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Featured Article

Development of a dual task interference assessment tool: evaluating test-retest reliability and concurrent validity in community-dwelling older adults

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ABSTRACT

This study aimed to develop and evaluate the reliability and concurrent validity of the Dual Task Interference Assessment Tool (DTIT) in community-dwelling older adults. A total of 93 participants (42 with cognitive decline and 51 without) were assessed using the DTIT, which evaluates dual-task abilities across four domains: upper extremity, lower extremity, balance, and functional mobility. Motor tasks included cup stacking, tandem gait, step block, and the Timed Up and Go (TUG) test, while cognitive tasks involved serial subtraction, word generation, counting backward by months, and Reciting Alternate Letters (RAL). Motor (mDTE) and cognitive (cogDTE) dual-task interference were calculated for each task. Significant group differences were observed in all DTIT subscales, except for the mDTE of DTIT_Lower Extremity ($p = 0.308$). Test-retest analyses demonstrated excellent reliability for all DTIT subscales, with no significant learning effect between sessions ($p > 0.05$). Strong concurrent validity was confirmed by significant correlations between DTIT_Upper Extremity and NHPT, DTIT_Balance and the Functional Reach Test, and DTIT_Lower Extremity/Functional Mobility and walking speed ($p < 0.05$). The DTIT is the first instrument to comprehensively assess dual-task interference in older adults, with and without cognitive decline. Thanks to its robust psychometric properties, it can be used as a practical clinical and research tool to identify dual-task difficulties and monitor rehabilitation outcomes.

Introduction

Performing concurrent cognitive and motor tasks is a fundamental aspect of daily life. However, as cognitive and motor demands increase, individuals may experience performance decrements, particularly in complex motor activities such as walking, balancing, or upper limb tasks.[1,2] This phenomenon, known as dual-task interference, has been widely studied to understand the interplay between cognition and motor control. Dual-task assessments provide valuable insights into cognitive-motor interactions and have been utilized to evaluate neurological conditions, fall risk, and functional impairments in older adults.[3–5]

Current dual-task evaluation methods predominantly focus on gait-based assessments, examining how walking performance is influenced by simultaneous cognitive tasks.[6–11] However, growing evidence suggests that upper extremity dual-task performance may be a more sensitive indicator of cognitive function than gait-based assessments.[12] Unlike walking, which is a largely automated activity, upper extremity tasks require more precise motor control and greater cortical activation, making them valuable in assessing cognitive-motor integration.[13,14]

Despite the widespread use of dual-task paradigms, no comprehensive, standardized tool exists that evaluates both upper and lower extremity function under dual-task conditions. Existing protocols vary in cognitive task complexity, motor task selection, and difficulty, making it challenging to establish a unified framework for dual-task performance evaluation.[11–14] While specific dual-task protocols have been developed for patient populations, such as stroke survivors or individuals with dementia, a more holistic approach is needed.

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Most existing methods focus on locomotion, such as dual-task walking tests or cognitive Timed Up and Go (TUG) variants. Although these assessments are valuable for evaluating gait-related interventions, they provide limited information on dual-task performance involving the upper extremities and other motor functions. Additionally, gait-based protocols often employ a restricted range of cognitive tasks that insufficiently challenge executive functions. Many assessments examine only a single dimension, such as gait or balance, rather than providing a multi-domain evaluation of cognitive-motor interactions.

To address these limitations, we developed the Dual Task Interference Assessment Tool (DTIT), multi-domain instrument designed to evaluate upper and lower extremity performance, balance, and functional mobility under standardized cognitive loads. By incorporating both extremities and multiple motor domains into a single assessment, the DTIT aims to provide a more comprehensive understanding of cognitive-motor interactions in older adults.

