Association Between Timed Up-and-Go and Memory, Executive Function, and Processing Speed

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OBJECTIVES: To determine which cognitive tests are independently associated with performance on the Timed Up-and-Go Test (TUG).

DESIGN: Data were obtained from Wave 1 of The Irish Longitudinal Study on Ageing (TILDA), a population-based study assessing health, economic, and social aspects of aging.

SETTING: Community-dwelling adults completed a home based interview and a health center–based assessment.

PARTICIPANTS: TILDA participants aged 50 and older with a Mini-Mental State Examination (MMSE) score of 10 or greater (N = 4,998).

MEASUREMENTS: Participants completed a battery of cognitive assessments including the Montreal Cognitive Assessment (MoCA), Color Trails Test, word and letter fluency, choice reaction time, sustained attention, prospective memory, word recall, and picture memory. Linear regression was used to determine univariate and multivariate associations between TUG and each cognitive test.

RESULTS: Slower TUG time was associated with poorer performance on all cognitive tests in univariate analysis ($P < .05$). In multivariate analysis, poorer performance on the MoCA, letter fluency, Color Trail 1, cognitive reaction time, mean sustained attention response time, and prospective memory were independently associated with slower TUG time ($P < .05$).

CONCLUSION: Slower TUG time is independently associated with poorer performance on global cognition, executive function, and memory tests and slower processing speed. This highlights that TUG is more than just a simple mobility task and suggests that a comprehensive cognitive assessment is important for individuals with mobility difficulties. **J Am Geriatr Soc 60:1681–1686, 2012.**

Key words: physical mobility; cognitive function; older adults

The Timed Up-and-Go (TUG) test is a simple, well-established test of lower extremity function and mobility. It requires an individual to stand up from a seated position, walk 3 m at a comfortable pace, turn around, walk back to the chair and sit down.[1] Poor TUG performance is correlated with slow gait speed[1] and poor balance and functional indexes,[1] and it predicts global health decline,[2] disability in activities of daily living,[2–4] falls,[4] recurrent falls,[2] and nursing home placement.[5]

Walking relies on cognitive processes such as attention and executive function.[6] Executive function includes "a set of cognitive skills that are responsible for the planning, initiation, sequencing, and monitoring of complex goal-directed behaviour."[7] Because TUG involves additional components such as turning and transfers from sitting to standing, it is not surprising that recent research has reported cross-sectional associations between TUG and cognition and has highlighted that it is a much more complex task than originally thought. Most studies have examined associations between TUG and executive function, although this domain is involved to some extent in most other cognitive tasks as well.[8]

Timed Up-and-Go performance is slower in community-dwelling adults with poorer performance on verbal fluency (executive function) and backward attention span (working memory) tests[9] and in those with Alzheimer's disease.[10,11] TUG has also been weakly correlated with Mini-Mental State Examination (MMSE) score, digit span, verbal fluency,[9] and memory.[12] Poorer global cognition has been shown to be an independent predictor of slower TUG in community-dwelling older adults,[13,14] and poorer

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executive function was an independent predictor of slower TUG (at fast pace) in adults with amnesic mild cognitive impairment.[15] These links between TUG and executive function are not surprising because longitudinal research has found that poorer executive function predicts mobility impairment in community-dwelling older adults,[16] but the potential of other cognitive domains (processing speed, attention, and memory) to affect functional mobility is not fully understood and has been largely neglected in the research. Therefore, the aim of this study was to examine the cross-sectional associations between TUG and a range of tests of multiple cognitive domains in community-dwelling older adults. Specifically, the goal was to identify which cognitive domains contribute independently to TUG performance.

METHODS

Study Design

The Irish Longitudinal Study on Ageing (TILDA) is a large prospective cohort study of the social, economic, and health circumstances of community-dwelling older people in Ireland. This study is based on the first wave of data, which was collected between October 2009 and July 2011. The sampling frame is the Irish Geodirectory, a listing of all residential addresses in the Republic of Ireland. A clustered sample of addresses was chosen, and household residents aged 50 and older and their spouses/partners (of any age) were eligible to participate. Ethical approval was obtained from the Trinity College Dublin research ethics committee, and all participants provided written informed consent.

