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Normative Data for the D-KEFS Color-Word Interference and Trail Making Tests Adapted in Greek Adult Population 20–49 Years Old

Marianna Tsatali [1,2,*], Fotini Surdu [2], Andromachi Konstantinou [2] and Despina Moraitou [1,3]

[1] Laboratory of Psychology, Department of Cognition, Brain and Behavior, School of Psychology, Aristotle University of Thessaloniki (AUTh), Greece; mtsatali@yahoo.gr; demorait@psy.auth.gr
[2] Department of Psychology, School of Humanities and Social Sciences, University of Western Macedonia, Kozani, Greece; mtsatali@yahoo.gr; fotini.surdu@outlook.com; andromachikons@gmail.com
[3] Lab of Neurodegenerative Diseases, Center for Interdisciplinary Research and Innovation, Aristotle University of Thessaloniki, Hellas (CIRI - AUTh); demorait@psy.auth.gr
* Correspondence: mtsatali@yahoo.gr; Aristotle University of Thessaloniki Campus PC 54124 Thessaloniki Tel.: +30 2310 995205

Abstract: Background: This study was designed to adapt the Delis-Kaplan Executive System (D-KEFS) version of the Color-Word Interference (CWIT) and Trail making Tests (TMT) in Greek adult population from 20 to 49 years old, since it is of research as well as clinical importance to detect executive functions' impairment in young adults with neurological or/and psychiatric conditions. Aims: Norms for the Greek adult population have been calculated to be available for neuropsychologists and health professionals who work in relevant settings. Methods: The study sample consisted of 101 healthy adults (41% male and 60% female), aged 20 to 49 years (M=32.16, SD=11.57) with education from 12 to 19 years of schooling (M=14.51, SD= .89). Pearson correlation test as well as chi square test were conducted to examine potential associations between gender, age, education, and participants' performance. Afterwards, we calculated normative data using raw scores and transformed them to percentile scores. Finally, Greek norms were compared to the original raw scores, which were transformed in scaled scores by Delis et al. (2001). Results: The findings showed that age was the only variable which affected CWIT, whereas level of education as well as age were predictive factors for most TMT conditions, except for the visual scanning test (Condition 1). Gender did not affect both tests. Finally, D-KEFS norms for CWIT and TMT are available for Greek adult population to help clinicians detect executive functions' deficits and therefore adjust tailored therapeutic strategies. Additionally, it is of great importance to use these tests for research purposes. Conclusion: Given that executive functions are assumed as high- level skills, which are highly related to everyday functionality, adapted tests contribute not only to assess the progression of any existing neurological as well as psychiatric disorders, but they can also be used to evaluate patients' ability to live independently, as well as their access to work.

Keywords: D-KEFS; color-word interference; executive functions; normative data; trail making test

1. Introduction

Basic Characteristics of the Delis-Kaplan Executive Function System (D-KEFS)

Executive functions constitute an active functional system, with various meaningful domains: working memory, planning, fluency, inhibition, and set shifting [1]. They are also defined as a set of control processes that enable individuals to manage and direct their attention, thoughts, and actions to achieve adaptive goals [2]. According to Diamond (2013) [3], executive functions are also divided in three main categories; Working memory, through updating, inhibiting and shifting the individual keeps the information active from attentional distraction [4]; Inhibition, where the individual deliberately inhibits dominant or automatic impulses when necessary [4]; and Shifting, in which the individual is able to alternate and shift between tasks or mental sets.

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D-KEFS is a neuropsychological battery which assesses a wide range of executive functions, such as cognitive flexibility, inhibition, planning, conceptualization, abstract thinking, set shifting, consisting of nine D-KEFS tests; Trail Making Test (TMT), Verbal Fluency Test, Design Fluency Test, Color–Word Interference Test (CWIT), Tower Test, Twenty Questions Test, Word Context Test, Sorting Test and Proverb Test, while most of its tests are widely used in the field of neuropsychology [5] individually or paired [6], using either relatively new, or standardizations from other established clinical or experimental tests by other researchers [7]. For example, the CWIT had initially created by Stroop in 1935 [8], whereas TMT is a modification of the traditional test created by Brown and Partington in 1942 [7]. Each D-KEFS test gives primary as well as optional scores, which provide qualitative information about participants' cognitive performance [9]. The inclusion of switching conditions constitutes a major characteristic of the D-KEFS among others [10]. In specific, these new switching conditions have been added to several of the D-KEFS tests, including the TMT, CWIT, Verbal Fluency Test and the Design Fluency Test. To sum, it is worth emphasizing that the D-KEFS is the first set of executive functioning tests, weighted in a large and representative national American sample, designed exclusively to assess executive functions [11].

$CWIT_{D\text{-}KEFS}$

The $CWIT_{D\text{-}KEFS}$ is one of the most widely used tools measuring processing speed, which is verbally mediated [12], as well as executive functions such as inhibition, switching, and cognitive flexibility. Additionally, it also assesses participants' perseverance and tendency to act towards impulsive and unplanned responses in verbal modality. The basic requirement of the Stroop tests is to assess participants' ability to suppress a well-learned, automatic response (for example word reading) in favor of a task which is not familiar (for example naming the printed ink color of incongruously named color names) [13]. Therefore, the 'Stroop interference effect' refers to the inhibition of a demanding task which prerequisites an automatic response, which is accompanied to a slower response speed as well as a lower accuracy of the incompatible task [14].

$CWIT_{D\text{-}KEFS}$ constitutes a newer version of the Stroop Color and Word Test (SCWT; Stroop, 1935 [8]), including four separate conditions with increasing complexity. Although research has previously focused on neuropsychological assessment in older adult population with dementia [15], in recent years more focus is given also to healthy population as well as those adults with neurological and psychiatric conditions [15–20]. In this context, $CWIT_{D\text{-}KEFS}$ has been used in healthy as well as clinical population for example in young and older adults with traumatic brain injury and frontal lesions [21–24], Parkinson's Disease [25], anorexia [26], frontal-lobe or temporal-lobe epilepsy [27], Autism Spectrum Disorder [28], cerebrovascular disease [29], substance use disorders [30], mild cognitive impairment due to Parkinson's disease [31], and dementia due to various etiologies [32,33]. Hence, adapting widely used and highly complex neurocognitive tests, contributes to the current focus of research and clinical practice.

