

A Study to Determine the Norms for The Trail Making Test for the Age Range of 20-49 in Turkey



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SUMMARY

Objective: The main goal of the study is to determine the normative values of the Trail Making Test (TMT) for people between 20-49 years of age; to examine the effect of age, education and sex variables over TMT scores and to identify the reliability coefficient of the test.

Method: The sample of the study consisted of 133 women and 130 men, 261 voluntary and healthy participants in total. The data of the research was collected according to a 3x2x2 factorial experimental design; and the participants were distributed to experimental conditions well balanced in terms of levels of age, education and sex. TMT A and B form, and Beck Depression Scale (BDS) were applied for the assessment.

Results: Seven scores were calculated to determine Turkish normative values; 3x2x2 factorial multivariate variance analysis was applied in order to identify the effect of levels of age, education and sex over TMT scores. According to the results of the analyses, it was found that education significantly influenced the scores, while age and sex variables did not ($p < .05$). The test-retest reliability coefficients of the TMT changed between .71 and .87.

Conclusion: This study indicates that TMT B and subtest scores, in particular, were affected by education in subjects within the age range of 20-49 years. Additionally, normative values depending on the means of TMT scores for 20-49 age group were obtained in the study; TMT was demonstrated to be a reliable assessment tool.

Key Words: Trail Making Test, neuropsychological tests, standardization, executive functions

INTRODUCTION

The Trail Making Test (TMT) was first developed by the psychologists employed in the Army of the United States of America (Reitan 1955), and it is among the most commonly used neuropsychological tests globally. TMT that measures the executive functions including the working memory, complex attention, planning and set shifting, is a test that requires visual-spatial processing and motor skills. TMT consists of two parts, namely, A and B. TMT is an executive function

test; Part A of TMT evaluates the speed of processing based on visual detection skill, while the part B evaluates the skill of set switching between stimulus sets and following the sequence (Reitan 1958, Crowe 1998). The completion time of part B is longer in comparison with the completion time of part A, and part B requires more visual-spatial processing because of its complex structure (Lezak 1995). In addition, the level of difficulty of the part B is higher as compared to part A, as it requires more motor speed, agility and attention (Schear and Sato 1989).

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In the relevant literature, the normative values in the frame of the standardization of TMT have been commonly created based on the completion times of the test. The normative data studies were created with an emphasis on test completion time scores (Tombaugh 2004, Steinberg et al. 2005). The aging process that affects motor speed (Shimoyama et al. 1990), and the completion time for both parts of TMT is prolonged with increasing age (Steinberg et al. 2005). Although the period required for completion of the test increases with age, the completion time for part B in the elderly population is longer than that of part A, because of the level of difficulty of tasks in both subparts are different (Lezak 1995). Although the completion times for parts A and B are also affected by educational level, the effect of educational level indicates a difference when compared to subtests. The effect of education on the time score of part B is greater (Tombaugh 2004).

It is commonly mentioned in the relevant literature that TMT scores are not affected by sex (Robins-Wahlin et al. 1996, Vakil et al. 2009, Waldmann et al. 1992). In contrast, TMT normative values have been separately created for males and females. In a study carried out in elderly participants, it was reported that males completed the TMT faster than females (Elias et al. 1993). Further, results of the standardization study carried out in our country for TMT scores on a Turkish elderly adult population over 50 years of age have shown that the main effect of gender on TMT time A and B time scores and TMT time A+B times scores are significantly different, and scores were different with regard to gender, as observed in the A and B timer scores of TMT (Cangöz et al. 2009). However, although there are studies with large samples that have demonstrated a significant influence of sex TMT scores (Wiederholt et al. 1993); results obtained in studies carried out on specific age groups have given conflicting results (Soukap et al. 1998, Tombaugh 2004).