The study design has previously been described in detail.[17] Briefly, there were three parts to data collection: a computer-assisted personal interview that included detailed questions on sociodemographic characteristics, wealth, health, lifestyle, social support and participation, use of health and social care, and attitudes toward aging; a self-completion questionnaire; and a health assessment that research nurses performed. Eight thousand one hundred seventy-five individuals aged 50 and older were interviewed, of whom 5,037 (61.6%) agreed to attend the health center assessment. Inclusion criteria for the present analysis was a MMSE score of 10 or greater to ensure understanding of the test procedure and valid TUG data, making 4,998 participants eligible for the study.

Data Collection

Education was dichotomized into primary/secondary and tertiary levels. Height and weight were measured, allowing body mass index (BMI) to be calculated. The number of doctor-diagnosed chronic conditions was obtained from the following: heart attack, heart failure, or angina pectoris; cataracts; stroke; diabetes mellitus; lung disease; asthma; arthritis; osteoporosis; cancer; Parkinson's disease; peptic ulcer; hip fracture; hypertension; and high cholesterol. Number of regular medications was also recorded. Depression was assessed using the 20-item Center for Epidemiologic Studies Depression Scale (CES-D), on which scores of 16 or greater represent clinically relevant depressive symptoms.[18]

Mobility was assessed with the TUG using a chair with armrests and a seat of height of 46 cm. Participants were asked to rise from the chair, walk 3 m at normal pace to a line clearly marked on the floor, turn around, walk back to the chair, and sit down again. Walking aids were allowed if required, and no instructions were given about the use of participants' arms. The time taken from the command "Go" to when the participant was sitting with their back resting against the back of the chair was recorded using a stopwatch. In addition to TUG, gait was assessed using a 4.88-m electronic walkway with embedded pressure sensors (GAITRite; CIR Systems, Inc., Havertown, PA). Participants started and finished 2.5 m before and after the walkway to allow for acceleration and deceleration. Average gait speed was calculated from two walks performed at normal pace.

Participants underwent a comprehensive cognitive assessment including two tests of global cognition—the MMSE[19] and the Montreal Cognitive Assessment (MoCA).[20] A number of cognitive tests were used to assess function in four cognitive domains (executive function, processing speed, attention and memory); see Table 1 for full details of these tests. Most cognitive tasks assess more than one domain, but for the purposes of this study, each test was classified according to the main cognitive component (Table 2).

The Color Trails Test was used as an alternative to the Trail-Making Task because it removes any cultural or language bias.[21] Color Trail 1 mainly reflects visual scanning and processing speed, and Color Trail 2 requires visual scanning, attention, and mental flexibility, making it an executive function task. The clock and cube drawing tasks were extracted from the MoCA as additional measures of executive function and visuospatial skills. Participants also completed two verbal fluency tasks, which measure expressive language and executive function. These tests assess the ability to devise a strategy to search for and list words (e.g., categories of objects, verbs, words with similar letters), switch between these categories, and use short-term memory to keep track of the words that have already been recited.[22]

Sustained attention is also an executive function requiring arousal and the ability to focus attention on and process specific stimuli over a prolonged period of time. It is required to focus on an activity for long enough to complete a cognitively planned activity, any sequenced action, or any thought. It is assessed using the Sustained Attention to Response Task (SART).[23] The choice reaction time test used a computer based program to assess concentration and processing speed. Cognitive reaction time was the time taken to release a button in response to a stimulus.

Prospective memory, which is defined "as remembering to do something at a particular moment in the future or as the timely execution of a previously formed intention"[24 (p. 25)] was also assessed and requires attention, memory, and executive function. Episodic memory was assessed using a word recall test. Visual reasoning and visual memory were assessed using the visual reasoning and picture memory tests from the Revised Cambridge Examination for Mental Disorders of the Elderly.[25] The visual reasoning test also measures executive function.

