The Influence of Processing Speed, Attention, and Inhibition on Texas Functional Living Scale Performance

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Abstract

Objective: Attention, inhibition, and processing speed are related to functional decline among older adults. This study attempts to clarify the relationships between these cognitive factors and adaptive functioning.

Method: We examined relationships between attention, inhibition, and processing speed, with scores on the Texas Functional Living Scale (TFLS), a performance-based measure of daily functioning, in a mixed clinical sample of 530 older adults who were referred for an outpatient neuropsychological evaluation.

Results: The current study used a confirmatory factor analysis (CFA) to derive a three-factor cognitive model consisting of attention, inhibition, and processing speed. Results from a hierarchical regression, which included factor scores from the CFA, revealed that processing speed was the only significant predictor of TFLS performance when all three cognitive factors were included within a single model.

Conclusion: These results highlight the influence of processing speed as an important indicator of functional decline among a clinical population of older adults.

Introduction

Cognitive and functional decline can limit autonomy in older adulthood, particularly among those with neurocognitive disorders. Therefore, early identification of cognitive and functional decline in aging populations is important in the diagnosis and management of neurodegenerative conditions. Although the negative relationship between age and cognition has been well established (Nickl-Jockschat et al., 2012; Salthouse, 2003, 2010), with changes often manifesting as declines in functional capabilities (Gold, 2012; Nikolova, Demers, & Béland, 2009), it is known that independence for activities of daily living (ADLs) or instrumental activities of daily living (IADLs) are also dependent upon motor and perceptual capabilities (Mlinac & Feng, 2016). Additionally, the impact of environmental processes and coping related factors have been considered when examining contributors to disability status (Barberger-Gateau, Fabrigoule, Amieva, Helmer, & Dartigues, 2002; Verbrugge & Jette, 1994). However, much of the research remains focused on the association between neuropsychological functioning and the ability to manage ADLs/IADLs.

Prior research evaluating the impact of cognition on ADLs and IADLs has broadly supported the role of executive functioning (EF) in evolving impairment in older populations (Back-Madruga et al., 2002; Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Boyle et al., 2003; Farias, Harrell, Neumann, & Houtz, 2003; Jefferson, Paul, Ozonoff, & Cohen, 2006), whereas other studies have highlighted the influence of non-EF-related cognitive functions (Hall, Vo, Johnson, Barber, & O'Bryant, 2011; Hinkin et al., 2002). Glisky (2007) proposed that age-related reductions in attention (Craik, 1986), processing speed (Salthouse, 1996), and inhibition (Hasher, Zacks, & May, 1999) may influence ADL/IADL functioning, with research identifying

specific links between reduced attention and processing speed and decreased mobility (Owsley & McGwin Jr., 2004) and worse driving (Anstey, Windsor, Luszcz, & Andrews, 2006; Edwards et al., 2006; Edwards, Bart, O'Connor, & Cissell, 2010).

In fact, prior neuroimaging studies generally support this theory in showing reduced white matter integrity and reduced gray matter volume in areas commonly associated with cognitive slowing, attention, and disinhibition in advancing age (Brugulat-Serrat et al., 2020; Burgmans et al., 2011; Hedden & Gabrieli, 2004; Hong et al., 2015; Ishikawa, Meguro, Ishii, Tanaka, & Yamaguchi, 2012; Kerchner et al., 2012; MacPherson et al., 2017; Turken et al., 2008; Wolf et al., 2014).