The cognitive and behavioral characteristics measured by TMT are not limited with time scores. In fact, in the relevant literature it was observed that evaluations involving the time difference for both parts (Arbuthnott and Frank 2000), time rates (Lamberty et al. 1994) and derived subtest scores based on the sum of the times for both parts have been made in addition to the completion time scores and parts A and B. These scores are highly correlated with the cognitive skill tests, and are negatively affected by different cognitive disorders (Carrigan and Hinkeldey 1987). With the B-A score based on the difference in completion times for both parts, the effect of the speed component is eliminated, and therefore, precise measurement of attention, flexibility and set shifting is provided (Holtzer et al. 2005). The time rate derived by dividing the completion time for Part B by the completion time for Part A (B/A) is used for the evaluation of the executive functions. In addition, the derived B/A subtest score displays a strong correlation with the tasks requiring switching between

the cognitive sets (Arbuthnott and Frank 2000) with age and educational level. Thus, it has been stated that the B/A derived subtest score is a suitable scanning variable for the evaluation of disorders related to executive functions (Lamberty et al. 1994). Likewise, the A+B score found as the sum of the scanning time scores of both parts are sensitive for the stages of dementia, and the total scanning time prolongs in parallel with the progression of dementia (Gaul and Brown 1970).

In addition to the TMT time score and its derivatives, scores related to the number and type of error are also calculated. However, the findings of the studies on this issue are controversial. Although, there are some studies showing that error analyses do not have the same effect in this issue (Klusman et al. 1989), there are also studies indicating the reverse (Horton 1979). The TMT B error scores increase related to age; however, no significant changes are observed in the TMT A scores (Rasmusson et al. 1998). On the other hand, the TMT error rate is less sensitive for age-dependent slight differences as compared to the TMT completion time score (Ashendorf et al. 2008). In other words, it maintains the feature of being a suitable measurement tool that can be used in the evaluation of cognitive functions for life, since the error scores do not increase proportionally with increasing age.

Because of the easiness of the TMT application and scoring and its sensitiveness for neuropsychological disorders, it has been adapted and standardized for many cultures. TMT provides important information for the evaluation of dementia types including Alzheimer disease and frontotemporal dementia and the disorders involving the deterioration of executive functions including visual-motor scanning, planning, set shifting or complex attention (Lezak 1995). Consequently, normative data studies, both in Turkey (Cangöz et al. 2009) and abroad (Heister et al. 2005, Hashemite et al. 2006) have been carried out mostly on individuals who are 50 years old or older. In the study of Cangöz et al. (2013) also, cut-off values were determined for all the subtest scores; the results of the study have shown that TMT time scores (A, B, A+B, A-B) are effective measurement tools to differentiate with Alzheimer type dementia (AD) from healthy individuals; and the result of ROC analysis demonstrated that the TMT B time scores and A+B derived subtest time scores are sensitive and specific for the differentiation of AD patients from healthy individuals (Cangöz et al. 2013). Results of the Baştuğ et al. study (2013) on the Oral Trail Making Task (OTMT), which is the oral version of TMT, have shown that TMT is capable of significantly differentiating AD patients from healthy individuals.

The number of studies investigating the effects of demographic variables on the TMT scores is relatively small in number (Tombaugh 2004, Zalonis et al. 2008, Hamdan and Hamdan 2009). Although TMT is widely used in clinical sessions, the normative values for groups under 50 years of age in Turkey do not exist. Cognitive disorders are not unique for

individuals older than 50 years of age. The neuropsychological tests which have been standardized and used in the clinical evaluations and basic scientific studies in Turkey are indispensable assessment tools, not only for patients with dementia older than 50 years of age; but also for the evaluation all kinds of cognitive disorders and therapeutic activities for individuals of younger age groups. One of the basic objectives of this study is to obtain the normative values of TMT for individuals in the 20-49 age range in Turkey. Another objective of the study was to determine if TMT scores differed according to age group, educational level and gender. In addition, we aimed to evaluate the calculation of the reliability coefficients of the TMT with the test-retest method in this study.