$TMT_{D\text{-}KEFS}$

TMT is a modification of the traditional test created by Brown and Partington in 1942 [7], considered as one of the oldest, well-established and widely used neuropsychological tests. Therefore, it constitutes an inseparable part of the neuropsychological assessment administered in people with neurological and psychiatric conditions. TMT assesses a set of high level cognitive functions, such as switching/divided attention, inhibition, updating, cognitive flexibility, and set shifting [34], given that neuroimaging studies have found that frontal lobes' dysfunction is highly related to executive functions' impairment [27,35,36]. Till now the majority of studies, which will be mentioned below, use the traditional version of TMT which includes only two conditions, number sequence and switching, instead of $TMT_{D\text{-}KEFS}$ which consists of five conditions including the previous from the traditional TMT version. Hence it is quite important to extract norms for $TMT_{D\text{-}KEFS}$, to evaluate its clinical as well as research manifestations.

$TMT_{D\text{-}KEFS}$ is a traditional tool to measure set-shifting (Letter–Number Switching) by including four baseline conditions (Visual Scanning, Number Sequencing, Letter Sequencing, and Motor

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Speed). Therefore, TMT has been shown to be sensitive to the presence of brain injury, and frontal lobes' lesions [37,38], mainly on the Number-Letter Switching condition [39], autistic and Asperger's disorder among adolescents and adult population [28], psychiatric patients suffering from schizophrenia [40], whereas patients with frontal lobe epilepsy were disproportionately impaired compared to patients with temporal lobe epilepsy on the Number-Letter Switching condition (McDonald et al., 2005). Additionally, recent study by Hacker et al. (2024) [41] showed that $TMT_{D\text{-}KEFS}$ could effectively detect patients with TBI among orthopedic population and healthy participants.

Demographics' Effects - the Role of Age and Education

Delis et al. (2001) [42] assume that age significantly affects participants' performance across all D-KEFS tests. In specific, the longitudinal study by Adólfsdóttir et al. (2017) [18] demonstrate age-related changes in $CWIT_{D\text{-}KEFS}$ performance, particularly in inhibition and switching among middle-aged and older adults, where the decline in performance on these abilities appeared to persist, even after controlling for baseline test conditions, processing speed, test retest familiarity, gender, and years of education. Moreover, Zhao et al. (2020) [43] found that switching condition of $CWIT_{D\text{-}KEFS}$ was associated with age, which is also in agreement with previous studies used the version of the CWST and Stroop test [44,45] respectively, whereas the homotopic connectivity of the ventromedial prefrontal cortex mediated the relationship between age and CWIT inhibition reaction time. Van der Elst et al. [12] reported that age-related decline was stronger for individuals with less education. On the other hand, Magnusdottir et al. (2021) [46] found that individuals with more education exhibited a stronger age-related decline. As regards the impact of gender, there is controversy across studies which found slightly better performance in women [46], while others found no gender effect [44,47].

According to studies [48,49], age and educational level as well as vocabulary have significant impact on participants' performance in TMT, especially the subtests of letter sequencing and switching [48]. It seems that younger participants need significantly less time to complete the subtests in comparison to older participants [25,49–51], whereas older age and lower educational level are negatively related with satisfactory completion of the tests across all conditions [52]. To sum, regarding TMT, age is assumed as the most important factor which affects participants' performance [48], despite the controversy across studies which highlight education as the most predictive factor [48,53,54]. To sum, according to authors of the D-KEFS [42], age constitutes the predominant factor affecting performance across all D-KEFS subtests, and probably this is the reason why their initial normative data scores were stratified by age.

Study's Aim

Till now, there are almost no studies in Greece using D-KEFS in clinical and non clinical population; however, few studies administered D-KEFS in Greek older adults with vascular risk, Subjective Cognitive Impairment, as well as clinical population, in order to compare older adults with minor and major vascular problems with their healthy counterparts. All of them used the American raw scores to test their hypothesis [55–58]. To conclude, no previous studies using $CWIT_{D\text{-}KEFS}$ and $TMT_{D\text{-}KEFS}$ in young adult population exist.

Finally, the already existing research concerning previous versions of Stroop and TMT was conducted in Greek healthy adults by Zalonis et al. [45,49], who however did not use the D-KEFS version but mainly the traditional Stroop as well as TMT versions. Therefore, the $TMT_{D\text{-}KEFS}$ and $CWIT_{D\text{-}KEFS}$ have not been previously used in Greek adult population in research as well as in clinical practice. No previous normative data study exists, because only American age-adjusted norms from D-KEFS are available. Moreover, $CWIT_{D\text{-}KEFS}$ and $TMT_{D\text{-}KEFS}$ belong to those D-KEFS tests which are in common use, although, their traditional versions (Stroop test and TMT) are used more commonly in neuropsychological assessment, which may reflect lack of data in this field, or a need to extend relevant literature [59].

The present study aims to calculate norms in a typical Greek adult population based on age (20-29 years, 30-39 years, 40-49 years), to measure basic executive functions, but also to introduce this tool in clinical practice for the general population and patients with neurological and psychiatric

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conditions. As regards $CWIT_{D\text{-}KEFS}$, results showed that age was the only predictor. As regards the $TMT_{D\text{-}KEFS}$, age and educational level were predictors for most conditions, except for the visual scanning. Despite that the initial version of the D-KEFS did not calculate separate norms stratified by educational level, we extracted norms matched for age and education.