Methods

Participants

The study was conducted between November 2023 and April 2024 with 93 community-dwelling older adults, aged 65 years or older. Among these participants, 42 had cognitive decline, and 51 were cognitively healthy. All participants were native Turkish speakers, and no difficulties in understanding the instructions or items of the tool were reported. All participants were recruited from Mugla Education and Training Hospital, Turkey. Cognitive status was assessed using the Mini-Mental State Examination (MMSE). Participants scoring $\geq$24 on the MMSE were classified as cognitively healthy, and those scoring $<$24 were classified as experiencing cognitive decline.[15]

The participants were screened for eligibility by a physiatrist and invited to participate if they met the following inclusion criteria: age over 65, no severe cardiovascular, neurological, or psychological conditions, the ability to walk 10 m without aids, and the ability to provide written informed consent. Exclusion criteria included conditions that significantly impacted walking ability, pain during standing or walking, and depressive symptoms (Geriatric Depression Scale - Short Form, GDS-SF $\geq$ 10).[14]

Ethical approval for the study was granted by the Ethics Committee of Mugla Sitki Kocman University Health Sciences (Decision No: 112, Date: 20/09/2023). All participants signed the informed consent form, and the study adhered to the ethical standards outlined in the Helsinki Declaration.

Development of the dual task interference assessment tool (DTIT)

A comprehensive literature review on dual-task assessments was conducted as the first step. Following this, the research team, which consisted of four physiotherapists, one physiatrist, and one biostatistician, held multiple face-to-face interviews. Based on these interviews and the literature review, the decision was made to develop an assessment tool encompassing four primary domains: upper extremity, lower extremity, balance, and functional mobility. Each domain needed to include four distinct types of assessments: single motor, motor-motor, motor-cognitive, and single cognitive tasks.[14]

As a result, a 16-step tool was developed, with four subtests for each of the four main domains. After finalizing the tool, it was sent to a team of 10 experts from various hospitals and universities for their feedback. This team included five physiatrists, two neurologists, and three physiotherapists. After receiving expert feedback, the tool was refined, and a pilot study was conducted with 20 community-dwelling older adults to finalize the conceptual framework of the Dual Task Interference Assessment Tool (DTIT).

First version of DTIT

The initial version of the DTIT was administered to 98 older adults. It included tasks such as building a tower with cups, the five-repeated sit-to-stand test, touching consecutive numbers with the toe, and the Timed Up and Go (TUG) test. For each motor task, secondary tasks were also introduced. For example, during the tower-building task, participants performed finger tapping; during the sit-to-stand test, they held a glass of water with a tray. In the balance task, participants held a mug with water while touching consecutive numbers with their toes. The TUG test included the additional task of passing a ball from hand to hand. Cognitive tasks were incorporated as follows: counting backward by months during the tower-building task, counting backward by days during the sit-to-stand test, touching non-consecutive numbers with the toe during the balance task, and performing serial subtraction during the TUG test. The tool showed acceptable validity results in the DTIT_Upper Extremity and DTIT_-Functional Mobility domains but not in the DTIT_Lower Extremity and DTIT_Balance domains. Consequently, the research team decided to revise the single motor tasks for these two domains.

Second version of DTIT

For the DTIT_Lower extremity and DTIT_Balance, which did not show valid results in the first version, the research team and expert opinions determined new single motor tests. The second version of the DTIT included building a tower with cups, the step-top test, tandem walking, and the TUG test and was conducted with 93 older adults. Along with each single motor task, secondary motor tasks were also performed, such as finger tapping while building the tower, transferring coins from pocket to pocket during tandem walking,[16] pressing the top of a ballpoint pen during the step-top test, and passing a ball from hand to hand during the TUG test. Cognitive tasks were implemented as follows: counting months backward while building the tower, counting backward from 200 by sevens during tandem walking, generating words during the step-top test, and counting letters of the alphabet in a skipping pattern during the TUG test (Table 1).[17]

Test administration sequence

Two physiotherapists, each with a master's or doctoral degree and extensive clinical and research experience, administered the tool. The assessment took place in a quiet room within the Physiotherapy and Rehabilitation Unit at Mugla Sitki Kocman Training and Education Hospital, ensuring minimal distractions. All instructions and interactions were provided in Turkish, the primary language of the participants.

