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Norm Determination Study of Trail Making Test, Enhanced Cued Recall Test and Clock Drawing Test for Turkish Sample Between 6-18 Years of Age

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ABSTRACT

Introduction: The aim of this study was to determine the developmental stages-specific normative values of Trial Making Test (TMT), Enhanced Cued Recall Test (ECRT) and Clock Drawing Test (CDT) which are commonly used in adults for the evaluation of cognitive functions affected by psychiatric and neurological diseases and developmental disorders for a healthy Turkish sample between 6-18 years of age.

Method: A total of 249 primary and secondary school students between 6-18 years of age and living in Ankara and educated in public and/or private schools participated in the study. Primary analysis was conducted by appropriate ANOVA and/or MANOVA for 2 (Developmental Stage: Middle-Late Childhood (6-11 years) and Adolescence (12-18 years)) x 2 (Gender: Female and Male) factorial design. In addition, another group of ANOVA and/or MANOVA analyses for 3 (Adolescence Sub-Stages) x 2 (Gender) was also performed for the adolescence stage that was sub-grouped as early (12-13 years), middle (14-15 years) and late (16+ years).

Results: Normative values were determined both for two different developmental stages and for the adolescence sub-stages. Comparisons indicated that main effect of gender and interactions were non-significant for all tests. On the other hand, the main effects of the developmental stage and adolescence sub-stages were significant for many of the test scores.

Conclusion: As a result of the study, three neuropsychological tests and their normative values for children and adolescents were presented as available for use in future research.

Keywords: Executive functions, memory, neuropsychological tests, trail making test, enhanced cued recall test, clock drawing test

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INTRODUCTION

The aim of the neuropsychological assessment is to analyze the relations between brain structure and processes and behavioral events. In the neuropsychological assessment process, the scores of individuals with neurological and/or psychiatric diseases obtained from psychometrically valid, reliable and standardized neuropsychological tests are compared with the normative values of healthy ones. Thus, it can be determined objectively that which cognitive functions are affected and how they are affected. Neuropsychological tests, which allow objective assessment of cognitive functions, are important tools that assist clinicians in diagnosis and differential diagnosis of some psychiatric, neurological and developmental diseases (1-2). Moreover, neuropsychological tests are widely used in many different fields such as forensic medicine/science, pilot training, cognitive rehabilitation in the world as well as in our country (3-4).

According to the Cognitive Developmental Theory of the well-known developmental psychologist Piaget, the age-related development in cognitive functions takes place in four basic stages: Sensorimotor (0-2 years), Preoperational (2-7 years), Concrete operational (7-11 years) and the Formal operational (11+ years) stages. These developmental stages reflect qualitatively different functionalities and every child universally goes through these developmental stages in the same order. Nevertheless, environmental factors such as education level and experiences can also affect the speed of cognitive development (5). In addition to cultural and environmental factors, traumatic brain injury, stroke, autism spectrum disorder, cerebral palsy and some neurodegenerative diseases also have the potential to affect cognitive functions.

Incidence studies in childhood stroke have increased especially in the last 20 years. The incidence of hemorrhagic stroke was 1.89/100000, and the incidence of ischemic stroke was reported as 0.63/100000 between 1965-1974 (6). Broderick et al. (7) reported these incidences as 1.5/100000 and 1.2/100000, respectively. This rate was found as about 150/100000 in children and adolescents hospitalized with a diagnosis of pediatric traumatic brain injury (PTBI) (8). Disruption in attention and executive functions after PTBI is among the most destructive and persistent symptoms. These cognitive impairments may persist in about 50% of cases into the post-injury years and adulthood (9). Losses in attention, memory and executive functions are closely related to education level and cause impairment in academic, social and behavioral areas (10). Neuropsychological tests are widely used in the assessment of impaired

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cognitive functions in a wide range of disease such as attention deficit and hyperactivity disorder, postpartum depression, learning difficulties, developmental coordination disorder and frontal lobe epilepsy in children and adolescents.

The Clock Drawing Test (CDT) and Trail Making Test (TMT) are used to evaluate different components of executive functions. It has been shown that executive functions are important for emotional experiences, motor functions and social interaction as well as academic success (e.g., 11). It is also known that cognitive flexibility, one of the key components of executive functions, has critical role on the imagination ability which contributes to daily planning and achieving goals (12). It is reported that TMT is a powerful neuropsychological assessment tool for executive functions especially due to its sensitivity to brain dysfunction in children. Reitan and Wolfson (13), for example, reported that children with brain damage between ages of 9-14 spent three times as much time to complete the test compared to their healthy control group. Therefore, researchers suggested that the TMT test, especially form B, is a useful neuropsychological assessment tool for children who need comprehensive neuropsychological evaluation. Since, TMT and CDT are tests that evaluate different components of the executive functions which are crucial for cognitive functioning, it makes it an important need to determine culture-specific normative values of these test for both childhood and adolescence.