2. Materials and Methods

Participants

The study's sample consisted of one hundred (101) healthy adults, aged from 20 to 49 years old (40% male and 60% female). The mean age was 32.21 years with mean education of 14.98 years of schooling (Table 1). Participants were recruited using the simple random sampling from the wider areas of North and South Greece; including towns, villages and islands which belonged to these areas. In more detail, participants were university students from the University of Western Macedonia, and Aristotle University of Thessaloniki, as well as other people from the aforementioned places of the country. Participants were enrolled in this study voluntarily, anonymously and after giving their written consent. Before their inclusion to the study, participants read the information sheet which stipulated that the research team could use their data for research purposes. In order to extract the Greek norms, all participants were divided into three age classes, a typical separation in normative data studies (age range 20–29; 30–39, and 40–49 years), two gender classes (men and women) and three educational classes (Secondary school final year and graduates: 10-12 schooling years, Diploma degree - University students - Bachelor degree: 13-16 years, and Master Degree - Doctorate studies: 16< years.

Table 1. Demographic distribution of the sample.

	Age groups			Total
Years of education	Age group 20-29	Age group 30-39	Age group 40-49	
10-12		15	15	30
13-16	19	11	10	40
16+	11	11	10	31

Study's inclusion criteria were the following: age from 20 to 49 years and Greek as their native language. The exclusion criteria were the following; presence of previous addictive disorder, psychosis and major depression, concurrent history of neurologic disease known to affect cognitive functioning, auditory functioning no sufficient to understand normal conversational speech, and visual acuity non-normal or non-corrected to anticipate visual stimuli.

Description of the D-KEFS Tests

CWIT

$CWIT_{D\text{-}KEFS}$ is the D-KEFS (Delis et al., 2001) [42] version of the Stroop Color and the Word Test (SCWT; Stroop, 1935), and therefore, it constitutes its newer version. Stroop test includes three separate conditions; Color naming speed, colors and words reading printed in black ink, and verbal responses' inhibition through colors naming written in discordant ink. A fourth trial added to the $CWIT_{D\text{-}KEFS}$ is named Inhibition/Switching condition, which requires to switch between color naming and word reading of color words printed in incongruent colors. Furthermore, the D-KEFS version appears to use the Comalli variant [60], in which color naming precedes word reading. To sum, CWIT conditions are the following; Color naming, Word reading, Inhibition, and Inhibition/Switching.

The $CWIT_{D\text{-}KEFS}$ measures inhibition/switching skills as cognitive flexibility, whereas provide the ability to assess participants' perseverance and tendency to act towards impulsive and unplanned responses in verbal modality. In more details, in the first condition the examinee is asked to name the colors he/she sees on the form (red, blue, green), hence, it measures naming speed in high frequency repeating stimuli, e.g color patches, as well as word- finding difficulty. The second condition requires reading the color words, printed in black ink, and therefore is measures the ability to read high-frequency repeated. The third condition involves color naming, where the word and the color in which it is printed are incompatible with each other (e.g., the word "green" is printed in red ink), and thus the examinee must name the color that it is printed and to inhibit his/her automatic tendency that prompts them to read the word. Therefore, the examinee is required to name colors when inhibiting the more automatic task of reading the words. Lower performance in condition 3 is associated to deficits in verbal inhibition over the deficiency in naming speed. However, unlike other versions of this test, in the CWIT$_{D\text{-}KEFS}$ there is also a fourth condition (the Inhibit/Switching condition), in which the examinee is asked to alternate at irregular intervals between reading color-words and naming color-words printed with discordant color [20]. Successful performance on this condition prerequisites naming speed, reading speed, cognitive flexibility and verbal inhibition. This provides an extra requirement not only to inhibit the tendency to read, but also to switch between different conditions through cognitive shifting [22]. In case that the examinee performs well in conditions 1-3, but fails on condition 4 it implies deficits in cognitive flexibility, whereas problematic performance in both conditions 3 and 4 suggests impairments in verbal inhibition and cognitive flexibility. For each of the four conditions, the main score is based on the time required to complete the test. In addition, the number of uncorrected and self-corrected errors as well as the number of total errors in each condition is also measured. Finally, three primary contrast variables were also calculated; Inhibition versus Color naming, Inhibition/Switching versus combined naming plus reading and Inhibition/Switching versus Inhibition, by subtracting the completion time scaled score for one or more component tasks from the completion time scaled score for one of the higher-level tasks in order.

Findings show an atypical pattern of performance, where most of the sample (57.1%) scored with faster completion time and/or fewer errors in the fourth condition than in the third, which may be attributed to two main factors. First, Lippa & Davis (2010) [61] argue that faster performance could be explained because color naming typically takes slightly longer than word reading, and the fourth condition involves only half as much color naming as the third. Second, the occurrence of fewer errors may be attributable to specific learning characteristics, such as increased verbal learning ability or increased semantic verbal fluency, which interacts with the order of test's administration, i.e., the inhibition condition always precedes the inhibition/switching condition [61].

Finally, since Delis et al. (2001) [42] focused on the interpersonal connection and comfort between the examiner and the examinee during the neuropsychological assessment, Barnett et al. (2022) [62] studied the influence of them on CWIT$_{D\text{-}KEFS}$ performance. Finding showed that lower interaction between the examiner and the examinee was associated with increased completion time of Inhibition condition, however, no differences were observed in Inhibition/Switching in relation to the interaction between them, which is perhaps explained by the fact that the third condition serves as a practical test for the suspension procedure in the Inhibition/Switching condition [61–63].

TMT

The TMT$_{D\text{-}KEFS}$ version provides a more detailed evaluation of neurocognitive performance by separating its conditions in control conditions (1, 2, 3, 5) which measure clinically relevant components of visuomotor sequencing skills as well as psychomotor speed, and on the other side, condition 4, which measures higher-order executive skills, for example flexibility, cognitive set-shifting [64]. The main outcome measure is time-to-completion in seconds across all TMT$_{D\text{-}KEFS}$ conditions. To conclude, TMT$_{D\text{-}KEFS}$ provides conceptual control conditions that provide the opportunity for detailed evaluation of neurocognitive performance by separating psychomotor speed and higher-order executive functions.