The role of processing speed appears particularly relevant, as neuropsychological measures designed to assess processing speed have demonstrated prognostic value in differentiating and monitoring the progression of neurocognitive disorders (Lu, Chan, Fung, & Lam, 2016; Lu, Chan, & Lam, 2017; Mortamais et al., 2017) as well as serving to detect subtle functional changes among individuals with Alzheimer's disease (Marson, 2015). Research further suggests that general cognitive slowing is associated with aging and may confound multiple cognitive processes (Salthouse, 1996), including general intelligence (Betjemann et al., 2010), attention (Lustig, Hasher, & Tonev, 2006; Stawski, Sliwinski, & Hofer, 2013), and EF (Albinet, Boucard, Bouquet, & Audiffren, 2012; Rey-Mermet & Gade, 2018; Salthouse, 2005). More recent studies suggest that the structure of an objective-testing measure, particularly those containing a speeded component, can potentially confound performance results. For example, a meta-analysis by Rey-Mermet and Gade (2018) examining inhibition and aging suggests that inconsistent findings may be related to task selection or how inhibition is considered, and the authors recommend examining speed-accuracy trade-offs in order to further investigate this relationship. Consistent with this idea, Lassen-Greene et al. (2017) demonstrated that individuals with mild cognitive impairment (MCI) were slower, but similarly accurate when compared to those without MCI. Moreover, studies have suggested that accounting for processing speed statistically may improve the specificity of test performance interpretations (Albinet et al., 2012; Karr, Hofer, Iverson, & Garcia-Barrera, 2019; Nigg et al., 2017; Roye et al., 2020).

The Texas Functional Living Scale (TFLS; Cullum, Weiner, & Saine, 2009) is an objective-performance measure designed to assess adaptive functioning among individuals who are 16–90 years of age. The TFLS contains 24 items intended to measure time and money management, communication skills, and memory. Although TFLS performance is assessed across five individual scales, including an additive Total score, factor analytic studies demonstrate support for the clinical utility of the Total score performance, as this was the only scale to consistently demonstrate adequate convergent and discriminant validity with other neurocognitive measures (Gonzalez, Soble, Marceaux, & McCoy, 2017; Lowe, Nguyen, Copeland, & Linck, 2020). Earlier versions of the TFLS have demonstrated good sensitivity when measuring functional change among those diagnosed with Alzheimer's disease (Weiner, Fields, Hynan, & Cullum, 2008) and have demonstrated good discriminant validity when determining level of care among individuals diagnosed with dementia (Weiner et al., 2007). Regarding the measure's relationship with individual cognitive domains, Total score performance on the TFLS has demonstrated moderate correlations with both abstract reasoning and processing speed indices within a large, non-clinical adult sample (Drozdick & Cullum, 2011).

Other studies examining TFLS performance in veteran and non-veteran mixed outpatient samples similarly found moderate to large correlations between the TFLS and both EF and processing speed measures as well as other measures of intelligence (Gonzalez et al., 2017; Nguyen et al., 2019). Unique to previous studies, results from Nguyen and colleagues (2019) demonstrated that a measure of shifting and abstract reasoning significantly predicted TFLS performance after controlling for non-EF performances (i.e., memory, visuospatial ability, processing speed, language, and attention). Notably, speeded measures were included within both EF and non-EF domains, within domain relationships were derived theoretically instead of statistically, and, although multiple measures were used to determine EF and non-EF performance, individual cognitive domains within these two constructs were not always assessed using multiple measures (i.e., processing speed). Therefore, this suggests that further examination of relationships between the TFLS and domain-specific cognitive performance may be warranted.

The purpose of the current study is to examine the relationships between attention, inhibition, processing speed, and objective IADL performance, as measured by the TFLS. Although previous studies have explored relationships between TFLS performance and cognition (Drozdick & Cullum, 2011; Gonzalez et al., 2017; Nguyen et al., 2019), to our knowledge, the predictive influence of attention, inhibition, and processing speed have never been directly compared to this measure. This study attempts to clarify previously identified relationships between cognition and adaptive functioning by comparing statistically driven latent cognitive factors comprised of multiple performance measures and their predictive influence on TFLS performance.