Table 1. Description of the Cognitive Tests Included in This Study

Cognitive Test	Instruction (Cognitive Component Assessed)	Scoring
Mini-Mental State Examination	30-item scale (attention, concentration, memory, language, visuoconstructional skills, calculations, and orientation)	Score (maximum 30)
MoCA	30-item scale (attention, concentration, memory, language, visuoconstructional skills, calculations, orientation, executive function and conceptual thinking)	Score (maximum 30)
Color Trails test	*Color Trail 1*—draw line connecting circles numbered 1–25 in consecutive order (visual scanning and processing speed)	Time (seconds)
	Color Trail 2—connect numbered circles alternating between pink and yellow circles, e.g., pink 1, yellow 2, pink 3 (visual scanning, attention and mental flexibility (executive function))	Time (seconds)
	Trail time difference (executive function)	Time (seconds)
Clock drawing (from MoCA)	Draw a clock showing 10 past 11 (visuospatial skills, executive function)	Face, numbers, and hands (maximum score 3)
Cube drawing (from MoCA)	Copy a drawing of a cube (visuospatial skills, executive function)	Correct/incorrect
Word fluency	Name as many animals as possible in 1 minute (expressive language and executive function)	Number of words
Letter fluency (from MoCA)	List as many words as possible beginning with "F" in 1 minute (expressive language and executive function)	Number of words
Visual reasoning	Three boxes with objects inside and one empty box. Identify the missing object to complete the pattern from a list of six options; six sequences (executive function)	Number of correct answers (maximum score 6)
Choice Reaction Time	Depress a button on keyboard and wait for a stimulus (yes/no) to appear on screen. Press corresponding yes/no button on keyboard in response; approximately 100 repetitions (concentration and processing speed)	Cognitive reaction time (ms)—time taken to release the button in response to the stimulus
Sustained Attention to Response Task	Repeating sequence of numbers from 1 to 9 for approximately 4 minutes. Numbers appear every 300 ms; sequence of 207 numbers throughout the test. Click in response to each number except three (arousal, attention, processing speed, executive function)	Response time (mean, standard deviation, coefficient of variation) Commission errors (clicked mouse when number 3 appeared)—vigilance Omission errors (did not click mouse when a number other than 3 appeared)—inattention
Prospective memory	Remind interviewer to record the time when they indicate the end of the memory and concentration tasks (attention, memory and executive function)	Successful/not successful[a]
Word recall (immediate, delayed)	Ten words read out by computer or interviewer. Repeat as many words as possible immediately and at a later time during the interview (episodic memory)	Number of words recalled (maximum score 10)
Picture memory test	*Acquisition*: Name six well-known objects shown in pictures *Recall*: Recall objects shown previously at a later time during interview with no forewarning (visual memory) *Recognition:* Identify each object when pictured alongside two similar objects (visual memory)	Number of objects named (maximum score 6 for each)

MoCA = Montreal Cognitive Assessment.

[a] Successful performance, participant remembered to perform the task.

Statistical Analysis

Statistical analyses were performed using STATA version 12 (StataCorp LP, College Station, TX). All analyses were weighted with respect to age, sex, and education to the Quarterly National Household Survey (2010) to ensure that data were nationally representative. Data were further weighted according to health status and sociodemographic factors to account for those who did not attend a health assessment.[26] Because the TUG was positively skewed, it was inverse transformed. Four linear regression models were used to examine the relationship between inverse TUG (dependent variable) and cognition. In Model 1, the univariate associations between TUG and each cognitive test were obtained. Model 2 adjusted for age, sex, education, height, BMI, number of chronic conditions, number of medications, and depressive symptoms. Next, all confounders and all cognitive variables were added to the model simultaneously (Model 3). Color Trail time difference and SART standard deviation (SD) were not entered into this model because they are functions of other parameters that were entered into the model. Gait speed was added as an explanatory variable in Model 4, which allowed the associations between the cognitive tests and the nonwalking components of TUG to be identified. Complete covariate data were available for 4,544 (91.1%) participants. Complete case analysis was used for multivariate analyses (i.e., all missing data were treated as missing at random). Standardized beta coefficients are presented.