Moreover, memory functions are known to be negatively affected from disorders such as post-traumatic stress disorder, attention deficit and hyperactivity disorder (14). Even if, Enhanced Cued Recall Test (ECRT) used for memory testing developed for older people, it is also applicable for children and young people.

Neuropsychological tests which are used to evaluate cognitive functions such as executive functions and memory with scientific methods in both children and adults, are determinant in planning effective intervention programs as well as accurate diagnosis and realistic treatment practices. It is known that neuropsychological tests, regardless of their verbal nature or not, are not culture-independent, and therefore, normative values appropriate for the cultures they will be used must be determined. In this regard, it is extremely important to have tests with culture-specific norms to be used for evaluation of cognitive processes in health children and cognitive assessment to assist clinical diagnosis for children with psychiatric/neurological/developmental diseases.

To sum up, the main purpose of our study was to determine the normative values of three neuropsychological tests, namely the TMT, CMT and ECRT in Turkish sample aged 6-18 years, according to age/education level and gender. In this context, it was aimed to compare middle-late childhood (6-11 years) and adolescence period (12-18 years) (5) among general developmental stages and to create corresponding norm tables. In addition to this comparison, the adolescence period was grouped as early (12-13 years), middle (14-15 years) and late (16+ years) adolescence as suggested by Berk (15) and test performances of sub-periods of adolescence was compared and the corresponding normative values were determined.

METHOD

Participants

Every year in our country, the children who complete 66th month of age at the end of September and the children with 60-66 months of age who are decided to be ready for primary school in terms of their development and whose family had written request are enrolled in the first grade of primary schools (16). Considering this information, the research sample consisted of a total of 249 volunteer primary or secondary school students living in Ankara, between ages of 6 and 18, studying in the state and / or private schools in three districts (Mamak, Keçiören and Çankaya) representing different socio-economic levels. Written consent was obtained from the students and their parents before the application of the tests. Snowball sampling method was used in the selection of participants. Participants who do not have any known neurological and/or psychiatric diseases, whose native language is Turkish, who do not have visual/hearing problems or have these problems corrected were included in the study. The extreme data of two participants were not included to the further analyses.

Materials

Trail Making Test (TMT): It is used to evaluate executive functions, which are also defined as functions of frontal region such as visual tracking, mental flexibility, sustainable attention, concentration, visual-motor conceptual scanning, motor speed, planning, numerical information, abstract thinking, response inhibition, set shifting and tolerance to inhibition. TMT was developed by Reitan (17). The norm study of the TMT for those between ages of 20 and 49 (18) and standardization, validity and reliability study of TMT for those over ages of 50 (19-20) have been conducted. The test consists of two form, namely, TMT-A and TMT-B. Form A consists only numbers from 1 to 25, Form B, on the other hand, consists of numbers from 1 to 13 and the first 12 letters (A-I) of the alphabet. In the Form A, the participants are asked to combine all the numbers by drawing lines in consecutive order, starting from the number 1 (from 1 to 2, from 2 to 3 and so on). In the form B, on the other hand, participants are asked to combine numbers and letters by drawing lines in order of one number and one letter (from 1 to A, from A to 2, from 2 to B and so on). Participants are reminded to be as fast as possible and always to keep the pencil on the paper in both form. The implementation of TMT takes approximately 10 minutes.

Enhanced Cued Recall Test (ECRT): The test was developed by Grober et al. (21) to distinguish the memory performance of healthy elderly from the performance of dementia patients. Adaptation and validity study on Turkish sample was conducted by Saka et al. (22). The ECRT consists of 16 black and white drawings. The test material is a booklet consisting of a total of 4 cards with 4 drawings each. Each card is shown one by one and the participant is asked to name the drawings that matches the "semantic cue" given. When all cards are shown, three recall tests are given. Each of these recall test consists of free recall and cued recall tests in which cues are presented only for the unremembered drawings in free recall part. The implementation of ECRT takes approximately 15 minutes.