In detail, the first condition is named visual search and requires visual scanning. The second condition includes numerical sequence and measures simple visual attention and visual scanning,

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visual- motor skills, and psychomotor speed. The third condition consists also a visual - motor task and verbal learning task which measures grammatical sequence. The fourth condition measures the number-letter alternation assessing divided attention, cognitive flexibility, set shifting by alternating two different sets of cognitive stimuli [65]. The fifth condition assesses motor speed [66]. Conditions 2 and 3 are often used to measure processing speed, while condition 4 is considered an index of cognitive function [66]. However, according to a previous study [16], the TMT$_{D\text{-}KEFS}$ condition 4 was the only measure of executive functions which is clearly assumed as a functional ability index. To perform well in the switching tests, the examinee must have visual scanning and motor speed abilities to extract the score data, and the following test may describe problems in the above domains [64]. Lezak et al. (2012) [67] argue that TMT is assumed as one of the most highly sensitive tools to detect neurocognitive deficits, and therefore, has an inseparable role in executive functions' evaluation.

The first four conditions are presented on a page A3, on which were scattered circles with numbers and letters as indicators. In condition 1 of visual scanning, the participant has to delete the number 3 located in random order on the reference sheet among other numbers and letters. In the number sequence condition, the examinee has to draw a single line connecting sequentially in ascending order numbers from 1 to 16, which are in random order on the reference sheet between letters. Correspondingly, in condition 3 of the letter sequence, the examinee has to connect letters in order of the alphabet, from A to P, which are randomly presented among other numbers. In the number-letter alternation condition 4, the participant has to draw a line, alternating the connections between numbers and letters sequentially. In more detail, starting from the number 1 the participant has to draw a line to A, then from A to the number 2, from number 2 to the letter B and so on until he/she reaches the letter P. In the motor speed condition 5, the A3 reference sheet consists of a single dotted line on which empty circles are scattered. The examinee has to draw a line following the dotted line and passing through the circles located along the course (Table 2). Except for condition 4 which has a maximum time limit of 240 seconds, the remaining conditions have a limit of 150 seconds. In each case, the participant is asked to complete the tests as quickly as possible. If the participant would make an error, the condition was interrupted, saying that an error had been made, and examiner waited for the participant to find the error and continue the condition, without interrupting the stopwatch. Four out of the five basic test conditions can empirically show whether participants' poor performance in the switching conditions is due to higher-level deficits in cognitive flexibility or due to impairments in the underlying skills needed to perform the switching tests, such as motor speed, visual scanning, and sequence of numbers or letters [48]. For example, poor performance in the alternation test may be due to deficits in visual search and motor control, whereas better performance in the letter-sequence condition may contribute to better performance in the number-letter alternation condition [66].

Table 2. Ratio of letters between the English and Greek alphabets for conditions 1-4 of TMT.

	Numbers															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Letters																
English	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Greek	Α	Β	Γ	Δ	Ε	Ζ	Η	Θ	Ι	Κ	Λ	Μ	Ν	Ξ	Ο	Π

Ethics

Consent was obtained from the Ethics Committee of the University of Western Macedonia, to approve the processing of the participants' data. Demographic information, such as age, gender, and education, was collected, adhering to the law of the European Union since 28 May 2018, which allows the use of sensitive personal data for research purposes. Participants were told and consented to that, upon a written request, their data could be removed from the online database. The study was aligned with the principles outlined in the Helsinki Declaration (World Medical Association, 1997).

Procedure

Initially, a pilot study administered to a total of 10 people, most of them were university students of the Psychology Departments, to evaluate CWIT and TMT$_{D\text{-}KEFS}$ tests in order to avoid concomitant problems in data collection. Before their inclusion to the study, participants read the information sheet, which mentioned that the researchers could use their clinical data for research purposes. Additionally, they were told that they would be able to withdraw from the study whenever they wanted without facing any consequences or giving any explanation. Before the completion of the consent form, the participants were told that their records would be coded and anonymized for future research purposes. After signing consent to participate in the research, a short structured interview followed to collect demographic information, including the participant's gender, age, and education level. These data were accompanied by a code, which included the initial letters of the participant's name in combination with the number of the series of administration (e.g. PM54), to preserve anonymity, but also to facilitate the identification process of the participants in the statistical database. D-KEFS tests' administration was conducted in a quiet environment at the University premises, mainly during morning hours, in order to perform better without external interference.

The neuropsychological assessment lasted about half an hour maximum and involved a face-to-face assessment. In specific, the instruction sheet of each condition was presented in front of the participants, before each test's administration.

Statistical Analyses

At first, a Pearson correlation test was applied for continuous variables, to examine whether there was a correlation between demographic variables with the two D-KEFS tests. Despite that D-KEFS subtests raw scores are otherwise converted to scaled scores having a mean of 10 as well as a standard deviation of 3, in the current analyses we provide only raw scores to identify participants' performance. Finally, inferential cut off scores were also calculated to select the score under which the possibility for an individual to belong to the normal population was below 10% and therefore would be assumed as low performance. The D-KEFS provide primary and optional variables; in order to provide both global as well as more detail evaluation about participants' performance. In the current study, only primary measures were used, in agreement with similar studies in literature. The Total Achievement scores attributable to each measure are as follows: CWIT$_{D\text{-}KEFS}$ (the four conditions measuring Time-to-Completion, Errors and three primary contrast measures; Inhibition versus Color naming, Inhibition/Switching versus combined naming plus reading and Inhibition/Switching versus Inhibition), and TMT$_{D\text{-}KEFS}$ (the five conditions measuring Time-to-Completion). It is worth mentioning that performance in CWIT$_{D\text{-}KEFS}$ is measured not only by completion time on each of the four trials, and the total number of errors on each trial, but also for corrected and uncorrected errors on the inhibition and inhibition/switching trials. However, the present norms were extracted by completion of time in each condition.

