model of PASAT. PET studies found that PASAT activates widespread, non-contiguous foci in the superior temporal gyri, bifrontal and biparietal sites and the anterior cingulated and bilateral cerebellar sites (Lockwood et al., 2004). A similar distribution was found in fMRI and SPECT studies showing activation in the dorsolateral prefrontal cortex, right and left superior temporal gyrus, right and left medial frontal cortex and cerebellum (Hattori et al., 2009; Lazeron et al., 2003).

The early utilization of PASAT has been linked to Traumatic Brain Injury (Gronwall & Wrightson, 1981; Levin et al., 1987), but the current use has a wider clinical application, especially in neurological diseases which involve frontal or subcortical lesions in relatively young patients (< 65 years of age), such as Multiple Sclerosis and HIV infection (Moore et al., 2012; Rosti et al., 2006; Sonder et al., 2014). The PASAT has also been used in a variety of other clinical populations, including those with pain disorders (Sjøgren et al., 2000a), lupus erythematosus (Shucard et al., 2004), cancer (Sjøgren et al., 2000b), depression (Johnson et al., 1997), hypoglycemia (Gold et al., 1995;

Schächinger et al., 2003) and asthma (Weersink et al., 1997).

Different PASAT versions are in use. They vary on the basis of the stimulus presentation modality (auditory versus visual), the inter-stimulus interval of presentation (constant versus changeable) and the procedure of calculation (number of errors versus inter-stimulus interval).

In the PASAT original version, called PASAT-244 (the numbers of stimuli, Gronwall, 1977), a series of 61 pseudo-random digits is presented through the auditory canal four times and each time the interval of presentation differs (2.4; 2.0; 1.6 and 1.2 sec). This version has been criticized because the practice effect, obtained by using the same 61-digit series four times, affected the performance. With the aim of reducing the practice effect, Levin and colleagues (1987) proposed an alternative auditory version, called PASAT-200, which includes four different series of 50 digits, respectively presented with an inter-stimulus interval of 3.0, 2.4, 2.0 and 1.6 seconds. Both PASAT 244 and 200, however, require a long administration time, tend to frustrate patients and could undermine their cooperation during the clinical evaluation.

Fos and colleagues (2000) created a visual modality version of PASAT, called Paced Visual Serial Addition Test (PVSAT), in which digits are visually presented and participants have to say the sum of the digits aloud. The auditory version is known to be more difficult than the visual one because the oral articulation of the response interferes with the oral digit presentation.

Royan and colleagues (2004), created a computerized version of PASAT, called Adjusting-PSAT. This version makes the Inter-Stimulus Intervals (ISIs) contingent on the correctness of the response: during the administration, the interval between digits increases by 20 ms every time an incorrect response occurs and decreases by 20 ms whenever a correct response is made. A recent virtual reality PASAT task (VR-PASAT) has also been developed (Parsons & Courtney, 2014).

Lastly, some version of the PASAT has been incorporated into neuropsychological batteries to evaluate cognitive disorders in multiple sclerosis. Examples are the Brief Repeatable Battery of Neuropsychological Tests (Amato et al., 2006), the Minimal Assessment of Cognitive Function in Multiple Sclerosis (MACFIMS) (Migliore et al., 2016) and the Multiple Sclerosis Functional Composite (MSFC) (Fischer et al., 2001; Rudick et al., 2002; Tombaugh, 2006).

A survey of literature showed that PASAT raw scores can be influenced by sociodemographic variables such as age, education, gender, IQ and ethnicity. For example, Diehr and colleagues (1998, 2003) used a sample of 400 Caucasian and African American adults and analyzed the influence of age, education, ethnicity and gender. In this study, everything but gender had a significant effect on PASAT scores. The authors underlined that in the previous studies, IQ could have masked education and ethnicity effects. Other studies have used IQ score as a significant predictor of PASAT scores (Brittain et al., 1991; Wiens et al., 1997). However, in our opinion, the use of IQ scores as a demographic factor is a serious limitation in applying normative data to clinical populations, because premorbid IQs are rarely available.