Materials and Methods

Participants and Procedures

Participants included in this study were adult patients referred for a neuropsychological evaluation at an academic medical outpatient clinic between January 2016 and June 2021. The process of obtaining archival data via electronic medical records was

Table 1. Demographic information

Characteristics	n	All patients	No diagnosis	MCI/mild NCD	Major NCD
N	—	530	215	136	179
Age	—	74.58 (7.35)	73.9 (7.64)	73.60 (6.74)	76.13 (7.25)
Education	—	13.89 (2.67)	13.89 (2.59)	13.94 (2.75)	13.84 (2.77)
Gender (women)	—	56% (n = 297)	58% (n = 125)	56% (n = 71)	61% (n = 101)
Race/ethnicity (%)					
Caucasian	—	89.20%	91.20%	88.80%	89.80%
African American	—	6.20%	5.60%	6.70%	6.80%
Latinx	—	1.50%	0.90%	2.20%	1.70%
Other	—	0.90%	0.90%	2.20%	1.70%
Cognitive performance					
CPT omission	268	14.11 (19.67)	13.91 (20.72)	9.96 (13.77)	19.93 (22.71)
CPT ß	268	1.49 (1.98)	1.47 (1.91)	1.59 (2.49)	1.41 (1.27)
RBANS digit span	505	8.77 (2.26)	8.90 (2.42)	9.02 (2.25)	8.43 (2.02)
RBANS coding	505	27.40 (11.56)	29.64 (11.82)	30.44 (10.16)	21.92 (10.79)
SCWT word	204	51.31 (15.74)	76.15 (21.30)	83.11 (18.38)	70.32 (16.03)
SCWT color	204	76.74 (19.60)	51.67 (16.18)	57.14 (15.12)	43.94 (12.74)
[a]SCWT interference	204	−0.01 (1.00)	0.03 (0.91)	0.14 (1.17)	−0.22 (0.90)
TMT A (s)	513	64.44 (43.95)	57.00 (35.95)	55.34 (33.93)	80.88 (54.41)
TFLS total	530	36.15 (10.16)	38.07 (9.33)	40.32 (6.96)	30.70 (10.86)

Note. MCI = mild cognitive impairment; NCD = neurocognitive disorder; CPT = Conners' Continuous Performance Test II; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; SCWT = Stroop Color Word Test; TMT = Trail Making Test; TFLS = Texas Functional Living Scale.
[a]Standardized residual score.

approved by the local Institutional Review Board. Assessments were conducted by licensed clinical neuropsychologists, psychometricians, and pre-doctoral and post-doctoral psychology trainees, who were supervised by a licensed neuropsychologist. Assessments were conducted using a flexible battery approach. Missing data were managed using a pairwise deletion method for correlation and hierarchical regression analyses, whereas multiple imputation was used for the confirmatory factor analysis (CFA). A patient's data were included if the individual completed a TFLS during their assessment, was at least 60 years old, and provided valid effort, as indicated by their performance on standalone and/or embedded validity measures (see in the following). Additionally, performance variables were standardized within the sample and outliers (z-scores = ±3.5) were removed prior to analyses. Frequency totals of each variable can be found in Table 1. Overall, 11 individuals were excluded from analyses and the final sample consisted of 530 individuals as part of a mixed clinical sample. Participants were between 60 and 94 years old (M = 74.7 years; standard deviation [SD] = 7.4) and had an average education of 13.8 years (SD = 3.0). Most of the sample identified as White (89.4%), and just over half identified as women (55.1%). Further demographic and diagnostic characteristics of the sample are described in Table 1.

Measures

Performance validity. Objective performance validity was determined based on a patient's performance on a combination of the following measures: Test of Memory Malingering (Tombaugh, 1996), Wechsler Adult Intelligence Scale-fourth edition (WAIS-IV; Wechsler, 2008), digit span, reliable digit span, and California Verbal Learning Test-second edition (Delis, Kaplan, Kramer, & Ober, 2000), forced choice. Validity scores were set in accordance with standard, manual-based cut-off scores.