An alpha value of .05 (two-tailed) was used. The statistical analyses were performed by the SPSS software v 27 (IBM Corp. Released 2020. IBM SPSS Statistics for Macintosh, Version 27.0. Armonk, NY: IBM Corp).

3. Results

Demographic distribution is shown in Table 1. In line to the initial norms, no gender classifications were extracted in contrast to age which was associated with both tests, and therefore their norms were stratified by age. Education was not correlated to CWIT$_{D\text{-}KEFS}$, instead of TMT$_{D\text{-}KEFS}$ which found to be significantly related to schooling years, hence its norms were matched with age and education. Norms were established using percentiles scores (Tables 3–11). Specifically, we calculated the raw mean scores, as well as their standard deviation. Afterwards, we converted the raw scores into percentile scores. Inferential cut off scores were then calculated to extract those under the lowest 10%, which is the 10th percentile, which is traditionally applied as low performance [68]. Scores above the 95% of the population were regarded as superior performance.

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Table 3. Norms for the Trail Making Test (TMT) in conditions 1 to 5 in adults aged 20-29 years old.

	TMT1	TMT2	TMT3	TMT4	TMT5	TMT1	TMT2	TMT3	TMT4	TMT5
%ile	13-16 years of education (Education-Class 2)					16< years of education (Education-Class 3)				
95	12.25	17.60	18.30	42.95	16.85	17.00	21.00	25.00	50.00	20.00
90	13.00	19.30	20.60	46.60	21.30	17.00	21.00	25.00	50.00	20.00
75	15.00	20.25	25.25	57.00	28.25	17.75	22.50	25.75	51.50	20.75
50	19.50	25.00	29.50	68.50	36.00	21.00	27.00	27.50	59.50	25.00
25	24.00	29.00	34.75	73.75	45.50	22.25	28.00	33.25	72.00	29.25
10	29.80	34.10	39.70	93.40	49.70	-	-	-	-	-
M.	20.47	25.31	30.34	67.94	36.00	20.33	25.67	28.83	61.17	25.00
S.D.	6.77	5.49	8.06	15.89	11.70	2.42	2.94	3.86	10.02	4.05

Notes: M=Mean score, SD=Standard Deviation, TMT1= Visual scanning, TMT2=Number sequencing, TMT3=Letter sequencing=, TMT4= Number-Letter Switching, TMT5=Motor speed.

Table 4. Norms for the Trail Making Test (TMT) in conditions 1 to 5 in adults aged 30-39 years old.

	TM1	TM2	TM3	TM4	TM5	TM1	TM2	TM3	TM4	TM5	TM1	TM2	TM3	TM4	TM5
%ile	10-12 years of education (Education-Class 1)					13-16 years of education (Education-Class 2)					16< (Education-Class 3)				
95	20.00	19.00	27.00	65.00	31.00	16.00	15.00	19.00	53.00	20.00	15.00	14.00	18.00	45.00	16.00
90	20.00	19.00	27.00	65.00	31.00	16.00	15.70	19.60	54.80	25.40	15.80	15.60	18.40	47.80	17.20
75	20.00	19.00	27.00	65.00	31.00	17.00	22.00	23.00	61.00	35.00	17.00	19.00	23.00	55.50	24.50
50	23.00	27.00	30.00	103.00	40.00	19.00	27.00	33.00	69.00	39.00	20.00	23.00	26.00	60.00	33.00
25	-	-	-	-	-	23.00	40.00	51.00	80.00	45.00	25.50	29.50	31.50	74.00	45.00
10	-	-	-	-	-	27.20	46.60	63.60	140.0	64.00	27.60	32.80	38.60	87.60	54.40
Mean	23.00	27.00	29.33	91.67	43.33	20.00	29.53	37.67	79.20	40.80	21.38	24.15	27.00	64.77	34.54
S.D.	2.12	8.00	2.08	23.18	14.29	3.91	11.09	15.71	29.15	11.74	4.53	5.95	6.50	13.31	13.54

Notes: M=Mean score, SD=Standard Deviation, TMT1= Visual scanning, TMT2=Number sequencing, TMT3=Letter sequencing=, TMT4= Number-Letter Switching, TMT5=Motor speed.

Table 5. Norms for the Trail Making Test (TMT) in conditions 1 to 5 in adults aged 40-49 years old.

	TM1	TM2	TM3	TM4	TM5	TM1	TM2	TM3	TM4	TM5	TM1	TM2	TM3	TM4	TM5
%ile	10-12 years of education (Education-Class 1)					13-16 years of education (Education-Class 2)					16< (Education-Class 3)				
95	15.00	18.00	20.00	40.00	27.00	14.00	22.00	23.00	51.00	14.00	18.00	23.00	27.00	69.00	24.00
90	15.00	18.00	20.00	40.00	27.00	14.40	22.40	25.00	55.80	15.20	18.00	23.00	27.00	69.00	24.00
75	20.00	24.00	26.50	84.00	33.50	17.50	24.00	28.50	70.00	29.50	19.00	24.00	29.50	75.75	31.50
50	23.00	30.00	42.00	107.0	45.00	19.00	29.00	33.00	73.00	40.00	20.50	27.50	34.50	87.00	38.50
25	27.50	39.00	44.00	138.0	71.00	23.50	34.00	40.00	84.50	48.50	24.25	32.25	48.25	97.50	42.25
10	-	-	-	-	-	28.80	39.20	53.00	133.8	69.00	-	-	-	-	-
Mean	23.78	31.78	36.22	106.6	50.89	20.38	29.69	35.23	80.23	40.08	21.63	27.88	38.25	86.63	37.75
S.D.	6.07	10.15	10.37	36.25	20.15	4.646	5.83	9.38	26.84	16.36	3.70	4.19	10.75	11.55	8.36

Notes: M=Mean score, SD=Standard Deviation, TMT1= Visual scanning, TMT2=Number sequencing, TMT3=Letter sequencing=, TMT4= Number-Letter Switching, TMT5=Motor speed.