In Italy, normative data for PASAT have been previously published (Ciaramelli et al., 2006). However, in this study single digits were replaced with numbers from 1 to 20 and this choice may have increased the arithmetical abilities demanded on PASAT performance and may have been a confounding factor when studying attentional processes.

The aim of our study was to provide Italian norms for PASAT through the standardization procedure of the Equivalent Scores (Capitani, 1997; Capitani & Laiacona, 1997, 2017) to render performance scores on PASAT comparable with those obtained on other neuropsychological tests commonly used in Italy. We adopted the PASAT auditory version included in MSFC battery (Fischer et al., 2001; Rudick et al., 2002), a relatively brief PASAT form, in order to avoid discomfort.

2. Methods

2.1 Participants

We enrolled 146 healthy Italians (70 men; 76 women) excluding those who reported a current or past history of central nervous system diseases, such as brain injury or stroke, epilepsy, diagnosis of mild cognitive impairment or dementia, hearing loss or hearing aid users, medical pathologies (e.g., hypertension, diabetes) severe enough to interfere with nervous system functioning, hospitalization or protracted treatment for psychiatric illness, and/or substance abuse. In addition, only participants with an educational level of at least 8 years were included to avoid having false positives related to the low arithmetical abilities. Sample age ranged from 18 to 83 (mean = 46.45; *SD* = ± 16.26), and education from 8 to 19 years (mean = 13.05; *SD* = ± 4.05). The demographic characteristics of the sample are presented in Table 1. All the subjects gave their informed consent, and the study had full ethical approval. The study was carried out in accordance with the Declaration of Helsinki on Ethical Principles for Medical Research.

Table 1. Distribution of the experimental sample according to age and education level. Values are numbers of participants

Age (years)	Education (years)			Total
	8-12	13-16	≥17	
18-29	5	9	13	27
30-39	9	9	9	27
40-49	10	13	6	29
50-59	9	8	10	27
60-69	11	7	7	25
≥70	5	3	3	11
Total	49	49	48	146

2.2 Procedure

Before proceeding to the PASAT administration, all the subjects underwent a neurologic examination to exclude, as far as possible, those with neurological abnormalities. Experienced neuropsychologists administered the PASAT in a quiet room. PASAT was composed of 61 single digit numbers, presented through the auditory canal. Digits were administered by using a recording file containing an Italian-language pre-recorded voice (Online Resource 1). The inter-stimulus interval was 3 seconds. The computerized file we used allowed us to control the ISI accuracy. During the test, each participant was asked to sum the two most recent digits of the series. For example, if the digits "3" and then "5" were presented, the participant should have responded "8"; if, after the digit "5", the digit "6" was presented, the participant should have responded "11". The answer was manually scored as correct only when it was given prior to the presentation of the next digit (Appendix A). Because the rate of presentation was 3 seconds, the test lasted about three minutes. The score we used was the number of correct responses (maximum = 60). PASAT administration was preceded by an oral explanation phase and a practice trial. Participants were given the following instructions:

"*You are going to hear a long series of single digit numbers, coming from the computer loudspeaker. The voice you will hear is going to say a number every three seconds. Every time you hear a new number, you have to sum the last number presented to the second last one and you have to say aloud the result. For example, the voice will say the first number and you shouldn't say anything. Then the voice will say the second number, and you should add the first number to the second one. You will hear then the third number, and you will have to add the second number to the third one, and so on. Continue to add the next number to the previous one".*

Because of the PASAT's complexity, we decided to inform participants in advance of difficulties they could face while performing the test and we suggested how to overcome them:

"You should pay attention not to add the next number of the series to the result of the sum you've just said. You have to consider that, because the digits range from 1 to 9, your answer should not be greater than 18. If you realize that your answers are progressively increasing and that they are higher than 18, you should be aware that you're not following the correct instructions. You should also consider that PASAT is a long test. Not being able to keep up with the numbers during PASAT performance is quite normal. When it happens, don't worry, you should try to concentrate again and to continue the test".

After the oral explanation, participants were submitted to a brief 11-digit practice trial. If, during the practice trial, instructions were thought to have been misunderstood, the run-in phase was repeated. Prior to analysis, age, education, gender and the PASAT, scores were examined for accuracy of data entry and fit between their distribution and the assumption of multivariate analysis.