Attention. Attention was assessed using omission errors from the Conners' Continuous Performance Test II (CPT-II; Conners et al., 2004), a computerized test of sustained attention and response inhibition. Omission errors, or the frequency of nontargets a subject failed to respond to, are commonly used as a measure of attention (Delisle & Braun, 2011; Homack & Riccio, 2006; Malloy-Diniz, Fuentes, Leite, Correa, & Bechara, 2007; Strauss, Sherman, & Spreen, 2006) and have high internal consistency and test–retest reliability (Conners et al., 2004; Strauss et al., 2006). A second measure of attention came from the Digit Span subtest of the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 2012). Digit Span requires participants to verbally repeat sequences of numbers in the same order as the examiner and has demonstrated moderate to strong convergent validity with the WAIS-IV Digit Span subtest in clinical and non-clinical samples (Calamia, Roye, & Lemke, 2018; McKay et al., 2007).

Inhibition. The first measure of inhibition was response style (β) from the CPT-II. This variable is expressed as a function of speed/accuracy trade-off and is used to detect impulsivity. Response style has demonstrated fair test–retest reliability independently and good test–retest reliability when combined with CPT-II indices for neurological assessment (.92; Homack & Riccio, 2006). Second, the Color-Word Interference trial from the Stroop Color Word Test (SCWT; Golden, 1978) was included as a measure of inhibition. The SCWT has been well established as a measure of inhibition (Lucas et al., 2005; Steinberg, Bieliauskas, Smith, & Ivnik, 2005; Verhaeghen & De Meersman, 1998) and demonstrates diagnostic sensitivity among older adults with dementia (Amieva, Phillips, Della Sala, & Henry, 2004; Ben-David, Tewari, Shakuf, & Van Lieshout, 2014). As it has been suggested that the processing speed component of this task may affect performance among older adults with dementia (Ben-David et al., 2014), a standardized residual score was created by regressing out performance on the first two trials from the Interference trial (Nigg et al., 2017).

Processing speed. The processing speed factor consisted of four speeded variables, two tasks requiring oral responses and two requiring a motor component. Speeded measures requiring oral responses included the Word and Color trials from the SCWT. Motor tasks included the Coding subtest from the RBANS and Trails A from the Trail Making Test (TMT; Reitan, 1958). Although Coding is part of the Attention Index on the RBANS, the task emulates the Coding subtest from the WAIS-IV, which was designed to measure processing speed. Both tasks demonstrate strong convergent validity with one another ($r = .83$; McKay et al., 2007). Additionally, TMT-A is recognized as a measure of output speed (Nigg et al., 2005, 2017; Strauss et al., 2006).

Texas Functional Living Scale. The TFLS is a 24-item performance-based measure designed to assess IADLS. It contains five subscales: Time, Money and Calculation, Communication, and Memory, as well as a Total score to interpret an overall level of functioning. *T*-scores can be determined for each subscale with interpretations ranging from "High Average" to "Severely Impaired." The TFLS exhibits adequate validity and reliability with multiple measures of adaptive functioning (Cullum et al., 2009). Internal consistency within the current sample was .78.

Data Analyses

Raw performance scores were used to avoid reducing measure variance with demographically normed performance scores. A CFA was estimated on the cognitive constructs each variable was designed to assess (see Fig. 1). Analyses were conducted using MPlus Version 7 (Muthén & Muthén, 2012) to test the fit of the proposed three-factor model. Multiple fit statistics were interpreted to determine goodness of fit, including Pearson chi-square, Comparative Fit Index (CFI) value >.90 (Bentler, 1990), Root Mean Square Error of Approximation (RMSEA) $\leq$.08 with a probability RMSEA $\leq$.05 (Steiger, 1990), and Standardized Root Mean Square Residual (SRMR) <.08 (Brown, 2014). Latent variable factor scores were extracted from the CFA and included within the correlation and multiple regression analyses, which were analyzed using SPSS version 26.