Table 6. Norms for the Color-Word Interference (CWIT) in conditions 1 to 4 in adults aged 20-49 years old.

	Age group 20-29				Age group 30-39				Age group 40-49			
%ile	CWIT1	CWIT2	CWIT3	CWIT4	CWIT1	CWIT2	CWIT3	CWIT4	CWIT1	CWIT2	CWIT3	CWIT4
95	21.00	16.05	33.05	39.05	16.10	16.10	31.65	44.00	20.55	16.55	37.75	47.75
90	21.20	17.00	35.10	43.00	20.00	17.10	37.30	48.10	21.20	17.10	42.30	52.00

75	24.00	18.00	37.00	47.00	24.00	19.00	44.75	52.75	24.75	19.00	49.75	56.75
50	25.00	20.00	41.00	51.50	25.00	20.00	49.50	60.00	25.00	21.00	56.00	64.00
25	29.75	22.00	50.00	57.00	29.00	21.25	57.75	68.25	30.00	23.25	62.00	70.00
10	30.90	23.90	59.80	63.60	30.90	22.90	60.90	80.00	31.90	26.00	65.00	80.00
M.	26.28	20.15	44.25	52	25.70	20.13	50.27	60.77	26.43	21.40	55.43	64.47
S.D	3.78	2.66	9.44	8	4.24	2	9	10.45	3.67	3.26	8.44	9.89

Notes: M= Mean score, SD= Standard Deviation, CWIT1= Color naming, CWIT2= Word reading, CWIT3= Inhibition, CWIT4= Inhibition/Switching.

Table 7. Norms for the Color-Word Interference (CWIT) for the CWIT1 in Errors (Total score, Corrected and Non Corrected) in adults aged 20-49 years old.

	Age group 20-29			Age group 30-39			Age group 40-49		
%ile	Uncorr	Corrected	Total	Uncorr	Corrected	Total	Uncorr	Corrected	Total
95	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
90	00.00	00.00	00.00	00.00	00.90	00.90	00.00	00.90	00.90
75	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
50	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
25	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
10	00.00	00.00	00.00	00.00	00.90	00.90	00.00	00.90	00.90
M	00.00	00.05	00.05	00.00	00.10	00.10	00.00	00.10	00.10
S.D	00.00	00.22	00.22	00.00	00.30	00.30	00.00	00.30	00.30

Notes: M= Mean score, SD= Standard Deviation, CWIT2= Word reading, Uncorr= Uncorrected errors, Corrected= Corrected errors, Total= Total errors.

Table 8. Norms for the Color-Word Interference (CWIT) for the CWIT2 in Errors (Total score, Corrected and Non Corrected) in adults aged 20-49 years old.

	Age group 20-29			Age group 30-39			Age group 40-49		
%ile	Uncorr	Corrected	Total	Uncorr	Corrected	Total	Uncorr	Corrected	Total
95	00.00	00.45	00.00	00.00	00.00	00.00	00.00	00.00	00.00
90	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
75	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
50	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
25	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
10	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
M	00.03	00.00	00.03	00.00	00.00	00.00	00.00	00.03	00.03
S.D	00.15	00.00	00.15	00.00	00.00	00.00	00.00	00.18	00.18

Notes: M= Mean score, SD= Standard Deviation, CWIT2= Color naming, Uncorr= Uncorrected errors, Corrected= Corrected errors, Total= Total errors.

Table 9. Norms for the Color-Word Interference (CWIT) for the CWIT3 in Errors (Total score, Corrected and Non Corrected) in adults aged 20-49 years old.

	Age group 20-29			Age group 30-39			Age group 40-49		
%ile	Uncorr	Corrected	Total	Uncorr	Corrected	Total	Uncorr	Corrected	Total
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1.00	1.00
50	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.25	2.25
25	0.00	2.90	3.00	0.00	2.00	0.00	1.00	3.00	3.00
10	1.00	3.00	3.95	0.45	2.00	0.00	2.45	3.00	3.45
M	0.10	0.73	0.83	0.03	0.73	0.77	0.23	0.93	1.17
S.D	0.30	1.08	1.23	0.18	0.69	0.67	0.67	1.04	1.28

Notes: M= Mean score, SD= Standard Deviation, CWIT3= Inhibition, Uncorr= Uncorrected errors, Corrected= Corrected errors, Total= Total errors.

Table 10. Norms for the Color-Word Interference (CWIT) for the CWIT4 in Errors (Total score, Corrected and Non Corrected) in adults aged 20-49 years old.

	Age group 20-29			Age group 30-39			Age group 40-49		
%ile	Uncorr	Corrected	Total	Uncorr	Corrected	Total	Uncorr	Corrected	Total
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
50	0.00	1.00	2.00	0.00	1.00	1.00	1.00	1.00	2.00
25	1.00	2.00	3.00	1.00	2.00	3.00	2.00	2.00	4.00
10	2.90	3.00	4.00	1.00	3.00	3.90	3.00	3.00	5.90
M	0.78	1.40	2.15	0.40	1.13	1.53	1.27	1.27	2.53
S.D	1.09	1.00	1.47	0.56	1.13	1.38	1.28	1.11	1.97

Notes: M= Mean score, SD= Standard Deviation, CWIT3= Inhibition, Uncorr= Uncorrected errors, Corrected= Corrected errors, Total= Total errors.

Table 11. Norms for the Composite Scaled-Score Equivalents of Scaled Scores by All age Groups.