Participants first completed single motor tasks, followed by motor-motor and motor-cognitive tasks, and finally, single cognitive tasks while seated. The duration of single cognitive tasks was matched to their corresponding motor-cognitive conditions. For example, if a participant required 30 s to complete the tower-building task while counting backward by months, they were given the same duration to perform the cognitive task alone.[18]

Performance was measured using a stopwatch, with one researcher recording task duration and interruptions, while another documented secondary task performance. To minimize learning effects, participants rested for 5 min between conditions. Different numbers or word categories were used in practice and actual tests to prevent memorization effects. Each session lasted approximately 20 min. Dual-task instructions encouraged balanced task

Table 1
Comparison of the first and second versions of the DTIT.

Domain	First Version (n = 98)	Second Version (n = 93)	Reason for Revision	Psychometric Performance
Upper Extremity	Tower building + finger tapping (motor), counting backward by months (cognitive)	Tower building + finger tapping (motor), counting months backward (cognitive)	Retained (acceptable validity in first version)	Valid and reliable in both versions
Lower Extremity	Five-repeated sit-to-stand + holding tray with water (motor), counting backward by days (cognitive)	Step-top test + pressing pen (motor), word generation (cognitive)	Sit-to-stand with tray showed poor validity → replaced	Improved validity in second version
Balance	Toe touching numbers while holding mug with water (motor), toe touching non-consecutive numbers (cognitive)	Tandem walking + coin transfer (motor), counting backward from 200 by sevens (cognitive)	Mug + toe touching tasks had low validity → replaced	Improved validity in second version
Functional Mobility	TUG + passing ball (motor), serial subtraction (cognitive)	TUG + passing ball (motor), Reciting Alternate Letters (RAL) (cognitive)	Retained (acceptable validity in first version)	Valid and reliable in both versions

*This table summarizes the main differences between the first and second versions of the DTIT. Tasks for the Lower Extremity and Balance domains were revised due to insufficient validity in the first version. The revised tasks demonstrated improved psychometric performance, while tasks in the Upper Extremity and Functional Mobility domains were retained with minor adjustments.

prioritization, such as "Walk as fast as you can while performing the subtraction task as quickly and accurately as possible."

Dual task effect calculation

The motor and cognitive interference effects were quantified using the Dual Task Effect (DTE) calculations. The motor DTE (mDTE) and cognitive DTE (cogDTE) were computed using the following formulas:

Motor Dual Task Effect

$$= (Motor\ DT - Motor\ ST)\ /\ Motor\ ST\ x\ 100\%$$

Cognitive Dual Task Effect

$$= (Cognitive\ DT - Cognitive\ ST)\ /\ Cognitive\ ST\ x\ 100\%$$

where Motor DT and Cognitive DT refer to the performance under dual-task conditions, and Motor ST and Cognitive ST represent performance in single-task conditions. A higher DTE value indicates greater interference, reflecting decreased performance under dual-task conditions. These formulas have been widely used in clinical and experimental dual-task research.[19]

Test-retest reliability

Test-retest reliability was assessed by conducting a second measurement session one week after the initial assessment. The same motor and cognitive tasks were evaluated under single- and dual-task conditions. A one-week interval was chosen to minimize potential changes in participants' mobility and cognitive function. Data from 30 participants with cognitive decline and 30 without were analyzed based on COSMIN criteria, which recommend a minimum sample of 30 for test-retest reliability assessment.[20]

Concurrent Validity

To evaluate concurrent validity, DTIT scores were compared with the Nine Hole Peg Test (NHPT), Functional Reach Test (FRT), and walking speed. Significant correlations were expected between NHPT and DTIT_Upper Extremity, walking speed and DTIT_Lower Extremity/DTIT_Functional Mobility, and FRT and DTIT_Balance.