2.3 Data analysis

Analyses were performed using SPSS Statistics for Windows, version 15.0 (SPSS Inc., Chicago, Ill., USA).

For PASAT standardization, the Equivalent Scores (ES) procedure was followed (Capitani, 1997; Capitani & Laiacona, 1997, 2017). ES methodology allows a direct comparison among performance on different neuropsychological tests within and between individuals (see Capitani, 1997 for psychometric details). The influence of age, education and gender was evaluated through linear models of covariance. In order to check for the linear model to be the best choice to shape the relationship between age and PASAT score, the quadratic component of age was tested for significant contribution in accounting for variance of the dependent variable. Power polynomials method was used to test the curvilinear quadratic fit of this relationship (Cohen et al., 2003).

The transformation of the concomitant variables that proved to be most effective in reducing the residual variance was adopted. The effect of each concomitant variable was tested within the complete model by removing the effect held in common with the other variables. Expected scores were derived from this method by taking into account demographic variables which significantly influenced PASAT scores.

Multiple regression analysis was performed to check for the presence of an interaction effect between variables that significantly influence PASAT scores (Aiken & West, 1991). It allowed the testing of the significance of the interaction term (Cohen, 1978; Cohen et al., 2003).

Starting from the linear model equation, adjusted scores for each participant were calculated by adding to or subtracting the contribution of the significant concomitant variables from the raw score. Adjusted scores were subsequently converted into a 5-point ordinal scale to obtain ES, in which 0 indicates scores equal or higher than the outer tolerance limit (5%) and 4 the equal or better scores than the median value of the sample. ES of 1, 2 and 3 are intermediate scores between the central value and the pathology threshold (Capitani & Laiacona, 2017).

3. Results

Table 2 shows PASAT mean scores and standard deviations of the 146 participants grouped by age and education. With the use of a $p < .001$ criterion for Mahalanobis's distance, no multivariate outliers among the variables were found. Homoscedasticity was examined via scatter plots indicating reasonable consistency of spread through the distributions. No significant correlations among gender, age and education were found indicating that multicollinearity was unlikely to be present. This hypothesis has been further confirmed by collinearity diagnostics results.

Table 2. PASAT mean values and, in round brackets, standard deviations, divided per age and education groups over 146 participants

Age (years)	Education (years)			Total
	8-12	13-16	≥17	
18-29	41.80 (8.76)	53.89 (6.62)	54.23 (7.54)	51.81 (8.67)
30-39	42.78 (6.50)	42.11 (10.49)	51.78 (8.33)	45.56 (9.40)
40-49	44.20 (7.98)	48.38 (9.94)	47.67 (11.36)	46.79 (9.47)
50-59	35.44 (6.39)	41.75 (8.65)	54.70 (7.15)	44.44 (11.00)
60-69	37.55 (7.93)	39.57 (14.02)	51.14 (5.98)	41.92 (10.93)
≥70	36.60 (11.87)	43.00 (4.58)	45.67 (7.02)	40.82 (9.37)
Total	39.82 (8.30)	45.57 (10.59)	51.29 (8.03)	45.77 (10.29)

The results from the polynomial multiple analysis of regression of PASAT score on age are displayed in Table 3. The addition of the quadratic component did not significantly improve the R^2 value.

Table 3. Polynomial Multiple Regression Analysis of Pasat score on Age

Hierarchical Model

Equation	*IVs*	*I*	F_I	*df*
Linear	Age	.092	14.593***	1,144
Quadratic	Age, Age^2	.003	0.450	1,143

***$p < .001$

Note: I is the increment of R^2

Both age and education were found to significantly influence the PASAT score whereas gender was not influential (Table 4). Regarding interaction, the cross-product term was found not to statistically influence PASAT score.
The linear model which proved to be most effective in reducing the residual variance was:

$$Y = 45.77 - (0.150 * age) + (1.41 * education)$$

where Y represents the participant's predicted PASAT score, based on their age and education. This model accounts for 28% of the variance.