METHOD

Participants

The study consisted of 272 participants included in the 20-49 age range. Since eleven participants with extremely marginal values were excluded, the final sample of the study consisted of 261 participants, 133 females and 130 males. One hundred and twenty-two participants had an educational experience between 6 and 11 years, and 139 participants had educational experiences of 12 years or more. The sample consisted of healthy volunteers residing in Bursa, working in public or private entities and/or retired from such entities. Participants were reached using the snowball sample method. The medical and/or psychiatric histories of each participant were obtained based on their oral expressions. Participants diagnosed with any psychiatric or neurological disease or using any drugs that affect the cognitive processes were excluded from the sample. Furthermore, participants who obtained 17 points or higher in the Beck Depression Scale (Beck 1961) were excluded from the study.

The number of participants was determined with 3 (Age: 20-29, 30-39, 40-49) x 2 (educational level: 6-11 years, 12 years and over) x 2 (gender: male, female) factorial research design, and the number of participants under the experimental conditions ranged between 19 and 26. The distribution of the participants according to conditions and their demographic characteristics are given in Table 1.

Table 1. Mean age and standard deviation values of participants (ages between 20 and 49) depending on gender and education level

Age Groups	Between 6 and 11 years		12 and above years	
	Female	Male	Female	Male
20-29	25.32±2.45 (n=19)	25.00±2.51 (n=22)	25.05±2.16 (n=21)	24.72±2.54 (n=25)
30-39	34.35±2.52 (n=20)	34.32±2.54 (n=19)	34.46±2.64 (n=26)	33.95±2.75 (n=21)
40-49	44.65±2.84 (n=23)	43.53±2.59 (n=19)	45.00±3.12 (n=22)	44.67±3.16 (n=24)

MATERIALS

Trail Making Test: The TMT is a test that requires visual-motor and conceptual scanning, motor speed, planning, digital information, abstract thinking, inhibition of response tendency created by the physical properties of the stimulus, set shifting, concentration and tolerance against inhibition (Lezak 1995). The TMT consists of two parts, namely, the parts A and B. Stimulus items are scattered on the test form in both parts. Numbers were used as the stimulus item in part A, and the task of the participant was to join the circles including numbers successively and in the correct order (1-2-3-4-5...). Part B includes letters and digits placed within circles, and task of the participant is to link the letters and digits in the correct consequent order (1-A-2-B-3-C-4-D...) with straight lines. The TMT application materials consist of four pages in A4 size and for each of the parts A and B, there are practice and test sections on each page.

Original forms of parts A and B of TMT were used in the study. Unlike the original of the test, letters “Ç”, “Ğ” and “İ” of the Turkish alphabet have been added in the Part B (Cangöz et al. 2009). No limitations were set on the completion time of the test, and apart from the completion time of the tests, the number of error and the derived subtest scores were calculated for both parts.

Although different methods have been suggested for the scoring of TMT, seven scores were calculated for the complete TMT in the context of the present study: completion time for part A (Time A); completion time for Part B (Time B); within the period of completion of Part A, the number of erroneous actions of the participant, after which the participant is taken back to the previous circle with the warning of the researcher to obtain the correct result (Error A); within the period of completion of Part B, the number of erroneous actions of the participant, after which the participant is taken back to the previous circle with the warning of the researcher to obtain the correct result (Error B); the time difference score obtained by subtracting the completion time for Part A from the completion time of the Part B (B-A); sum of the completion times for Parts A and B (A+B); and the time ratio found by dividing the completion time of Part B by the completion time of the Part A (B/A). Completion time scores of TMT and its derivatives are calculated in seconds. The TMT scores used in this study are the same with the TMT scores used in the study of Cangöz et al. (2009), except for the B/A time score and the TMT number of corrections.