%ile	Inhibition vs. Color Naming	Inhibition/ Switching vs Combined Naming + Reading	Inhibition/Switching vs. Inhibition
95	3.00	2.00	2.00
90	3.00	1.00	2.00
75	2.00	1.00	0.75
50	0.00	-1.00	-1.00
25	-2.00	-2.00	-2.00
10	-3.00	-4.00	-3.00
M	-0.21	-0.98	-0.56
S.D	2.32	2.09	1.88

Notes: M= Mean score, SD= Standard Deviation.

CWIT norms for the four conditions were matched to age; Color Naming ($p>0.05$), Word Reading ($p<0.05$), Inhibition ($p<0.01$), and Inhibition/Switching ($p<0.01$), but not stratified by gender and education, because no differences were observed between men and women, as well as between the three educational classes. On the contrary, TMT$_{D\text{-}KEFS}$ performance was strongly dependent on age and education, according to Pearson test, and therefore, different age and education-related norms have been extracted in each D-KEFS test's conditions: Visual Scanning ($p>0.05$), Number Sequencing ($p<0.05$), Letter Sequencing ($p<0.05$), Letter–Number Switching ($p<0.01$) and Motor Speed ($p<0.01$).

4. Discussion

To our knowledge, there are no norms outside the original American age-adjusted norms presented in the D-KEFS manual by Delis et al. (2001) [42] available for clinicians and researchers in Greece. Despite some previous versions of Stroop and TMT validated in Greek adult population, this is the first study which measures the effects of demographic variables on CWIT$_{D\text{-}KEFS}$ as well as TMT$_{D\text{-}KEFS}$ performance and provide normative data for the Greek sample. Moreover, there is a lack in literature regarding neuropsychological tests' normative data studies in the age range between early to middle adulthood, whereas no particular focus was given to the socio-demographic effect in examinees performance. This research gap is supposed to be covered by the current study.

Regarding CWIT$_{D\text{-}KEFS}$, it was created to improve the Stroop version by including an inhibition/switching trial, which was designed to be more difficult than the inhibition trial by means of completion time, as well as number of errors. Overall, the results of the current study suggest that the $CWIT_{D-KEFS}$ can be regarded as a measure of performance in processing speed/executive functioning, however, till now there are no studies comparing the CWIT with the old Stroop test. The results of the current study showed that age was a predictive factor of $CWIT_{D-KEFS}$ performance across its conditions, also in agreement with previous studies from Lippa and Davis (2010) [61], Zhao et al. (2020) [43] and Espenes et al. (2024) [69]. In fact, the three age classes of the sample differed by means of their performance in $CWIT_{D-KEFS}$ mainly regarding the last two conditions. Based on Pearson test, age classes differed statistically significantly in condition 3 ($r = .489$, $n = 100$, $p < .001$), 4 ($r = .514$, $n = 100$, $p < .001$) and 2 ($r = .219$, $n = 100$, $p < .005$). Additionally, regarding condition 2, it is worth mentioning that the average and upper percentile scores among the three age classes were identical with subtle differences, whereas those between 30-39 years old had a slightly better performance followed by those between 20-29, and those between 40-49 years old. However, this slightly lower performance of younger counterparts compared to adults who belong to the 30-39 age group does not necessarily mean lower executive functioning, because various factors, such as fatigue, low motivation or reduced attention could affect their performance [70].

Kurniadi et al. (2021) [20], found moderate correlation between education with $CWIT_{D-KEFS}$ performance in condition 3 ($r = .212$, $n = 101$, $p < .005$) and condition 4 ($r = .319$, $n = 100$, $p < .001$), whereas Karr et al. (2018; 2019 [71,72]) found that performance in the D-KEFS was proportional to participants' level of education, which is in contrast to the results of the current study. Finally, regarding gender, no statistically significant correlation with performance was detected, which is confirmed by the study of Cutler et al. (2023) [24], in which the effect of gender did not play a significant role in the performance of the sample across all test's conditions. Furthermore, in the longitudinal study by Adólfsdóttir et al. (2017) [18], a marginal correlation in performance was detected, as for the suspension condition they predicted that completion time increases per year by 0.61% for men and by 0.62% for women, while for the suspension condition/shift, the rates were 0.72% for men and 0.70% for women.

The primary variable of the $CWIT_{D-KEFS}$ is completion time, errors and the three contrast measures mentioned previously. Therefore norms -at this stage of our study- were calculate only for them, because they are assumed as primary scores. Norms for the optional scores, that include the Inhibition/Switching versus Color naming as well as Inhibition/Switching versus Word reading using their scaled scores, were not included in the current study. It is worth mentioning that in the first two conditions total errors were almost zero for all age groups without exception. Then, in the condition 3, a limited number of errors were observed, most of which were self-corrected. This finding is probably related to the increase in completion time, relative to the previous baseline conditions, as correcting existing errors requires the participant to delay. Finally, in condition 4, the number of errors was twice as high as in condition 3, while the mean of uncorrected errors and self-corrections appeared almost equal, regardless of age. In fact, this finding agrees with the study of Lippa & Davis (2010) [61], where it was found that basically in people aged from 14 to 69 years, the average of errors was found greater in the condition 4 than in 3. However, it contrasts with the study of Barnett et al. (2022) [62], because they argue that condition 3 is assumed to function as a practice test for condition 4 that requires inhibitory control and switching. In general, as the last two conditions are considered more complex, it was observed that the participants largely seemed to sacrifice more time in completing them, trying to avoid mistakes.