Nine hole peg test

The NHPT consists of a wooden block with nine holes and nine plastic pegs that fit precisely into these holes. Participants are required to pick up the pegs individually from a box, insert them into the holes as quickly as possible, and then return them to the box. The total time taken from the start to the completion of the task is recorded as the performance score.[21]

Walking speed

Participants walked an 11-meter straight path, with 3-meter zones at each end for acceleration and deceleration. Walking speed was determined by measuring the time taken to cover the middle 5-meter segment and was expressed in meters per second.[22]

Functional reach test

The Functional Reach Test assesses balance and functional limits of stability. Participants stood with their arms at 90° flexion, fist closed, near but not touching a wall. The evaluator marked the initial position of the third metacarpal head on the wall. Participants then leaned forward as far as possible without stepping or losing balance, and the new position of the third metacarpal head was recorded. The distance between the initial and final marks was measured using a tape measure. The average of three trials was used for analysis.[23]

Sample size calculation

Sample size was determined using G*Power 3.1.9.6. Based on Lee et al. (2023), the effect size for walking speed was 1.17, with a Type I error probability of 0.05, test power of 0.95, and an allocation ratio of 1. Accordingly, a minimum of 20 participants per group was required.[15]

Statistical analysis

All statistical analyses were conducted using IBM SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Normality was assessed using the Kolmogorov–Smirnov test and further verified through visual inspection of histograms and Q–Q plots, as well as evaluation of skewness and kurtosis values. Test-retest reliability of the DTIT was evaluated using intraclass correlation coefficients (ICC) with a 95 % confidence interval (CI). Reliability was classified according to Fleiss (2011) as poor (ICC < 0.40), fair to good ($0.40 \leq$ ICC ≤ 0.75), or excellent (ICC > 0.75).[24] The Wilcoxon test was applied to compare mDTE and cogDTE scores between session 1 and session 2, assessing potential learning effects. Measurement error was quantified using the standard error of measurement (SEM) and the minimum detectable change (MDC). SEM was calculated as the square root of the error variance, while MDC was defined as 1.96 times the square root of the error variance multiplied by the SEM. SEM % and MDC % were

Table 2
Characteristics of participants (N = 93).

	With Cognitive Decline (n = 42)	Without Cognitive Decline (n = 51)	p value
Age (years) /mean±SD	70.54 ± 4.57	70.98 ± 5.47	0.87
Gender / n (%)			
Male	19 (45.2 %)	14 (27.5 %)	*x2*= 3.183
Female	23 (54.8 %)	37 (72.5 %)	p = 0.07
Education level / n (%)			
Primary Education	17 (40.5 %)	20 (39.2 %)	*x2*= 0.138
High School	13 (31 %)	14 (27.5 %)	p = 0.99
University	11 (26.2 %)	16 (31.4 %)	
Postgraduate	1 (2.4 %)	1 (2.0 %)	
Previous occupation / n (%)			
Homemaker	5 (11.9 %)	31 (60.8 %)	*x2*= 24.106
Laborer	12 (28.6 %)	8 (15.7 %)	$\mathbf{p < 0.001}$
Civil Servant	18 (42.9 %)	7 (13.7 %)	
Retired Teacher	7 (16.7 %)	5 (9.8 %)	
Body Mass Index (kg/m2) / mean±SD	26.69 ± 3.67	25.72 ± 3.52	p = 0.13
MMSE (0–30) / mean±SD	21.11 ± 1.22	25.58 ± 1.16	$\mathbf{p < 0.001}$
GDS-SF (0–15) / mean±SD	6.06 ± 2.02	7.02 ± 3.01	p = 0.78

GDS-SF: Geriatric Depression Scale (GDS-short form); IQR: interquartile range; MMTE: Mini Mental State Examination; SD: standard deviation.

Table 3
The DTIT results (mean ± standard deviation) of groups.