Clock Drawing Test (CDT): CDT was used for the first time as part of the Boston Aphasia Battery (23). CDT evaluates functions such as comprehension, planning, visual memory, reconstruction, visual spatial abilities, motor planning, numerical information, abstract thinking, inhibition of tendency created by the physical properties of the stimulus itself and tolerance to inhibition. In summary, it is a neuropsychological test that can provide general information about intellectual and perceptual skills and is widely used to distinguish healthy adults from those with cognitive impairments (especially Alzheimer's dementia and other type of dementia) and easily and quickly applied. There are different versions of CDT that differ in terms of material, application and scoring. In this study, the 4- point version was used, in which the clock circle was not given ready and a drawing of a clock showing ten past eleven (clock 11:10) was asked. The norm and validity-reliability study of this version for healthy elderly sample aged 50 years and over were performed for our country (24). The implementation of CDT takes approximately 5 minutes.

Procedure

Ethical approval was obtained from Hacettepe University Ethical

Table 1. Participants' Recognition Ratio of the Drawings in the Original Version of the ECRT

Grade	Grape	Tiger	Foot	Table	Screwdriver	Shoe	Guitar	Motorcycle	Spinning Top	Tomato	Spider	Pan/Container	Sailboat	Door	Eagle	Carriage
3	100	76	94	76	94	100	94	88	94	94	88	70	41	94	76	47
4	100	94	94	70	100	94	100	94	94	100	94	64	70	94	70	52
5	100	95	95	70	95	100	100	90	80	95	95	65	40	95	85	40
M	100	89	94	72	96	98	98	90	89	96	93	67	50	94	78	46

Note. M = Mean. The values given are percentages.

Committee for this current study (decision date: 04.05.2016 and decision number: 16969557-340).

Preliminary Study: As stated before, ECRT is a neuropsychological test developed for the sample above 60 years of age and due to its nature, it has the potential to be affected by cultural and age-related factors. For this reason, a preliminary study was conducted before collecting the norm data to test the familiarity of the original drawings (black-white object drawings) used for the elderly sample for the children and young people who constitute the sample of the current study. For this purpose, ECRT drawings were presented in a single session to a total of 54 volunteer students educating in the third (*n* = 17), fourth (*n* = 17) and fifth (*n* = 17) grades of primary school. Then, the familiarity of the drawings was analyzed (see Table 1). The families of these students who were not involved in the main norm study approved their children's participation of these preliminary study.

As a result of the preliminary study, drawings ("sailboat", "pan/container" and "carriage") with a recognition percentage less than 70 at any grade level were determined. In the main study "ice cream" "tv remote" and "umbrella" was used instead of "sailboat", "carriage" and "pan/container" respectively. For the new drawings, difficulty and discrimination values were determined by Ekinci Soylu and Cangöz (25) in the Boston Naming Test-Turkish Version (BAT-TR). However, they were chosen among alternative images that were not used in the mentioned study. The distinctiveness and difficulty levels of the three selected drawings were summarized in Table 2.

Table 2. Discrimination and Difficulty Levels of New Drawings Added to ECRT.

	Discrimination	Difficulty
Ice cream	Very good	Quite Easy
Tv remote	Very good	Quite Easy
Umbrella	Very poor	Very Easy

Main Study

Special care was taken to have participants from all grade levels from 1st to 12th in order to represent all of the different educational levels in the developmental stages we examined. Application of the tests were carried out as face to face in an environment quiet and suitable for testing. Informed consent form was obtained from the participants and their families, and after the demographical information form, TMT, ECRT and CDT were applied in random order in a single session. Neuropsychological tests were administered by three experienced researchers who had graduate-level training in applying and scoring these tests. The distribution of the participants as a function of developmental stages and adolescence sub-stages is summarized in Table 3 and Table 4.

A 2 (Developmental Stage) x 2 (Gender) factorial design with both independent variables were between group factors was used in the current study. A 3 (Adolescence Sub-Stages) x 2 (Gender) with both independent variables were between group factors was also used for the additional analyses regarding adolescence sub-stages. The dependent variables are the scores obtained from each neuropsychological test. Nine different scores were calculated for TMT: TMT Number of Corrections, TMT-A Number of Errors, TMT-A Time, TMT-B Number of Corrections, TMT-B Number of Errors, TMT-B Time, TMT-B Time + TMT-A Time, TMT-B Time – TMT-B Time and TMT-B Time / TMT-A Time. Time-related TMT scores are presented in seconds. Nine different scores were calculated for ECRT:

Table 3. Mean Age of the Participants by Developmental Stage and Gender

Developmental Stage	Male	Female	Total
Middle-Late Childhood (6-11 age)	n = 54; M = 8.72, SD = 1.43	n = 57; M = 8.87, SD = 1.56	n = 111; M = 8.80, SD = 1.49
Adolescent (12-18 age)	n = 67; M = 14.79, SD = 1.75	n = 69; M = 14.87, SD = 1.81	n = 136; M = 14.83, SD = 1.77
Total	n = 121	n = 126	N = 247

Note. M = Mean, SD = Standard Deviation

Table 4. Mean Age of the Participants by Adolescence Sub-Stage and Gender

Adolescence Sub-Stages	Male	Female	Total
Early (12-13 years of age)	n = 18; M = 12.44, SD = 0.51	n = 20; M = 12.60, SD = 0.50	n = 38; M = 12.53, SD = 0.51
Middle (14-15 years of age)	n = 23; M = 14.61, SD = 0.50	n = 20; M = 14.50, SD = 0.51	n = 43; M = 14.56, SD = 0.50
Late (16+ years of age)	n = 26; M = 16.58, SD = 0.64	n = 29; M = 16.69, SD = 0.60	n = 55; M = 16.64, SD = 0.62
Total	n = 67	n = 69	N = 136

Note. M = Mean, SD = Standard Deviation

Free Recall (1st Trial), Cued Recall (1st Trial), Free Recall (2nd Trial), Cued Recall (2nd Trial), Free Recall (3rd Trial), Cued Recall (3rd Trial), Total Free Recall, Total Cued Recall and Total Recall. Finally, a total of nineteen, one dependent variable for CDT, was used as the dependent variables. Pairwise comparisons for the significant effects of ANOVA (for the tests with single dependent score) or MANOVA (for the tests with more than one dependent score) analyzes were reported as Bonferroni corrected.

RESULTS

Results for Comparisons between Middle-Late Childhood and Adolescence

Results for TMT: A 2 (Developmental Stage: Middle-Late Childhood and Adolescence) x 2 (Gender: Female and Male) multivariate analyses of variance (MANOVA) was used to analyze TMT scores. According to the results the main effect of the gender (*Pillai's Trace*=0.04; $F_{(7,237)}$=1.41, p>.05, η_p^2=.04) and the interaction of developmental stage and gender were non-significant (*Pillai's Trace*=0.31; $F_{(7,237)}$=1.08, p>0.05, η_p^2=0.03). The main effect of developmental stage, on the other hand, was significant (*Pillai's Trace*=0.36; $F_{(7,237)}$=19.40, p<0.001, η_p^2=0.36). The scores on which developmental stage had a main effect were TMT-A Correction ($F_{(1,243)}$=4.30, p<0.05, η_p^2=0.02), TMT-A Time ($F_{(1,243)}$=115.22, p<0.001, η_p^2=0.32), TMT-B Time ($F_{(1,243)}$= 44.65, p<0.001, η_p^2=0.15), TMT-B Time – TMT-A Time ($F_{(1,243)}$=24.98, p<0.001, η_p^2=0.09) and TMT-B Time+TMT-A Time ($F_{(1,243)}$=62.22, p<0.001, η_p^2= 0.20). When these results were examined, it was observed that the performance of the individuals in adolescence stage were better than the individuals in middle-late childhood stage in all of scores listed above. Since the main effect of gender was not significant the genders were combined in the TMT norm table (see Table 5).

Results for ECRT: A 2 (Developmental Stage: Middle-Late Childhood and Adolescence) x 2 (Gender: Female and Male) multivariate analyses of variance (MANOVA) was used to analyze ECRT scores. Results indicated that only the developmental stage main effect was significant (*Pillai's Trace*=0.19; $F_{(7,237)}$=8.20, p<0.001, η_p^2=0.19). This variable had main effect on the scores of Free Recall (1st Trial) ($F_{(1,243)}$=20.60, p<0.001, η_p^2=0.08), Cued Recall (1st Trial) ($F_{(1,243)}$=5.42, p<0.05, η_p^2=0.02), Free Recall (2nd Trial) ($F_{(1,243)}$=12.69, p<0.01, η_p^2=0.05), Free Recall (3rd Trial) ($F_{(1,243)}$=44.55, p<0.001, η_p^2=0.15), Cued Recall (3rd Trial) ($F_{(1,243)}$=13.26, p<0.001, η_p^2=0.05), Free Recall Total ($F_{(1,243)}$=39.26, p<0.001, η_p^2=0.14), Cued Recall Total ($F_{(1,243)}$=8.90, p<0.01, η_p^2=0.03) and Total Recall ($F_{(1,243)}$=32.70, p<0.001, η_p^2=0.12) except Cued Recall (2nd trial). Main effect of gender (*Pillai's Trace*=0.04; $F_{(7,237)}$=1.57, p>0.05, η_p^2=0.04) and the interaction of gender and developmental stage (*Pillai's Trace*=0.04; $F_{(7,237)}$=1.49, p>0.05, η_p^2=0.04), on the other hand, was not significant. Thus, genders were combined in the norm table of ECRT (see Table 6). Results indicated that adolescents are less dependent on cue to remember what they have learned than those in middle-late childhood stage.