Results

Preliminary Analyses

Regarding the hierarchical regression, the assumptions of normality, linearity, and homoscedasticity of residuals were met. Additionally, prior to running a hierarchical linear regression analysis, the data were assessed for multicollinearity. Variance inflation factors were determined to be less than four, which indicated acceptable levels of multicollinearity (O'Brien, 2007). Hierarchical linear regressions were conducted to examine the unique contributions of latent cognitive factors while controlling for potential confounding demographic influences. Notably, the cognitive variables were factor scores extracted from a CFA.

Specifically, Step 1 of the regression included age and education to account for demographic variance, whereas Step 2 included three cognitive variables derived from factor scores: attention, inhibition, and processing speed.

Confirmatory Factor Analysis

The three-factor model of cognitive performance indicated an inadequate fit (SRMR = .09). The modification indices within the model output noted that a residual correlation between two scores from the same subtest (SCWT Color and Word trials) would improve model fit (M.I. = 11.84), suggesting they may have a relationship beyond what is being calculated by the individual
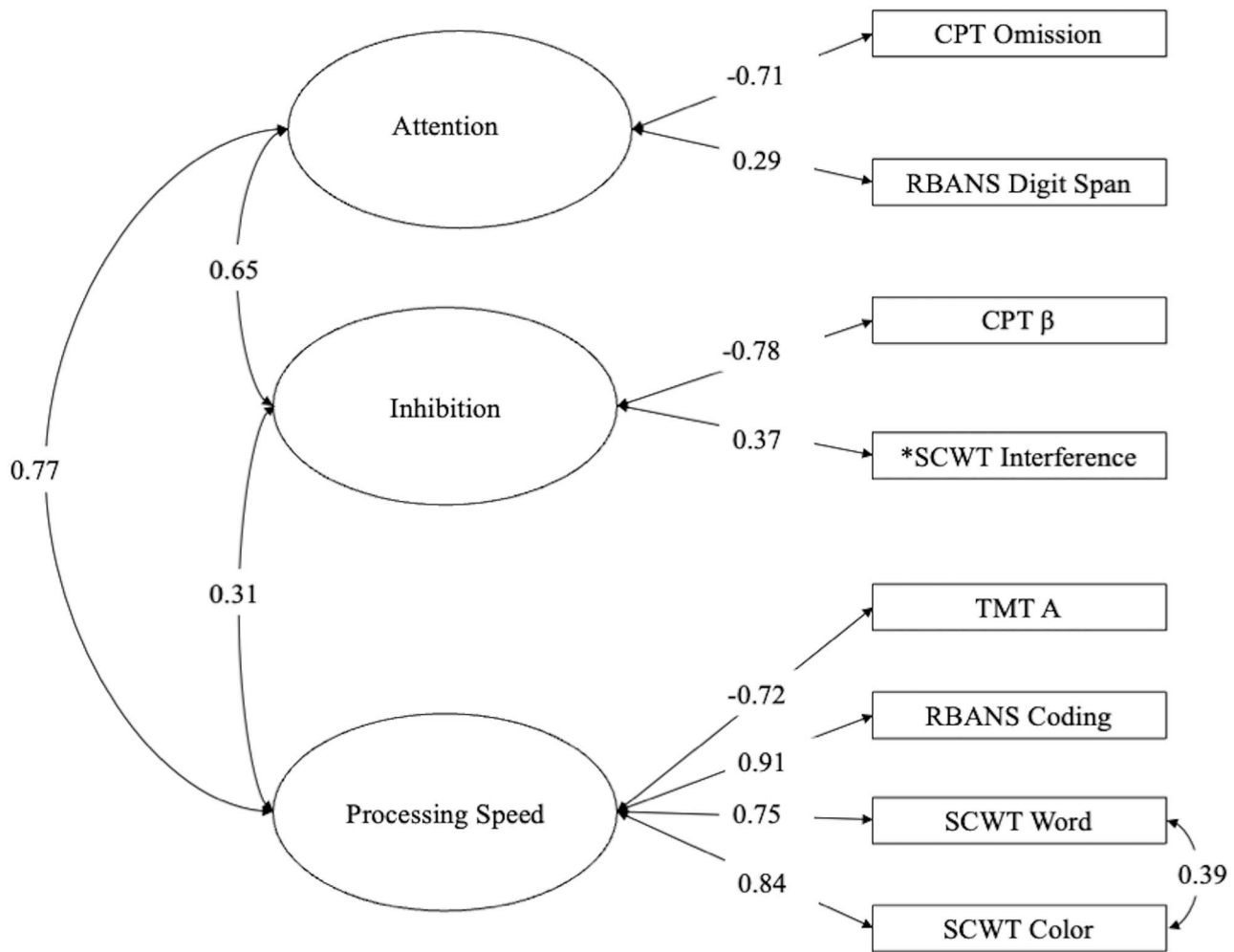
Fig. 1. Three-factor models of cognition. CPT = Conners' Continuous Performance Test; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; β = CPT Response Style; SCWT = Stroop Color Word Test; TMT = Trail Making Test. *Indicates a value that was residualized of variance attributable to a control variable.