	With Cognitive Decline (n = 42)	Without Cognitive Decline (n = 51)	p value
Upper Extremity			
mDTE	−93.88 ± 1.90	−91.21 ± 4.06	$p < 0.001$
CogDTE	−99.68 ± 0.31	−98.37 ± 0.62	$p < 0.001$
Lower Extremity			
mDTE	- 82.80 ± 10.02	−80.90 ± 5.60	p = 0.308
CogDTE	−94.60 ± 1.22	−93.48 ± 2.30	p = 0.003
Balance			
mDTE	−97.42 ± 0.63	−96.50 ± 1.43	p = 0.001
CogDTE	−99.57 ± 0.14	−98.75 ± 0.43	$p < 0.001$
Functional Mobility (TUG)			
mDTE	−87.83 ± 5.07	−85.44 ± 4.61	p = 0.018
CogDTE	−94.60 ± 1.22	−93.48 ± 2.30	$p < 0.001$

DTIT: Dual Task Interference Assessment Tool; mDTE: Motor dual task interference; CogDTE: Cognitive dual task interference.

expressed as percentages of their respective means. Concurrent validity of the DTIT was assessed using Spearman's rank correlation coefficients (r) between DTIT subcomponents and related measures. Correlations were interpreted as low ($r < 0.2$), moderate (r = 0.2–0.5), or high ($r > 0.5$).[25] Statistical significance was set at $p < 0.05$.

Results

Table 2 presents the descriptive characteristics of participants with cognitive decline (n = 42) and without cognitive decline (n = 51). The mean MMSE score was 21.11 ± 1.22 in the cognitive decline group and 25.58 ± 1.16 in the cognitively healthy group. No significant differences were found between the groups in terms of gender, educational level, BMI, and GDS-SF scores. However, a chi-square test of independence revealed a significant association between previous occupation and cognitive status ($\chi^2(3) = 24.106$, $p < 0.001$). Post hoc examination of adjusted residuals showed that the proportion of homemakers was significantly higher in the group with cognitive decline, whereas the proportion of civil servants was significantly higher in the cognitively intact group. No significant deviations from expected values were observed for labourers or retired teachers.

Table 3 displays the descriptive statistics of the mDTE and cogDTE scores for each DTIT subscale. Significant group differences were observed in all DTIT subscales, except for the mDTE of DTIT_Lower Extremity (p = 0.308).

Table 4 presents the test-retest reliability results of the DTIT subscales. No significant learning effect was observed between the first and second testing sessions ($p > 0.05$).

Table 5 provides the results of the concurrent validity analysis. Significant correlations were found between DTIT_Upper Extremity and NHPT, DTIT_Balance and Functional Reach Test, and DTIT_Lower Extremity/DTIT_Functional Mobility and walking speed ($p < 0.05$), supporting the study hypothesis.

Discussion

This study aimed to investigate the test-retest reliability and validity of the DTIT in older adults with and without cognitive impairment. The main findings demonstrated that motor-motor (mDTE) and cognitive-motor (cogDTE) dual task interference exhibited high validity and reliability and effectively discriminated between different levels of cognitive function in older adults. These results suggest that DTIT is a comprehensive and appropriate tool for assessing dual-task performance in this population.

Development of DTIT

The selection of motor and cognitive tasks for DTIT was based on previous studies and expert opinions, considering the interaction between motor and cognitive functions. Since no universally accepted gold standard exists for secondary tasks in dual-task assessments, task selection was carefully designed.[15,26] For upper extremity

Table 4
The mDTE and CogDTE reliability results of both groups.