RESULTS

The median age of the sample was 62 (interquartile range (IQR) 56–70), 54% were female, and 36% had attained

Table 2. Characteristics of the Sample (N = 4,998)

Characteristic	Value
Age, median (IQR)	62 (56–70)
Female, n (%)	2,711 (54)
Tertiary education, n (%)	1,820 (36)
Body mass index, kg/m^2, median (IQR)	28.7 (25.4–31.4)
Chronic conditions, median (IQR)	2 (1–3)
Medications, median (IQR)	1 (0–2)
Fall in previous year, n (%)	992 (20)
Center for Epidemiologic Studies Depression Scale score $\geq$16, n (%)	413 (8)
Timed Up-and-Go, seconds, median (IQR)	8.5 (7.53–9.81)
Global cognition	
Montreal Cognitive Assessment score, median (IQR) (range)	25 (23–27) (2–30)
Mini-Mental State Examination, median (IQR) (range)	29 (28–30) (12–30)
Executive function	
Color Trail 2, seconds, mean ± SD (range)	116.86 ± 44.42 (30–398)
Color Trail difference, seconds, mean ± SD (range)	57.79 ± 29.57 (–24.5–251)
Letter fluency, median (IQR) (range)	11 (8–15) (0–31)
Word fluency, median (IQR) (range)	20 (16–25) (0–50)
Visual reasoning, median (IQR) (range)	3 (2–4) (0–6)
Processing speed	
Color Trail 1, seconds, mean ± SD (range)	60.23 ± 29.44 (18–291)
Cognitive reaction time, ms, mean ± SD (range)	523 ± 159 (259–3,020)
Sustained Attention to Response Task	
Mean, ms, mean ± SD (range)	387 ± 102 (118–868)
SD, ms, mean ± SD (range)	128 ± 78 (22–483)
Coefficient of variation, %, mean ± SD (range)	0.33 ± 0.17 (.06–1.53)
Errors, median (IQR) (range)	3 (1–6) (0–23)
Omissions, median (IQR) (range)	5 (2–11) (0–116)
Memory	
Prospective memory, n (%)[a]	4,350 (87)
Immediate recall, median (IQR) (range)	6 (5–7) (1–10)
Delayed recall, median (IQR) (range)	6 (4–8) (1–10)
Picture acquisition, median (IQR) (range)	6 (5–6) (2–6)
Picture recall, median (IQR) (range)	3 (3–4) (0–6)
Picture recognition, median (IQR) (range)	6 (5–6) (0–6)

SD = standard deviation; IQR = interquartile range.
[a] Successful performance, participant remembered to performed the task.

tertiary level education (Table 2). They had a median of two chronic conditions, 8% had clinically relevant depressive symptoms, and 20% reported a fall in the previous year. Median TUG time for the sample was 8.5 seconds (IQR 7.53–9.81 seconds). Information on baseline performance on all cognitive tests is also provided in Table 2.

In univariate analysis, better performance on all cognitive tests was associated with faster TUG time ($P < .001$, Table 3). These associations were substantially less but remained statistically significant after adjusting for age, sex, height, BMI, education, comorbidity, number of medications, and depressive symptoms ($P < .05$) for most cognitive tests except picture memory task and cube drawing ($P > .10$) (Model 2). When all cognitive tests were entered into Model 3 simultaneously, MoCA and at least one test from each cognitive domain (letter fluency, Color Trail 1, cognitive reaction time, mean SART, and prospective memory) remained significantly associated with TUG time.