factors. After accounting for shared variance between these two scores, model fit was adequate for the proposed three-factor model (CFI = .94, RMSEA = .07, SRMR =.07). See Fig. 1 for the CFA model.

Correlations and Hierarchical Linear Regression Model

Correlations between latent cognitive factors, TFLS total score, and demographic variables are presented in Table 2. Results indicated that all three cognitive factors were positively related to TFLS performance, suggesting that better cognitive performance was related to better performance on the TFLS. Regarding the demographic variables, significant, negative relationships were observed between age and all performance-based measures, whereas years of education was positively related to all performance-based measures. Gender was not significantly related to any objective performance measures.

Results from the hierarchical regression (see Table 3) indicated that both age and years of education significantly predicted TFLS performance (ß = −.168, p < .001; ß = .100, p = .021) in Step 1. Step 2, which included all three cognitive factors, accounted for approximately 34% of the total variance in predicting TFLS performance. Within this model, only processing speed was predictive of TFLS performance (ß = .409, p = .003).

Table 2. Relationships between demographic characteristics and cognitive performance

Correlations among potential predictors	1	2	3	4	5
1. TFLS total	—				
2. Age	−.17*	—			
3. Education	.12*	−.11	—		
4. Attention	.58*	.18*	.19*	—	
5. Inhibition	.33*	.11	−.11	.76*	—
6. Processing speed	.62*	−.18*	−.15*	.92*	.50*

Note: TFLS = Texas Functional Living Scale. $^*p < .01$.

Table 3. Hierarchical regression analysis of predictors of TFLS Total score

Step	Predictor	Unstandardized coefficients		Standardized coefficients		R^2	R^2 Change	F	p
		B	SE	ß	p				
1						.042	.042	11.306	.000
	Age	−.231	.059	−.168	.000				
	Education	.375	.162	.100	.021				
2						.385	.343	64.747	.000
	Age	−.084	.049	−.061	.082				
	Education	.066	.132	.017	.621				
	Attention	3.215	2.351	.252	.172				
	Inhibition	−1.274	1.355	−.080	.348				
	Processing speed	4.482	1.511	.409	.003				

Note. N = 530; SE = standard error of B; Attention = factor score of attention measures; Inhibition = factor score of inhibition measures; Processing speed = factor score of processing speed measures.

Discussion

The purpose of the current study was to examine the utility of attention, processing speed, and inhibition as they related to adaptive functioning performance, which was measured by TFLS Total score. Results indicated that processing speed was the strongest predictor of TFLS Total performance among an older adult clinical sample. Findings further suggested that processing speed accounted for variance beyond that of attention and inhibition, which were not significantly predictive of TFLS Total score. Overall, the current findings support previous research suggesting the importance of processing speed as it relates to functional decline among older adults. Additionally, these findings may support the prioritization of processing speed measures when assessing daily functioning in a clinical setting.