		With Cognitive Decline (n = 30)	Without Cognitive Decline (n = 30)
Upper Extremity	ICC (2,1)		
mDTE	95 % CI of ICC (2,1)	0.972	0.989
CogDTE	SEM (SEM %)	0.948–0.985	0.980–0.994
	MDC95 (MDC95 %)	0.29 (0.31 %)	0.56 (0.61 %)
	ICC (2,1)95 % CI of ICC (2,1)	1.49 (1.58 %)	2.07 (2.26 %)
	SEM (SEM %)	0.910	0.975
	MDC95 (MDC95 %)	0.832–0.951	0.956–0.986
		0.04 (0.04 %)	0.08 (0.08 %)
		0.55 (0.55 %)	0.78 (0.79 %)
Lower Extremity			
mDTE	ICC (2,1)	0.994	0.975
	95 % CI of ICC (2,1)	0.989–0.997	0.956–0.975
CogDTE	SEM (SEM %)	1.54 (1.85 %)	0.78 (0.96 %)
	MDC95 (MDC95 %)	3.43 (4.14 %)	2.44 (3.01 %)
	ICC (2,1)	0.753	0.910
	95 % CI of ICC (2,1)	0.541–0.867	0.843–0.949
	SEM (SEM %)	0.18 (0.19 %)	0.32 (0.34 %)
	MDC95 (MDC95 %)	1.17 (1.23 %)	1.56 (1.66 %)
Balance			
mDTE	ICC (2,1)	0.806	0.982
CogDTE	95 % CI of ICC (2,1)	0.640–876	0.969–990
	SEM (SEM %)	0.09 (0.09 %)	0.20 (0.20 %)
	MDC95 (MDC95 %)	0.83 (0.85 %)	1.23 (1.27 %)
	ICC (2,1)	0.678	0.901
	95 % CI of ICC (2,1)	0.396–0.828	0.826–0.944
	SEM (SEM %)	0.02 (0.02 %)	0.06 (0.06 %)
	MDC95 (MDC95 %)	0.39 (0.39 %)	0.67 (0.67 %)
Functional Mobility			
mDTE	ICC (2,1)	0.998	0.997
CogDTE	95 % CI of ICC (2,1)	0.995–0.999	0.995–998
	SEM (SEM %)	0.18 (0.20 %)	0.64 (0.74 %)
	MDC95 (MDC95 %)	1.17 (1.33 %)	2.21 (2.58 %)
	ICC (2,1)	0.638	0.638
	95 % CI of ICC (2,1)	0.940–983	0.940–983
	SEM (SEM %)	0.78 (0.82 %)	0.32 (0.34 %)
	MDC95 (MDC95 %)	2.44 (2.57 %)	1.56 (1.66 %)

mDTE: Motor dual task interference; CogDTE: Cognitive dual task interference; ICC (2,1): intraclass correlation coefficient; CI: confidence interval; SEM: standard error of measurement; SEM %: SEM percentage to mean; MDC95: minimal detectable change at the 95 % confidence interval; MDC95 %: MDC95 percentage to mean.

Table 5
Correlation coefficients between the subscale scores of the DTIT and Nine Hole Peg Test, Walking Speed and Functional Reach Test.

	With Cognitive Decline (n = 42)			Without Cognitive Decline (n = 51)		
	Nine Hole Peg Test	Walking Speed	Functional Reach Test	Nine Hole Peg Test	Walking Speed	Functional Reach Test
Upper Extremity						
mDTE	rr=−0.827;$p < 0.001$	rr=0.352; $p = 0.02$	rr=−0.783;$p < 0.001$	rr=−324;$p = 0.021$	rr=0.066; $p = 0.647$	rr=−0.244; $p = 0.084$
CogDTE	rr=0.432;$p = 0.004$	rr=- 0.264; $p = 0.09$	rr=0.466;$p = 0.002$	rr=0.076; $p = 0.59$	rr=−0.088; $p = 0.540$	rr=0.133; $p = 0.354$
Lower Extremity						
mDTE	rr=0.711;$p < 0.001$	rr=- 0.505; $p = 0.001$	rr=0.726;$p < 0.001$	rr=−0.263;$p = 0.06$	rr=0.010; $p = 0.944$	rr=−0.249; $p = 0.07$
CogDTE	rr=0.699;$p < 0.001$	rr=- 0.604; $p < 0.001$	rr= 0.737;$p < 0.001$	rr=0.354; $p = 0.01$	rr=0.269; $p = 0.056$	rr=−0.364; $p = 0.009$
Balance						
mDTE	rr=−0.338;$p = 0.02$	rr=0.263; $p = 0.09$	rr=−0.399;$p = 0.009$	rr=−0.302;$p = 0.03$	rr=−0.170; $p = 0.23$	rr=0.273; $p = 0.05$
CogDTE	rr= 0.211;$p = 0.18$	rr=−0.295; $p = 0.06$	rr=0.165;$p = 0.30$	rr=−0.449; $p < 0.001$	rr=−0.301; $p = 0.03$	rr=0.435; $p = 0.002$
Functional Mobility						
mDTE	rr=−0.771;$p < 0.001$	rr=0.477; $p = 0.001$	rr=−0.773;$p < 0.001$	rr=−0.430;$p = 0.002$	rr=−0.426;$p = 0.002$	rr=0.082; $p = 0.567$
CogDTE	rr=−0.699 $p < 0.001$	rr=−0.604; $p < 0.001$	rr=−0.737;$p < 0.001$	rr=−0.354;$p < 0.001$	rr=0.269; $p = 0.05$	rr=−0.219; $p = 0.12$