Beck Depression Scale (BDS): The BDS was designed by Beck (1961) with the purpose of measuring the severity of depression in adolescents and adults, monitoring changes related to treatment and identifying the disorder. The BDS consists of 20 items, and administration takes about 15 minutes. In the evaluation of the scale, 0-9 points are interpreted as minimal depression, 10-16 points as mild, 17-29 points as medium and

Table 2. Mean and standard deviation values of TMT time subtest scores depending on age, education level and gender *

Score	Education level	Gender	20-29	30-39	40-49
A time	6-11 years	Female	36.47±11.07	40.55±13.11	38.61±11.67
		Male	35.82±8.86	33.05±10.78	36.05±10.80
	12 years and above	Female	36.14±7.37	35.46±9.58	38.73±10.63
		Male	34.08±12.32	35.48±9.44	38.13±9.53
B time	6-11 years	Female	80.26±32.21	92.55±27.79	94.96±32.81
		Male	85.14±29.84	71.58±25.94	81.37±27.76
	12 years and above	Female	67.57±24.82	70.58±20.11	72.50±25.13
		Male	66.68±22.81	68.43±23.18	79.63±24.72
B-A	6-11 years	Female	43.79±24.59	52.00±30.75	56.35±27.87
		Male	49.32±26.89	38.53±20.15	45.31±24.85
	12 years and above	Female	31.43±21.57	35.11±17.33	33.77±22.21
		Male	32.60±17.78	32.95±21.70	41.50±23.63
A+B	6-11 years	Female	116.74±41.42	133.10±30.70	133.56±40.60
		Male	120.95±34.85	104.63±34.24	117.42±34.02
	12 years and above	Female	103.71±29.59	106.04±26.30	111.23±31.56
		Male	100.76±32.07	103.90±27.96	117.75±29.08
B/A	6-11 years	Female	2.18±0.60	2.51±1.11	2.61±1.00
		Male	2.41±0.85	2.21±0.60	2.33±0.81
	12 years and above	Female	1.87±0.52	2.05±0.56	1.94±0.60
		Male	2.02±0.54	2.00±0.77	2.16±0.68

*TMT time and subtest scores depending on time were calculated in terms of seconds.

30-63 points are interpreted as severe depression. The validity and reliability studies for the scale in Turkey have been carried out previously (Tegin 1980, Hisli 1989).

Procedure

In the scope of TMT standardization study, six practitioners who will implement the test were trained on application and scoring of the tests. A preliminary interview was made with the potential volunteers before the application. In this preliminary interview, participants were informed about the study and evaluated with regard to inclusion criteria. The BDS was administered to participants who met these criteria, and participant with scores equal to or higher than 17 were excluded from the study. Applications were performed in houses or workplaces of participants after eliminating the potential environmental variables that may affect test performance.

Applications were given individually according to the instructions of TMT. A chronometer was used to measure test completion time. The completion time of the test were recorded in seconds for each part, and the subtest scores derived from time scores (B-A, A+B, B/A) were calculated. The error score for each part of TMT was obtained by counting the errors for each participant.

RESULTS

Before starting the analyses, we determined whether or not the data had a normal distribution. Time spent to complete for parts A and B and the subtest scores derived from times were converted into z scores. Outliers (n=11) with z-scores greater than ± 3.00 were discarded. After excluding the outliers from the sampling, the skewness and kurtosis values of the distribution were determined for each experimental condition, and the histogram values were examined visually. After concluding that the data had normal distribution, the final analyses were performed on the raw data obtained from 261 participants in total. Parametric statistical techniques were used to determine the effects of the predictive variables on the time and derived subtest scores. On the other hand, since the error scores are non-continuous variables, non-parametrical statistical techniques were used in the analyses of these scores.

Findings Related to the TMT Completion Time and Index Scores

The mean values and standard deviations of TMT scores obtained from 261 participants according to age, educational level and gender are given in Table 2. With the purpose of determining whether or not the time A, time B, B-A, A+B and

Table 3. MANOVA summary table of TMT time subtest scores according to predictive variables (F values)

	A Time	B Time	B-A	A+B	B/A
Age Level	1.092	1.910	1.203	2.101	0.792
Education Level	0.105	16.551***	19.853***	11.483***	16.175***
Gender	2.889	1.675	0.490	2.529	0.004
Age x Education Level	0.343	0.109	0.108	0.158	0.087
Age x Gender	0.334	1.421	1.218	1.301	1.309
Education Level x Gender	1.051	2.915	2.161	2.915	1.528
Age x Education Level x Gender	0.978	1.676	1.373	1.686	0.796