Results for CDT: A (Developmental Stage: Middle-Late Childhood and Adolescence) x 2 (Gender: Female and Male) analyses of variance (ANOVA) was conducted and the main effect of developmental stage was found significant ($F_{(1,243)}$=33.44, p<0.001, η_p^2=0.12). According to this result, the CDT scores of adolescences (M=3.75, SD=0.46) was significantly higher than scores of those in middle-late childhood stage (M=3.23, SD=0.93). The main effect of gender ($F_{(1,243)}$=0.30, p>0.05, η_p^2=0.00) and the interaction of gender and developmental stage ($F_{(1,243)}$=0.50, p>0.05, η_p^2=0.00) were not significant for CDT scores. Thus, genders were combined in the norm table of CDT (see Table 7).

Results for Comparisons of Adolescence Sub-Stages

Results for TMT: According to the results of the 3 (Adolescence Sub-Stages: Early, Middle and Late) x 2 (Gender: Female and Male) multivariate analyses of variance (MANOVA) the main effect of the gender (*Pillai's Trace*=0.05; $F_{(7,124)}$=0.98, p>0.05, η_p^2=0.05) and the interaction of developmental stage and gender were non-significant (*Pillai's Trace*=0.12; $F_{(14,250)}$=1.10, p>0.05, η_p^2=0.06). The main effect of adolescence sub-stages, on the other hand, was significant (*Pillai's Trace*=0.32; $F_{(14,250)}$=3.00, p<0.001, η_p^2=0.14). The scores on which adolescence sub-stages had a main effect were TMT-A Time ($F_{(2,130)}$=12.71, p<0.001, η_p^2=0.16), TMT-B Time ($F_{(2,130)}$=6.86, p<0.001, η_p^2=0.09), and TMT-B Time+TMT-A Time ($F_{(2,130)}$ =10.42, p<0.001, η_p^2=0.14). The source of these significant effects were summarized in Table 8. Other pairwise comparisons were not statistically significant.

Table 5. TMT Norm Table for the Developmental Stages

N=247	TMT-A Corr.	TMT-A Error	TMT-A Time	TMT-B Corr.	TMT-B Error	TMT-B Time	B-A	B+A	B/A
Developmental Stage	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**
Middle-Late Childhood (n = 111)	0.20 (± 0.57)	0.11 (± 0.31)	51.82 (± 20.63)	0.25 (± 0.92)	0.95 (± 1.59)	152.75 (± 113.65)	100.93 (± 103.40)	204.57 (± 126.47)	2.96 (± 1.57)
Adolescence (n = 136)	0.08 (± 0.28)	0.12 (± 0.37)	29.68 (± 10.98)	0.25 (± 0.64)	0.94 (± 1.31)	82.67 (± 39.69)	52.99 (± 37.11)	112.35 (± 44.88)	2.89 (± 1.28)

Note. M = Mean, SS = Standard Deviation, B-A = TMT-B Time – TMT-A Time, B+A = TMT-B Time + TMT-A Time, B/A = TMT-B Time / TMT-A Time, Corr. = Correction.

Table 6. CRT Norm Table for the Developmental Stages

N=247	F.R. (1)	C.R. (1)	F.R. (2)	C.R. (2)	F.R. (3)	C.R. (3)	F.R. TOT.	C.R. TOT.	TOT. R.
Developmental Stage	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**
Middle-Late Childhood (n = 111)	8.28 (± 1.88)	6.22 (± 1.87)	10.44 (± 2.24)	3.87 (± 1.85)	10.60 (± 2.54)	3.59 (± 2.01)	29.32 (± 5.09)	13.68 (± 4.31)	42.99 (± 4.27)
Adolescence (n = 136)	9.39 (± 1.94)	5.67 (± 1.83)	11.46 (± 2.28)	3.64 (± 2.00)	12.60 (± 2.18)	2.74 (± 1.69)	33.45 (± 5.24)	12.05 (± 4.26)	45.51 (± 2.60)

Note. M = Mean, SD = Standard Deviation, F.R. = Free Recall, C.R. = Cued Recall, TOT. = Total, TOT. R. = Total Recall. Numbers in parentheses indicate the number of trials.