DTIT: Dual Task Interference Assessment Tool; mDTE: Motor dual task interference; CogDTE: Cognitive dual task interference; r=Spearman rank correlation coefficient.

assessment, the tower-building task was chosen due to its simplicity, making it suitable for individuals of varying educational levels. This task demonstrated appropriate psychometric properties in both phases of the study. However, for lower extremity assessment, the five-repetition sit-to-stand test did not yield valid results. Its short duration failed to capture dual-task interference (i.e., performance deterioration when an additional motor or cognitive task was introduced). Similarly, in the balance subgroup, the initial task (touching 10 consecutive numbers on the floor with the toe) was ineffective due to its short duration. In contrast, the TUG test, selected for functional mobility assessment, exhibited strong validity and reliability across both study phases. This aligns with its frequent use in dual-task assessments.[6–8]

Following the removal of ineffective tests and the inclusion of more suitable alternatives, the final version of DTIT demonstrated strong validity and reliability. It includes tower-building with cups

for upper extremity assessment, a 15-second step test for lower extremity assessment, a 6-meter tandem walking test for balance assessment, and the TUG test for functional mobility assessment.

Concurrent validity

The absence of a gold standard for dual-task performance assessment posed a challenge in selecting appropriate tools for evaluating concurrent validity. The NHPT has previously been used in dual-task studies for upper extremity assessments,[27,28] and in the present study, both mDTE and cogDTE scores for DTIT_Upper Extremity exhibited excellent correlations with NHPT. Furthermore, the tower-building task with cups proved to be a simple, cost-effective, and widely accessible option, offering advantages over alternative assessments.

As hypothesized, DTIT_Lower Extremity and DTIT_Functional Mobility correlated significantly with walking speed, consistent with earlier findings.[18,19] However, the mDTE score for DTIT_Lower Extremity did not correlate with walking speed, likely because the additional motor task during the step test was insufficient to induce measurable motor-motor dual-task interference. Future research should explore incorporating more challenging secondary motor tasks for lower extremity assessments.

Postural stability impairments often emerge in dual-task scenarios, and previous research suggests that the decline in cognitive and balance abilities observed during dual-tasking may be explained by bottleneck and central sharing models.[29] When the primary task requires sustained attention, both cognitive and motor functions may be compromised, negatively affecting balance performance. The DTIT's ability to evaluate balance under dual-task conditions represents a key strength of this tool. Importantly, balance impairments during dual tasking are closely associated with increased fall risk in older adults. In this study, cogDTE and mDTE scores for DTIT_Balance correlated significantly with the Functional Reach Test, further supporting the validity of DTIT in assessing balance-related dual-task performance.

Finally, older adults frequently develop compensatory strategies to manage daily activities and mitigate the impact of cognitive difficulties. The use of such strategies has been reported to be more prevalent in cognitively intact individuals and those with mild cognitive impairment compared to individuals with dementia.[30] These adaptive mechanisms, together with the role of cognitive reserve, may help explain the variability observed in concurrent validity correlations between groups with and without cognitive decline.