The inhibition/switching trial was designed to be the most difficult as regards completion time and the number of errors. Of particular interest is the study by Lippa & Davis (2010) [61], which investigates the complexity of the fourth condition compared to the third in adult population with an average level of 14.8 years of schooling and a diagnosis of either neurological or psychiatric pathology. Among people between 14-69 years old the mean of errors in inhibition/switching condition is greater compared to the inhibition condition, whereas in those between 8-13 years old and 70-89 years old the errors' mean score is lower or equal with the ones in inhibition condition [61]. Moreover, longitudinal study of Adólfsdóttir et al. (2017) [18] demonstrates age-related changes in performance on inhibition, and combined inhibition and switching in middle-aged and older adults,

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where these populations have lower performance which appears to persist, even after controlling for baseline measures of processing speed, gender and years of schooling. Finally, norms for the three contrast variables; Inhibition versus Color naming, Inhibition/Switching versus combined naming plus reading and Inhibition/Switching versus Inhibition were shown to be around 0 across all age groups, which is in line with the American norms.

A previous normative data study for the Stroop version called as Trenerry's Stroop Neuropsychological Screening Test (SNST) was conducted by Zalonis et al. (2009a) [45] in Greek adult population between 18-84 years and education range 6-18 years of schooling. On the contrary to our results, their findings suggest that both age and education significantly contributed to SNST performance. However, no direct comparisons can be made between our findings with the study of Zalonis et al. (2009a) [45], because they included a broader sample in terms of age and education, which profoundly influenced examinees' performance. Additionally, between those with 20-29 years old in the sample of this study, no one had less than 13 years of education, something that seems to be representative of the educational level of young adults in Greece according to the official laws of the government. Nevertheless, according to their findings, age appeared to be the most predictive factor of SNST performance, compared to education. Their study calculated four variables: Color task; the time needed to read the 112 items, and in the Color–Word task; the number of errors; the number of self-corrections; and the interference score, were calculated by subtracting the number of errors from the total number of items completed in 120s. On the contrary, in our study we followed a totally different scoring method by measuring the completion time across the four conditions.

As regards the effects of demographics on $TMT_{D\text{-}KEFS}$, it is worth mentioning that most studies used the traditional version of the test, so despite that useful comparisons can be made, this controversy could be a limitation [52,73]. More specifically, previous studies which used the traditional version of the test in different populations show that TMT performance appeared to be related to age and years of schooling [49,50,52,54,74], which is also confirmed by the findings of the current study. Except from the study of Fine et al. (2011) [48], the remaining studies referred to the traditional version of the test, showed that age and level of education significantly related with TMT execution time [49,50,54,74]. A possible explanation could be that typically, motor speed gradually declines with age [53], which is also in agreement with the study of Cavaco et al. (2013) [52], who found that the performance becomes better as the level of education increases. Finally, Fine et al. (2011) [48] showed that the effect of higher educational level is stronger mainly in the conditions of letter sequence and number-letter switching, which is also confirmed by the results of the current study. Although many studies found that overall age has a greater impact on the overall test performance than education [53], in our study we found that across the three age classes, those with 16+ years of schooling did better than their peers with a lower level of education, indicating the improvement in motor speed in those with a higher level of education, which is also confirmed by some previous studies [54].

Regarding gender, no differences were found by means of $TMT_{D\text{-}KEFS}$ performance in the current study. According to literature review, previous studies observed differences between men and women. In specific, Cavaco et al. (2013) [52] found differences in the number sequencing condition, while study by Cangoz et al. (2009) [73] reported a relationship between gender and TMT conditions. However, the study of Cangoz et al. (2009) [73] was conducted in people aged over 50, so no clear comparisons can be made. Heterogeneity of results by means of gender may be attributed to uncontrolled or unmeasured factors, such as sample's characteristics, differences in men and women by means of educational level and/or cultural differences [75].

Finally, according to the findings mentioned above, it seems that age and educational level may be predictive factors of $TMT_{D\text{-}KEFS}$, because process speed declines with age [52,54] and increases with years of schooling [76]. These results are supported by theories about cognitive reserve which stress the protective role of education, among other factors, in cognitive decline, even in fluid intelligence aspects [77,78].

To compare the results of the current study with the first normative data study in Greek adult population by Zalonis et al (2009) [45], it was found that in their study they followed a totally different age clustering, because they divided their sample in 12 different groups; (16–19, 20–29, 20–40, 25–45, 30–50, 35–55, 40–60, 45–65, 50–70, 55–75, 60–80, 65–85) and three different from ours educational levels according to the number of years of schooling (<9, 10–12, 13<). At this point it must be noted that due to the absence of participants in the age group of 20-29 with educational level less than 10-12 years of schooling, the following category was not included in the normative tables. However, it is worth noting that the normative data scores in number sequence and switching conditions, which are common between the two TMT versions, in the age class who had 10-12 years of schooling was almost the same. Finally, given that age classes between the two studies are very different, comparing them is vague and insufficient.

Comparing Greek norms of CWIT with the American ones stratified also by age, it was found that our mean scores belonged to the same range in terms of scaled scores which is equivalent to the mean American score of 10 or 1 SD above, which is acceptable according to what was previously mentioned. Hence, despite that Greek adults had approximately slightly lower time of completion in some conditions, compared to Americans, this evidence can be attributed to higher educational levels across all age classes. Moving to the TMT_{D-KEFS}, Greek norms were equivalent to Americans, however, in some conditions Greek adults scored 1 SD higher compared to the American sample, which can be also explained by increased years of schooling. Finally, it can be assumed that CWIT and TMT norms for Greek adult population are equivalent to the original norms calculated by Delis et al. (2001) [42], hence they can be used by health professionals and researchers.

5. Limitations

The present research has some limitations that are worth mentioning. In particular, although an effort was made so that the sample corresponds to all levels of education, we did not manage to identify individuals exclusively with primary or secondary education for the age class of 20-29 years old. However, this seems to be representative for the Greek population. Additionally, level of intelligence was not considered in the current study, however given that all of them had more than 10 years of education, it can be assumed that intelligence was not a severe factor which could influence the current findings. Finally, both tests did not take into account the lexical characteristics of the sample, such as reading style or letter processing speed, differences which may have affected the processing of the Greek letter conditions in the visual-mental tracing.

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