Results are suggestive of an important relationship between processing speed and adaptive functioning. Specifically, analyses indicated that processing speed accounted for approximately 41% of the variance when both attention and inhibition factors were included in the same model. Previous research (Lassen-Greene et al., 2017; Wadley et al., 2020) similarly identified significant differences in speed and objective IADL performance between older adults with MCI and very early Alzheimer's disease as well as between individuals with and without MCI. Their research further demonstrated larger speed-accuracy disparities between those with and without MCI. Although the TFLS contains a Memory subscale and does not include a speeded scoring component, Drozdick and Cullum (2011) demonstrated the strongest correlations between TFLS performance and the WAIS-IV Processing Speed Index ($r = .81$) within their sample of individuals diagnosed with Alzheimer's disease while the WMS-IV memory indices correlations ranged from $r = .57$ to $r = .67$. These findings, combined with those from the current study, support the role of cognitive processing speed as an underlying factor for adaptive functioning among an aging sample (Marson, 2015) via its predictive relationship to TFLS Total performance.

Unique to previous studies examining TFLS performance, this is the first study, to our knowledge, to account for processing speed embedded within objective performance measures, and the first to construct a latent variable model of unique measures. Although past studies have compared index scores from the RBANS, WMS-IV, and WAIS-IV (Drozdick & Cullum, 2011; Nguyen et al., 2019), standardized scores found within those indices have the potential to limit the generalizability of performances, as raw scores are absent of normed demographics. Notably, the current study did not make direct comparisons between objective performance measures previously identified as being related to TFLS performance (i.e., Memory and EF). Although inhibition is an EF domain (Miyake et al., 2000), Nguyen and colleagues (2019) identified a measure of set-shifting and verbal abstract reasoning as the best predictors of TFLS performance after accounting for non-EF performances (i.e., processing

speed). However, the breadth of EF and non-EF measures included in their analyses should be considered, as this can increase the likelihood of shared variance within and between EF and non-EF measures and may artificially reduce the predictive power of certain variables. This suggests that future studies may benefit from further specifying adequate predictors of IADL performance by using a latent variable approach, removing specific factors that may confound performance (i.e., processing speed) and comparing such constructs to TFLS performance.

This study is not without limitations. First, although providing a flexible battery is common within a clinical setting, it can result in test selection bias and uneven distribution of cognitive measures within a research sample. For example, participants were only included in the current sample if they completed the TFLS during a neuropsychological evaluation. The inclusion of other performance measures was variable. Additionally, patients assumed to be "too impaired" or "functionally intact" may not have been given a TFLS during their evaluation, potentially skewing the current sample. However, the sample's size and similar clinical presentation to past studies examining the TFLS (Gonzalez et al., 2017; Lowe et al., 2020; Nguyen et al., 2019) suggest adequate generalizability of the current findings. Next, although the cognitive model proposed in the current study is grounded theoretically, the measures were limited to those available, resulting in an uneven number of measures used to construct each latent variable. Although this is a notable concern, each factor included multiple variables for each cognitive domain and the model demonstrated a good fit within the current sample. Lastly, the processing speed factor was constructed using more variables, which may account for a more robust processing speed variable within the three-factor, CFA model. However, this should not affect the predictive variance of the three cognitive factors and their relationship to adaptive functioning performance, as factor scores were standardized prior to being entered into the regression model. Given the current findings and previous research supporting the relationship between processing speed and adaptive functioning, future studies may benefit from examining the influence of processing speed on the relationship between EF and adaptive functioning. Additionally, future studies could also compare TFLS performances with and without an embedded timed component.

Overall, findings from the current study provide support for a relationship between processing speed and adaptive functioning among older adults. Although previous studies have examined the relationship between TFLS performance and other cognitive domains, to our knowledge, no studies have directly examined relationships between attention, inhibition, and processing speed, nor have previous studies accounted for speeded components embedded within neuropsychological measures, when identifying cognitive relationships. Future studies are encouraged to replicate these findings as well as to compare the influence of processing speed to previously identified cognitive relationships with the TFLS.

Funding

Conflict of Interest

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