Two equations were derived from the linear model:

- the first one allows to obtain adjusted scores from raw scores:

$$Sa = Sr + 0.15 * (age - 45.38) - 1.41 * (education - 13.05)$$

where *Sa* and *Sr* represent respectively the adjusted scores and the raw scores;

- the second one shows the points to add to or subtract from raw scores in order to obtain adjusted scores (correction grid):

$$A = 0.15 * (age - 45.38) - 1.41 * (education - 13.05)$$

where *A* represents the correction. Adjustment of raw scores decreases the influence of age and education and allows comparisons among the performance of participants with different ages and educations.

Table 4. Regression model significance

		P
Education	$F(1,143) = 39.744$	< .001
Age	$F(1,143) = 10.980$	.001
Gender	$F(1,144) = 0.616$	ns

Table 5 shows the correction grid obtained by combination of different ages and education to allow adjustment of raw scores of newly tested individuals. To calculate equivalent scores, adjusted scores were sorted in an ascending order. Table 6 shows the adjusted scores values which delimit equivalent scores, the number of participants of the sample comprising each equivalent score (density) and the cumulative frequency of participants with 0 to 1, 2, 3 and 4 ES. The value of the third sample observation represents the outer non-parametric tolerance limit: values equal to or lower than 28.94 indicate a pathological performance and correspond to a 0 equivalent score.

An equivalent score of 1 is given when the adjusted score ranges from 28.95 to 30.89. Adjusted scores between 30.90 and 38.57 coincide with an equivalent score of 2, whereas 3 is assigned to adjusted scores from 38.58 to 47.44. Finally, values equal to or higher than 47.45 correspond to a 4 equivalent score value. Because of the low representativeness of the 70-83 age group, the correction values applied to this subgroup are based more on the linear model than on the sample score.

Table 5. Correction grid according to age and education for raw PASAT scores

Age (years)	Education (years)		
	8	13	17
20	1.79	-3.91	-8.47
25	2.54	-3.16	-7.72
30	3.29	-2.41	-6.97
35	4.04	-1.66	-6.22
40	4.79	-0.91	-5.47
45	5.54	-0.16	-4.72
50	6.29	0.59	-3.97
55	7.04	1.34	-3.22
60	7.79	2.09	-2.47
65	8.54	2.84	-1.72
70	9.29	3.59	-0.97
75	10.04	4.34	-0.22
80	10.79	5.09	0.53

Table 6. PASAT Equivalent Scores. ES limits and distribution of ES within the sample

Equivalent Scores	Score Interval	Density	Cumulative Frequency
0	0-28.94	3	3
1	28.95-30.89	10	13
2	30.90-38.57	23	36
3	38.58-47.44	37	73
4	47.45-60	73	146

4. Discussion

The aim of this study was to offer Italian norms for the PASAT auditory form extrapolated from the MSFC battery. This reduced version to 61 required stimuli only takes 10 minutes to administer, and offers clear advantages in terms of reduced mental load and a more modest level of frustration and anxiety potentially induced by the traditional PASAT. Hence, this short version leaves more space for use in subjects with slight anxiety or mild depression. Another advantage is to foresee only one set of stimuli in order to prevent practice effect; in fact, this could prevent the subject from developing effective strategies to obtain better performance, which can happen in the more extended versions of the PASAT.

The test was administered to 146 healthy Italian participants, distributed for gender, age and education. We found that both age and education significantly influenced PASAT score, while gender did not. The decrease of PASAT scores with age in adults agrees with results found in several studies (Brittain et al., 1991; Ciaramelli et al., 2006; Diehr et al., 1998; Roman et al., 1991; Vanotti et al., 2016; Wiens et al., 1997).

The absence of a significant gender effect is also in agreement with most of the literature (Amato et al., 2006; Boringa et al., 2001; Ciaramelli et al., 2006; Wiens et al., 1997). In contrast, our result differs from those of Brittain and colleagues (1991) and Vanotti and colleagues (2016), who found that gender affected PASAT performance.