***p<.001

B/A scores differed significantly with age, educational level and gender, multivariate analysis of variance (MANOVA) with 3x2x2 factor was applied. With the purpose of seeing if the models created after the analysis were significant, values from the multi-variable test statistical method, Wilks' Lambda values, were examined. Accordingly, models related to the basic effects of age ($\lambda=.962$, $F=1.602$, $p<.145$) and gender ($\lambda=.986$, $F=1.180$, $p<.318$); the interaction effects between age and educational level ($\lambda=.991$, $F=.391$, $p<.885$), age and gender ($\lambda=.976$, $F=.995$, $p<.428$), educational level and gender ($\lambda=.982$, $F=1.479$, $p=.221$); and the triple interaction between age, educational level and gender ($\lambda=.977$, $F=.962$, $p<.450$) were found not to be significant. Based upon these findings, the completion times for the parts A and B of the Trail Making Test and the subtest scores derived from times do not show significant differences in the 20-49 age range and is not affected by gender. On the other hand, it was found that the Wilks' Lambda value of the model used to examine the basic effect of the educational level was significant ($\lambda=.924$, $F= 6.793$, $p<.001$). The MANOVA results related to the TMT time and derived subtest scores are summarized in Table 3. Upon examining the MANOVA results related to the educational level variable in detail, it was found that the completion time for the Part B ($F_{1-260}=16.551$, $p<.001$); B-A ($F_{1-260}=16.551$, $p<.001$), A+B ($F_{1-260}=11.483$, $p<.001$) and B/A ($F_{1-260}=16.175$, $p<.001$) derived subtest scores differed significantly based on educational level. On the other hand, the completion time for part A was not affected by educational level in the group of 20-49 years of age ($F_{1-260}=0.105$, $p<.747$). The mean values of TMT scores according to educational level, age group, and gender are given in Table 4.

Considering the mean values of TMT scores that differ significantly with educational levels, it was seen that participants with educational periods of 12 years or more completed the test in shorter times as compared to participants with educational periods of 6 to 11 years; similarly, the subtest scores derived from test times favored the participants with educational periods of 12 years or more.

Findings related to the TMT Error Scores

Considering the percent error of part A in TMT, it was seen that 88.5% of the participants did not make any errors, while 8.4% made 1 error, and 3.1% made 2 errors. On the other hand, the error rates in part B are higher as compared to part A. In part B, while 48.3% of the participants did not make any errors, 32.2% made 1 error, 13% made 2 errors, and 6.5% made 3 or more errors, and the maximum number of errors in part B was 7 (0.04%). Considering the percent error, it is seen that rate of not making an error is higher than rate of making an error. Since the error scores for parts A and B are discontinuous variables, non-parametric statistical techniques were used in the analyses of error scores. The effect of the age group variable on the error scores was analyzed using the Kruskal-Wallis Test, and the effect of educational level and gender variables were analyzed using the Mann-Whitney U Test. As a result of the analysis, it was found that the error scores of the part A ($X^2=.169$, $p<.919$) and the error scores of the part B ($X^2=2.020$, $p<.364$) did not differ significantly. The difference between the variables of educational level ($U=8353.50$, $p<.709$) and gender ($U=7986.50$, $p<.117$) were not significant with regard to part A. Similarly, the error score in part

Table 4. Mean, standard deviation and confidence interval values of TMT time and subtest scores according to education level *

	6-11 years		12 years and above	
	X $\pm$ sd	Confidence Interval (%95)	X $\pm$ sd	Confidence Interval (%95)
A time	36.83 $\pm$ 11.12	34.83-38.82	36.29 $\pm$ 9.94	34.63-37.96
B time	84.75 $\pm$ 30.05	79.36-90.13	70.96 $\pm$ 23.42	67.04-74.89
B-A	47.92 $\pm$ 26.30	43.20-52.63	34.67 $\pm$ 20.60	31.21-38.12
A+B	121.57 $\pm$ 36.89	114.96-128.19	107.26 $\pm$ 29.50	102.31-112.21
B/A	2.39 $\pm$ 0.85	2.23-2.54	2.01 $\pm$ 0.61	1.91-2.11

*TMT time and subtest scores depending on time were calculated in terms of seconds

B did not differ significantly from the educational level ($U=8097.50$, $p<.497$) and gender ($U=7610.50$, $p<.108$) variables.