Table 7. CDT Norm Table for the Developmental Stages

N=247	CDT Scores
Developmental Stage	**M (SD)**
Middle-Late Childhood (n = 111)	3.23 (± 0.93)
Adolescence (n = 136)	3.75 (± 0.46)

Note. M = Mean, SD = Standard Deviation

Because the main effect of gender was not significant, genders were combined in the norm table of TMT (see Table 9).

Results for ECRT: According to 3 (Adolescence Sub-Stages: Early, Middle and Late) x 2 (Gender: Female and Male) multivariate analyses of variance (MANOVA) the main effect of the gender (*Pillai's Trace*=0.10; $F_{(7, 124)}$= 2.02, p>0.05, η_p^2=0.10) and the interaction of developmental stage and gender were non-significant (*Pillai's Trace*=0.13; $F_{(14, 250)}$=1.26, p>0.05, η_p^2=0.07). However, the main effect of adolescence sub-stages was significant (*Pillai's Trace*=0.32; $F_{(14, 250)}$=3.44, p<0.001, η_p^2=0.16). This variable had significant main effect on the scores of Free Recall (1st Trial) ($F_{(1, 243)}$=20.60, p<0.001, η_p^2=0.08), Cued Recall (1st Trial) ($F_{(1, 243)}$=5.42, p<0.05, η_p^2=0.02), Free Recall (3rd Trial) ($F_{(1, 243)}$=44.55, p<0.001, η_p^2=0.15), Free Recall Total ($F_{(1, 243)}$= 39.26, p<0.001, η_p^2=0.14) and Total Recall ($F_{(1, 243)}$=32.70, p<0.001, η_p^2=0.12). Results indicated that adolescents were less dependent on cues to remember what they have learned than the other group. The source of these significant effects were summarized in Table 10. Other pairwise comparisons were not statistically significant.

Genders were combined in norm table for ECRT (see Table 11).

Results for CDT: According to 3 (Adolescence Sub-Stages: Early, Middle and Late) x 2 (Gender: Female and Male) analyses of variance (ANOVA), the main effect of the gender ($F_{(1, 130)}$=0.41, p>0.05, η_p^2=0.00), the main effect of adolescence sub-stages ($F_{(1, 243)}$=0.35, p>0.05, η_p^2=0.00) and the interaction of developmental stage and gender were non-significant ($F_{(1,243)}$=1.61, p>0.05, η_p^2= 0.02). However, in order to be ensure consistency throughout the text, the norm values for CDT were given on the basis of adolescence sub-stages by combining the genders (see Table 12).

Table 8. Significant Differences Between Adolescence Sub-Stages in terms of TMT Scores

Test Score	Comparisons	Mean Difference	Standard Error	p	r
TMT-A Time	Late - Early	-10.77	2.16	< .001	.40
	Late - Middle	-5.97	2.09	< .05	.24
TMT-B Time	Late - Early	-27.26	7.84	< .01	.29
	Late - Middle	-19.93	7.57	< .05	.22
TMT-B Time + TMT-A Time	Late - Early	-38.00	8.18	< .001	.38
	Late - Middle	-25.89	8.42	< .01	.26

Note. r = Effect Size

Table 9. TMT Norm Table for Adolescence Sub-Stages

N=136	TMT-A Corr.	TMT-A Error	TMT-A Time	TMT-B Corr.	TMT-B Error	TMT-B Time	B-A	B+A	B/A
Adolescence Sub-Stages	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**
Early (n = 38)	0.10 (± 0.31)	0.08 (± 0.27)	35.52 (± 15.53)	0.16 (± 0.44)	0.74 (± 1.65)	95.34 (± 55.00)	59.82 (± 54.49)	130.87 (± 59.70)	2.88 (± 1.88)
Middle (n = 43)	0.12 (± 0.32)	0.12 (± 0.39)	30.76 (± 8.65)	0.28 (± 0.80)	1.19 (± 1.29)	89.11 (± 36.09)	58.35 (± 32.44)	119.87 (± 41.26)	2.96 (± 1.03)
Late (n = 55)	0.05 (± 0.23)	0.16 (± 0.42)	24.80 (± 5.34)	0.29 (± 0.63)	0.89 (± 1.01)	68.88 (± 22.65)	44.08 (± 21.31)	93.68 (± 25.09)	2.84 (± 0.92)