Table 3. Standardized Beta Coefficients Outlining the Cross-Sectional Associations Between Inverse Time Up-and-Go Test (TUG) and Each Cognitive Test in Univariate (Model 1) and Multivariate Analysis (Models 2–4)

	Standard Beta Coefficient			
Test	Model 1	Model 2	Model 3	Model 4
Global cognition				
Montreal Cognitive Assessment	.232[c]	.075[c]	−.046[a]	.005
Mini-Mental State Examination	.221[c]	.086[c]	.008	−.003
Executive function				
Color Trail 2	−.335[c]	−.146[c]	−.023	−.006
Trail time difference	−.185[c]	−.055[c]	–	–
Letter fluency	.174[c]	.084[c]	.031[a]	.019
Word fluency	.171[c]	.059[c]	.012	.024[a]
Cube drawing	.146[c]	.016	−.009	−.019
Clock drawing	.140[c]	.053[c]	.010	−.008
Visual reasoning	.182[c]	.044[b]	−.005	.006
Processing speed				
Color Trail 1	−.371[c]	−.184[c]	−.100[c]	−.051[c]
Cognitive reaction time	−.222[c]	−.113[c]	−.051[c]	−.019
Sustained Attention to Response Task				
Mean, ms	−.238[c]	−.140[c]	−.096[c]	−.058[c]
SD, ms	−.280[c]	−.117[c]	–	–
Coefficient of variation	−.192[c]	−.049[c]	−.011	.010
Errors	−.225[c]	−.065[c]	.003	0
Omissions	−.261[c]	−.106[c]	−.015	−.005
Memory				
Prospective memory	.189[c]	.082[c]	.054[c]	.026[b]
Immediate recall	.240[c]	.085[c]	.031	.014
Delayed recall	.222[c]	.061[c]	−.001	.001
Picture acquisition	.072[c]	.028	−.007	.002
Picture recall	.136[c]	.021	−.014	−.011
Picture recognition	.118[c]	.023	−.012	−.007

The number of participants included in each regression analysis varied slightly depending on data available for each cognitive test and confounders. Model 1: Effect of each cognitive test on TUG performance in univariate analysis. Standardized β coefficients show how many standard deviation (SDs) that a dependent variable will change for a 1 SD increase in the predictor variable. Model 2: Effect of each cognitive test on TUG performance after adjusting for age, sex, height, body mass index, education, comorbidity, number of medications, and depressive symptoms. Model 3: Model 2 with all cognitive tests included in a single model. Model 4: Model 3 additionally adjusting for gait speed.
[a]p<.05, [b]p<.01, [c]p<.001.

Although statistically significant, the independent effects of cognitive tests were small. Under this multivariate model, for every standard deviation (SD) increase in letter fluency and for successful completion of the prospective memory task, inverse TUG increased by 0.031 and 0.054 SD, respectively, indicating faster TUG performance. For every SD increase in cognitive reaction time, Color Trail 1 time, and mean SART, inverse TUG decreased by 0.051, 0.100 and 0.096 SD, respectively.

Gait speed completely explained the contributions of MoCA, letter fluency, and cognitive reaction time in Model 4, whereas the standardized coefficients reduced but remained statistically significant for the other cognitive tests, with significant effects in Model 3. Therefore, the nonwalking components of TUG (standing, sitting, turning) were associated with the same cognitive factors as the entire TUG task.

Covariates other than cognitive tests explained 27.8% of variation in TUG, and considering all covariates including cognitive tests in Model 3 explained 29.7%. In Model 4, gait speed explained a large proportion of additional variance (total coefficient of determination = 64.0%).