Reliability Findings

The reliability study of the test was carried out with 24 participants from the sample in which normative data were collected. Participants displayed a balanced distribution with regard to educational level and gender: the reliability coefficient of the TMT scores was determined with test-retest technique on 12 participants with 6 to 11 years of education (6 females and 6 males) and 12 participants with 12 years of education (6 females and 6 males). The test-retest interval was 30 days. In the Pearson Product of Moments Correlation analysis, it was found that the scores of time A ($r=.87$), time B ($r=.77$), B-A ($r=.71$), A+B ($r=.82$) and B/A ($r=.76$) were significantly different ($p<.001$). Accordingly, the TMT time scores and subtest scores derived in relation with time have a consistent and decisive structure within the time sample.

DISCUSSION

In the scope of the objectives of the study, in a sampling in Turkey, the study consisted of healthy individuals under 50 years of age, with aims to see if TMT scores differed significantly according to age group, educational levels and gender, and reliability coefficients were calculated. Furthermore, the normative values of TMT scores based on mean values were obtained for three different age groups based on educational levels and gender.

It was shown in this study that the completion times of parts A and B and the derived subtest scores (A+B, B-A, B/A) did not differ in the 20-49 age group. Likewise, in the Brazilian standardization study carried out by Hamdan and Hamdan (2009) covering an age range of 18-81, it was shown that the A and B time scores did not differ significantly till 50 years of age, while the time scores differed in groups older than 50 years of age. Similarly, the B-A and B/A derived subtest scores of individuals under 50 years of age significantly differed depending on the age (Drane et al. 2002). In this context, the finding of this study that TMT time and derived subtest scores were not affected from the age variable is consistent with the related literature. The change in TMT scores appearing in relation with age are observed in individuals over 50 years of age. The B-A and B/A derived scores of individuals over 70 years of age are significantly different from those of younger individuals (Drane et al. 2002). Likewise, it was shown in a study on a Turkish sampling 50 years or older that TMT time scores and the correction scores for the subtests were affected by age (Cangöz et al. 2009). This result is rather important since it shows that there are differences in subjects 50 years and older with regard to executive functions including visual-motor scanning, planning, organization, abstraction and

changing sets. Age has a critical importance in the evaluation of the TMT performance, particularly in individuals older than 50 years (Elias et al. 1993), because the response time elongates in the healthy elderly population, as a part of the aging process, particularly with respect to motor speed (Soukup et al. 1998). This is attributed to the negative effects of the aging process on the frontal lobes (Pfefferbaum et al. 1994) and related executive functions (Grieve et al. 2007).

In this study, it was found that the effect of the age variable on the error scores in parts A and B were insignificant. Frequency of error related to age is higher in part B. This finding is consistent with the findings of Horton's study (1979). The error rate is less sensitive against age differences as compared to the TMT time score, and does not increase with age (Ashendorf et al. 2008). Similarly, the findings of this study showing that the error scores did not differ according to gender and educational level are consistent with the study of Cangöz et al. (2009) showing that error scores did not differ for individuals older than 50 years of age.

The relevant literature consistently shows that TMT time scores do not differ according to gender (Robins-Wahlin et al. 1996, Vakil et al. 2009, Waldmann et al. 1992). The findings of the present study have shown that TMT time and subtest scores derived based on time do not change according to gender. On the other hand, the number of studies showing that the time scores for part A (McCurry et al. 2001) or part B (Wiederholt et al. 1993) differed according to gender is limited. Similarly, Cangöz et al. (2009) demonstrated in a sampling from Turkey that the completion time for the TMT parts A and B and the A+B scores differed according to gender. When the relevant mean values of the said study are examined, it was seen that the completion of TMT was shorter in males than in females (Cangöz et al. 2009). When the findings of this study carried out on individuals younger than fifty years of age and the findings of the study carried out on the elderly population (Cangöz et al. 2009) are evaluated together as a whole, it is observed that the gender effect appears with aging in relation with the cognitive processes measured with TMT. TMT is an executive function test with a visual-motor component. The visual-motor skills are affected from the deterioration of the executive functions, and this effect creates a difference between the genders. Similarly, in a study examining the relation between the visual-motor tracking task (Stirling et al. 2013) and TMT time scores, visual-motor speed superiority in favor of males was observed, in parallel with the findings on the samplings from Turkey. However, further detailed studies on the cause of the effects of gender that appear with aging are required.