As regards the education effect, evidence in the literature is uncertain. Significant education effect has been demonstrated by previous studies (Amato et al., 2006; Boringa et al., 2001; Diehr et al.,1998; Vanotti et al., 2016), whereas other authors (Brittain et al., 1991; Wiens et al., 1997) which concluded that educational level was not influential, although they considered IQ level as a demographic covariate. Since the premorbid IQ of brain damaged patients is rarely available, we decided not to include the IQ level in the linear model. Moreover, Stuss and colleagues (1987) have suggested that the relationship between education and performances on PASAT may be due to the influence of calculation ability required by the test. For this reason, in order to avoid false positive cases, our recommendation is to administer the test only to subjects with at least Middle School education and no relevant attentional deficits or auditory impairment. Another limitation of the PASAT short version concerns the use of a single ISI that may decrease the difficulty of the test and its sensitivity. However, we believe that a single-repetition version of the PASAT could be a useful tool for clinical practice, in its application to a wide range of patients.

In conclusion, we believe that through the brief PASAT auditory version, Italian normative data may allow clinicians and researchers to achieve a validated result of executive functions in various clinical populations and avail of a useful measure to correlate with the results from other neuropsychological tests.

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APPENDIX A

Stimuli of the Paced Auditory Serial Addition Task (PASAT)

Istruzioni: "*Ascolterà una lunga serie di numeri a una cifra, provenienti dal computer. La voce che ascolterà pronuncerà un numero ogni tre secondi. Ogni volta che sente un nuovo numero, deve sommare l'ultimo numero presentato al penultimo e deve dire ad alta voce il risultato. Ad esempio, la voce pronuncerà il primo numero e lei non dovrebbe dire nulla. Quindi la voce dirà il secondo numero e lei dovrebbe aggiungere il primo numero al secondo. Sentirà quindi il terzo numero e dovrà aggiungere il secondo numero al terzo e così via. Continui ad aggiungere l'ultimo numero al penultimo. Dovrebbe prestare attenzione a non aggiungere l'ultimo numero della serie al risultato della somma che ha appena detto. Deve considerare che, poiché le cifre vanno da 1 a 9, la sua risposta non dovrebbe essere maggiore di 18. Se si rende conto che le sue risposte stanno progressivamente aumentando e che sono maggiori di 18, dovrebbe essere consapevole che non sta seguendo le istruzioni corrette. Dovrebbe anche considerare che il PASAT è un test lungo. Non essere in grado di tenere il passo con i numeri durante le prestazioni del PASAT è abbastanza normale. Quando succede, non si preoccupi, dovrebbe provare a concentrarsi di nuovo e continuare il test. Facciamo una prova prima di iniziare il test*".

TRIAL

9+1	**10**	________	4	**10**	________
3	**4**	________	9	**13**	________
5	**8**	________	7	**16**	________
2	**7**	________	1	**8**	________
6	**8**	________	4	**5**	________

TEST

1 + 4	**5**	____	3	**10**	____	8	**11**	____	4	**6**	____	7	**16**	____
8	**12**	____	5	**8**	____	1	**9**	____	8	**12**	____	9	**16**	____
1	**9**	____	3	**8**	____	7	**8**	____	3	**11**	____	3	**12**	____
5	**6**	____	6	**9**	____	4	**11**	____	1	**4**	____	1	**4**	____
1	**6**	____	8	**14**	____	9	**13**	____	8	**9**	____	5	**6**	____
3	**4**	____	2	**10**	____	3	**12**	____	5	**13**	____	7	**12**	____
7	**10**	____	5	**7**	____	7	**10**	____	7	**12**	____	4	**11**	____
2	**9**	____	1	**6**	____	2	**9**	____	1	**8**	____	8	**12**	____
6	**8**	____	5	**6**	____	6	**8**	____	8	**9**	____	1	**9**	____
9	**15**	____	4	**9**	____	9	**15**	____	2	**10**	____	3	**4**	____
4	**13**	____	6	**10**	____	5	**14**	____	4	**6**	____	8	**11**	____
7	**11**	____	3	**9**	____	2	**7**	____	9	**13**	____	2	**10**	____

PG ________

PC ________

PE ________