Reliability

This study demonstrated that both mDTE and cogDTE scores exhibited excellent test-retest reliability in both groups. As expected, mDTE scores showed higher reliability than cogDTE scores, likely due to the inherent variability of cognitive task performance (e.g., serial subtraction, word generation, counting backward by months, and RAL) across different time points. While ICC values were generally strong, some confidence intervals—particularly for Balance cogDTE—were relatively wide, indicating potential instability related to sample variability and underscoring the need for replication in larger cohorts.

When assessing individuals at different time points using DTIT, it is crucial to determine whether an observed change reflects a true difference rather than measurement error. The MDC is a clinically valuable metric for interpreting change scores in individual patients and is increasingly reported in research.[31] The low MDC values for the DTIT subgroups indicate that this tool has high clinical significance and is a sensitive assessment method. Venema et al. (2019) reported that older adults with cognitive impairment needed to improve DTE scores more than their cognitively intact counterparts for a change to exceed the threshold of measurement error.[31] Moreover, they found that less challenging tasks required smaller amounts of change in both groups. In the present study, older adults with cognitive impairment exhibited lower MDC values compared to those without impairment.

Reported DTE results in the literature are not always consistent due to variations in study populations, measurement parameters, and differences in the characteristics of dual-task paradigms (e.g., demographics, fall history, balance confidence, physical activity levels, general health status, depressive symptoms, health-related quality of life, and motor-cognitive abilities).[32,33] Therefore, direct comparisons of dual-task interaction outcomes across studies may not always be appropriate.

Study limitations

This study has several limitations. The primary limitation is the potential learning effect when tasks are repeated across multiple trials. Although test order was randomized to minimize this effect, some participants exhibited longer single-task durations compared to dual-task conditions, likely due to motor learning. To mitigate this issue, we recommend that DTIT practitioners conduct multiple practice trials before the first motor test to ensure that participants have fully learned the task. This approach can help eliminate the learning effect and allow for accurate baseline single-task duration measurements. The second limitation is that all tests were administered in a single session, which could have led to fatigue and influenced reliability. However, adequate rest periods were provided, and the results indicated no significant differences between the first and second measurements. Nevertheless, the total test duration (~30 min) was relatively long, which should be considered by DTIT practitioners.

Another limitation of this study pertains to occupational differences between the groups. Most cognitively intact older adults had an active working life, whereas the majority of participants with cognitive decline were homemakers. These differences may have contributed to the observed variability in DTIT scores, as varying occupational roles can impose different cognitive demands. Although significant group differences were observed, the relatively small mean differences may partly reflect this occupational imbalance. Additionally, the sample was drawn from older adults living in home and community settings in Mugla and its affiliated regions, including Bodrum and Marmaris. Compared to other regions, this population may represent a healthier and more intellectually engaged segment of the elderly population, which could limit the generalizability of our findings. Future studies should consider occupational background and broader geographic sampling to enhance external validity.

Conclusion

This study provides strong evidence supporting the test-retest reliability and concurrent validity of the DTIT, a novel tool designed to enhance the standardized assessment of dual-task performance. By evaluating dual-task interference across four domains—upper extremity, lower extremity, balance, and functional mobility—the DTIT offers a comprehensive and structured approach to assessing dual-task performance in older adults. As the first tool specifically developed to measure dual-task interference holistically, the DTIT holds significant potential for both clinical and research applications. Further studies are recommended to explore its applicability in diverse populations and across varying degrees of cognitive decline. It should also be compared with other multi-component dual-task tools, such as the Walking and Remembering Test or the Trail

Walking Test, to validate its clinical utility further and expand its scope of use.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Banu Bayar: Writing – review & editing, Supervision, Methodology. **Ayşen Canan Pakeloğlu:** Writing – review & editing, Writing – original draft, Data curation. **Meltem Koç:** Writing – review & editing, Writing – original draft, Methodology. **Eralp Doğu:** Methodology, Formal analysis. **Hüseyin Aydoğmuş:** Methodology, Investigation. **Kılıçhan Bayar:** Supervision, Methodology, Investigation.

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