TMT scores are affected by educational level. We found in our study that the scanning time for the part B and the derived subtest scores (A+B, B-A, B/A) differed significantly according to the educational level. The scanning time in part B and the

derived subtest scores of the participants with an education of 12 years or more is shorter in those with educational periods of 6 to 11 years. In other words, the completion time for the part B, which has a higher difficulty level, decreases with the increasing educational level. Likewise, when the effect of age is eliminated, it is seen that the effect of educational level appears only between the groups with a low educational level (1 to 8 years) and the higher educational level (9 years and over) (Hamdan and Hamdan 2009). It is probable that individuals with higher educational levels will complete the parts A and B in shorter periods when compared to individuals with lower educational levels. Completion times for TMT A and B shorten with increasing educational levels (Perianez et al. 2007).

Effects of educational level on the TMT scores are also seen in individuals older than 50 years of age (Cangöz et al. 2009, Wiederholt et al. 1993). The study of Bornstein and Suga (1988) on healthy elderly adults have shown that the TMT performance of participants with higher educational levels were better than that of the participants with education of 5 to 10 years; such that higher educational levels trigger the compensatory mechanisms within the aging process and allow elderly individuals performance better (Soukup et al. 1998). However, the educational level does not affect the completion times for parts A and B in TMT equally (Gaul and Brown 1970). As a matter of fact, it has been shown in this study that the completion time for part B and the derived subtest scores are more sensitive against the educational levels. This finding is consistent with the studies demonstrating that part B is affected more from the educational level (Ivnik ve 1996, Tombaugh 2004). While part A performance displayed a marked decrease with age, it is not affected by educational level (Tombaugh 2004). This can be explained with by the different levels of difficulty of TMT parts A and B (Gaudino et al. 1995) and different cognitive processes included in the two parts of the test (Gaudino et al. 1995). Part A measuring the visual search and cognitive scanning is easier than the other part. TMT B includes the executive function processes in addition to the characteristics measured in part A (Lezak 1995). The B-A and B/A are subtest scores derived from TMT completion time scores; these subtest scores are derived as precision measurement tools to determine executive function disorders (Lamberty et al. 1994, Arbuthnott and Frank 2000). It has been suggested that the B-A score, which can serve as a relatively pure indicator of the abilities responsible for executive control, reduces the requirements of the visual-cognitive functions and study memory (Sanchez-Cubillo et al. 2009). The results of this study are consistent with the relevant literature, if considered in this context.

One of the limitations of this study is the lack of subjects younger than 20 years old. Although the study design included the groups younger than 20 years of age, these individuals were excluded from the study, because statistically sufficient numbers in this age group could not be reached. Another

limitation of the study is that the norms of the graduates of primary school (5 years of education) and an illiterate sample are not represented. The sample of the study consisting of individuals living in Bursa Province and lack of representation of the other provinces in Turkey are other limitations of the study. Therefore, future studies may be carried out on samplings representative of the general population in Turkey by including individuals younger than 20 years of age, graduates of primary school and literate individuals to eliminate the limitations mentioned above.

In conclusion, this study has shown that the TMT scores are affected by educational level in individuals younger than 50 years of age, while the scores did not differ with younger age groups or gender. This study will contribute significantly to the usability of TMT, of which norms for the age groups over 50 years of age were determined by Cangöz et al. (2009), and now have been determined for the 20-49 age range, further 'contributing to the practical and basic scientific studies.

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