DISCUSSION

The current study has shown that functional mobility as measured using the TUG is independently associated with several domains of cognitive function. These results extend previous findings in two ways. First, they show that the relationship between TUG and cognition exists for the majority of cognitive tests at the univariate level, and second, poorer performance in global cognition (MoCA), executive function (letter fluency), and memory (prospective memory) tests and slower processing speed (Color Trail 1, cognitive reaction time, mean SART) are independently associated with slower TUG in multivariate analysis (Models 2 and 3). Previous studies reported poorer mobility in groups with poor cognitive function[10,11] and associations between slower TUG and poorer executive function and memory.[9,12] Other studies reported associations between slower TUG and global cognitive impairment,[14] poorer global cognition,[13] and poorer executive function[15] after adjusting for covariates. Because these models included only one cognitive test in their regression models, this makes them comparable with Model 2 in the current study.

Given the complexity of the TUG (involving transfers, turning, walking), the involvement of multiple cognitive domains is not surprising. Any task that involves planning and executing a goal-directed action requires executive function,[7] which explains the significant associations between TUG and verbal fluency tests. Prospective memory tasks require an individual to form and activate an intention to perform the future task after receiving a set of instructions. This requires executive function and episodic memory.

Distractions from competing stimuli rather than an individual forgetting which step comes next in the task often affect functional performance,[27] therefore focus and concentration are important for TUG performance. Sustained attention reflects this ability to maintain attention on the task and avoid distraction. Although errors of commission and omission would reflect deficits in vigilance and attention, respectively, greater mean SART, as found in this study, may reflect slower processing speed. This slower processing is also reflected in slower cognitive reaction time and the need for more time for Color Trail 1. Prolonged time to plan a move is particularly relevant for TUG, where fluid transitions between consecutive phases of the task are required.

These results suggest that slower processing speed is an important contributor to slower TUG and provide some support for the processing speed theory that age-associated declines in processing speed reflect a general constraint on all cognitive processing.[28] This theory suggests that many higher-level cognitive functions such as perception, encoding and retrieval, decision-making, and transforming information held in active memory depend on processing speed.[29]

Adjusting for gait speed in Model 4 allowed the nonwalking components of TUG to be distinguished from the task as a whole. Again, word fluency, Color Trail 1, mean SART, and prospective memory were significantly associated with TUG, although the sizes of the standardized coefficients were less than in Model 3. This suggests that the entire TUG task and the nonwalking components are both associated with cognitive performance across all domains, although it is possible that another unmeasured variable could influence this association. In addition, the associations between mobility and other health variables (e.g., age, BMI, comorbidity, medications, and depression) are much stronger than the associations with cognition, which play a comparatively small albeit significant role.

The main strengths of this study are the large, nationally representative data set and the detailed cognitive assessment, making it the most comprehensive analysis of the associations between TUG and cognition to date. Nevertheless, the results are directly applicable only to community-dwelling adults, and only those who attended a health assessment center were included.

These findings have several clinical implications. Previous research has shown that slower gait speed and gait impairment predict declines in executive function, attention,[30,31] and memory tasks.[31] Poorer executive function in cognitively intact older adults also predicts future memory decline,[27] accelerated decline in executive function, mobility impairment, and mortality.[16] TUG may be a useful tool to detect mobility impairment and possible cognitive impairment, but longitudinal data are required to determine whether slow TUG can identify individuals at risk of future cognitive decline.

Clinicians assessing TUG performance should consider the role of cognition, particularly when individuals have difficulty or take longer to complete the task than would be expected for their age and health profile. If factors such as injury, degenerative joint conditions, or walking aids cannot completely explain this mobility impairment, impaired cognitive function and a comprehensive cognitive assessment should be considered.

The results also support recommendations that early intervention to preserve mobility should focus on improving physical performance and executive function,[15] although interventions that improve other cognitive domains such as processing speed and memory should also be considered. In a meta-analysis, it was concluded that combined aerobic, strength, and flexibility training improved performance on all cognitive tasks (speed, visuospatial, controlled, and executive based), although the effects were greatest for executive tasks.[32] Furthermore, it was found that aerobic training (walking) increased activity in the frontal and parietal regions of the brain, whereas stretching did not.[33] Because these areas are involved in executive control and integration of sensory information, respectively, this further emphasizes the potential benefits of aerobic exercise for mobility and fall prevention.

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