Note. M = Mean, SS = Standard Deviation, B-A = TMT-B Time – TMT-A Time, B+A = TMT-B Time + TMT-A Time, B/A = TMT-B Time / TMT-A Time, Corr. = Correction

Table 10. Significant Differences Between Adolescence Sub-Stages in terms of ECRT Scores

Test Score	Comparisons	Mean Difference	Standard Error	p	r
F.R. (1st Trial)	Late - Early	1.65	0.39	< .001	.35
	Middle - Early	1.15	0.41	< .05	.24
C.R. (1st Trial)	Late - Early	-1.31	0.37	< .01	.30
	Middle - Early	-1.16	0.39	< .05	.25
F.R. (3rd Trial)	Late - Early	1.34	0.44	< .01	.26
F.R. (Total)	Late - Early	4.04	1.05	< .001	.32
	Middle - Early	2.88	1.10	< .05	.22
Total Recall	Late - Early	2.16	0.50	< .001	.35
	Middle - Early	1.45	0.53	< .05	.23

Note. F.R. = Free Recall, C.R. = Cued Recall, r = Effect Size

Table 11. ECRT Norm Table for Adolescence Sub-Stages

N=136	F.R. (1)	C.R. (1)	F.R. (2)	C.R. (2)	F.R. (3)	C.R. (3)	F.R. TOT.	C.R. TOT.	TOT. R.
Adolescence Sub-Stages	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**
Early (n = 38)	8.37 (± 1.68)	6.58 (± 1.69)	10.82 (± 2.35)	3.86 (± 1.87)	11.79 (± 2.18)	2.87 (± 1.51)	30.97 (± 5.29)	13.21 (± 3.91)	44.24 (± 3.24)
Middle (n = 43)	9.49 (± 1.64)	5.39 (± 1.63)	11.53 (± 2.08)	3.72 (± 2.15)	12.68 (± 1.99)	2.77 (± 1.59)	33.70 (± 4.51)	11.89 (± 4.17)	45.57 (± 2.69)
Late (n = 55)	10.02 (± 2.06)	5.25 (± 1.89)	11.85 (± 2.21)	3.49 (± 1.99)	13.09 (± 2.19)	2.64 (± 1.89)	34.96 (± 5.21)	11.38 (± 4.45)	46.34 (± 1.49)

Note. M = Mean, SD = Standard Deviation, F.R. = Free Recall, C.R. = Cued Recall, TOT. = Total, TOT. R. = Total Recall. Numbers in parentheses indicate the number of trials.

Table 12. CDT Norm Table for the Adolescence Sub-Stages

N=136	CDT Scores
Adolescence Sub-Stages	**M (SD)**
Early (n = 38)	3.79 (± 0.41)
Middle (n = 43)	3.79 (± 0.41)
Late (n = 55)	3.71 (± 0.53)

Note. M = Mean, SD = Standard Deviation

DISCUSSION

In accordance with the purpose of the study, norm tables for TMT, ECRT and CDT tests were obtained for the healthy children/young Turkish sample representing two developmental stages between 6-18 years of age and the adolescence sub-stages. There was no difference between genders in terms of all the sub-scores of the three neuropsychological tests. Namely, women and men performed similarly in these three tests.

When the results for developmental stages were examined, it was observed that adolescents were more successful in the most of TMT sub-scores (especially time-related scores) than the participants in middle-late childhood. In other words, adolescents were completed both TMT-A which especially measures visual tracking, sustainable attention, concentration, visual-motor conceptual scanning and motor speed and TMT- B which especially measures the different dimensions of executive functions such as mental flexibility, planning, numerical knowledge, abstract thinking, response inhibition, set shifting and resist to inhibition faster than those in middle-late childhood. These two groups, on the other hand, showed comparable performance in terms of error and correction scores. In this case, it can be claimed that the scores that is distinctive for the two groups are time-related TMT scores. It is known that the executive functions measured by the TMT are associated with the prefrontal areas of the brain (26). The frontal region continues to develop until later than other brain areas. Accordingly, it has been demonstrated that the set shifting ability which is critical for TMT, continues to develop until the age of 11, and that the performance after of the participants after that age reached the performance level of adulthood (27). Similarly, Kalkut et al. (28) reported that the set shifting performance of the 8-11 years of age group was lower than the performance of 12-13 years of age group. Moreover, Huizinge and Van der Molen (27) also reported that the development of inhibition processes begins to complete with adolescence. Inhibitory processes get involved in suppressing the invalid set while shifting between sets. It is thought that the time-related difference observed in the TMT-A section which does not require set shifting, on the other hand, may be related to other functions such as motor speed and sustainable attention. It has been demonstrated that sustainable attention develops rapidly and complete its development to great extent between 5-9 years of age which is followed by a plateau between 9-12 years of age and then continues until the age of 16 (29). Gasser et al. (30) tested children/young people between the 5-18 years of age in terms of their speed in different motor skills and reported that the majority of the motor speed development was completed rapidly in childhood and it slows down in adolescence even if it continues to develop. These findings highlight that both sustainable attention and motor speed component may contribute significant difference between adolescents and children for TMT-A performance.

It was observed that adolescence sub-stages differed from each other in terms of time-related TMT scores and that late adolescents completed both TMT-A and TMT-B forms faster than both middle and early adolescents. On the other hand, although it was observed that middle adolescents performed better than early adolescents in terms of time-related scores, this differences did not reach significance. Participants in different adolescence sub-stages had comparable performance in terms of error and correction scores. Different studies have reported that the critical age at which set shifting ability measured by TMT B reaches the level of development in adulthood is 11-12 years of age (27). On the other hand, it is known that the development of the motor speed and sustainable attention measured by TMT-A is mostly completed in childhood. Considering these information, even if the differences between adolescence and childhood period are reasonable, it can be expected that there would be no difference between participants in different adolescence sub-stages. The results of that late adolescents were more successful in both TMT-A and TMT-B form that other groups can be explained by the fact that the participants in the late adolescence group which is known to consist of 11^{th} and 12^{th} grades, are in the preparation period for the exams of Council of Higher Education for which both reaction time an accuracy are important. This preparation can be expected to speed up the overall test performance.

The non-significant results for gender comparisons for TMT were not surprising. Indeed, there are some studies revealed no gender difference in terms of executive functioning measured by TMT (e.g. 31).

When the CDT performance was examined, it was observed that those in middle-late childhood were less successful than adolescents, but there was no difference between adolescence sub-stages. It is known that CDT measures the planning, a component of executive functions. Best et al. (32) emphasize that planning ability generally continue to develop until the late childhood or adolescence. The findings that CDT performance did not differ in adolescence sub-stages but adolescents performed better than those in childhood seems consistent with the developmental processes of planning ability.

On the other hand, when the ECRT results were examined, it was found that individuals in adolescence were better at free recall and total recall performance than those in middle-late childhood. This result indicated cued recall scores of the participants in middle-late childhood were higher than the adolescents is expected, because the participants were provided cues not for all items, but only for the items that they could not remember in free recall trials. Considering the nature of the test, it can be said that adolescents need less cues when they need to remember the things that they have learnt before than those in middle-late childhood. We found that the difference in free recall performance was also valid between adolescence sub-stages. This results led to the conclusion

that the development of memory-related brain areas continues after childhood. Indeed, there are findings indicating that temporal areas which are known to be crucial for memory related functions, develop with age (33). Maril et al. (34), on the other hand, demonstrated that episodic encoding in childhood is based on perceptual systems whose development was not yet completed in that stage and that it was based on semantic information and frontal control systems in adulthood. That is, age-related developmental differences in different brain areas may lead to differences in memory strategies. Differences in free recall observed in adolescence sub-stages may be due to the difference in the level of development of the frontal areas and semantic information representations. Similarly, it is known that the difference observed in memory performance depending on age can be associated with the usability of attention and executive control process for memory which are the specific to prefrontal areas that continue to develop with age (35). Nevertheless, the lack of significant difference between late and middle adolescence in terms of free recall performance of the ECRT was interpreted as these two groups used similar memory strategies.

In summary, within the scope of the study, culture specific normative values of three different neuropsychological tests that measure various critical skills related to memory and executive functions for different developmental stages were determined. Considering that executive functions and memory are essential for daily functioning and can be impaired with many different developmental disorders, it is important to have cultural-specific normative values for the individuals in different developmental stages.

Committee Approval: Ethical approval was obtained from Hacettepe University Ethical Committee for this current study (decision date: 04.05.2016 and decision number: 16969557-340).

Informed Consent: Written consent was obtained from the students and their parents before the application of the tests.

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