A Validation Study of Memory and Executive Functions Indexes in French-Speaking Healthy Young and Older Adults*

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RÉSUMÉ

Des scores composites mesurant les fonctions temporales médianes (FTM)/la mémoire et les fonctions frontales (FF)/exécutives sont utilisés pour indexer les changements cognitifs reliés au vieillissement. L'utilisation de ces scores en recherche gagne en popularité, mais s'appuie essentiellement sur les résultats de tests neuropsychologiques auprès des populations anglophones. Cette étude visait à valider les scores composites des FTM/la mémoire et FF/exécutives auprès d'adultes francophones. Quatre-vingt-dix-huit participants sains (32 jeunes et 66 âgés) ont été évalués à l'aide de trois tests neuropsychologiques associés aux FTM et cinq tests associés aux FF. Une analyse factorielle effectuée sur les scores résiduels indépendants de l'âge indique que les tests associés aux FTM et ceux associés aux FF se regroupent en deux facteurs distincts. Une analyse de type « bootstrapping » impliquant 1 000 rééchantillons indique que sept tests sont stables. Cette étude valide pour la première fois en français, des scores composites mesurant les FTM et FF.

ABSTRACT

Medial temporal lobe (MTL)/memory and frontal lobe (FL)/executive functions indexes are used to measure changes related to cognitive aging. These indexes are based on composite scores of neuropsychological tests validated in English-speaking populations, and their use in aging research is growing in popularity. This study aimed at validating the MTL/memory and FL/executive functions indexes in French-speaking adults. Ninety-eight healthy participants (32 young and 66 older adults) were tested on eight neuropsychological tests, three associated with MTL/memory functions and five associated with FL/executive functions. Factor analysis indicated that residual scores independent of age and associated with MTL/memory functions grouped under one factor, and residual scores associated with FL/executive functions grouped under another factor. Bootstrapping analysis with 1,000 resamples confirmed stability for seven neuropsychological tests. This study provides the first validation of the MTL/memory and FL/executive functions composite scores in French-speaking adults, which may be used to assess cognitive changes in aging research.

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Introduction

It is generally agreed in the literature that cognitive functions are differently affected by aging (Craik & Salthouse, 2008; Lemaire & Bherer, 2005). Research has repeatedly demonstrated that episodic memory and executive functions are two cognitive domains especially vulnerable to the detrimental effects of aging (e.g., Craik & Salthouse, 2000; Phillips & Henry, 2008). *Episodic memory* refers to memory for events associated with spatial and temporal contexts (Tulving, 1972) and has been associated with medial temporal lobe (MTL) functions, as first illustrated by the well-known case of the patient referred to as H.M. (Scoville & Milner, 1957). *Executive functions* are thought to be high-level functions enabling control of complex cognition (Lezak, Howieson, & Loring, 2004). They encompass different abilities such as planning, organization, switching, inhibition, and monitoring of other cognitive operations. Executive functions are also involved in working memory which is a function that supports online manipulation and temporary storage of information (Baddeley & Hitch, 1974; Miyake & Shah, 1999). Executive functions have been associated with frontal lobe (FL) functions based on studies of brain-damaged individuals with lesions restricted to the FL region (Alexander, Stuss, Picton, Shallice, & Gillingham, 2007; see Alvarez & Emory, 2006 for a meta-analysis of performance on executive tasks in frontal-damaged patients studies; Benton, 1968; Miller, 1964; Stuss et al., 1983).

In line with these previously reported associations between cognitive functions and brain regions, evidence suggests that aging negatively affects MTL and FL regions (see Fjell & Walhovd, 2010, for a recent review of brain volume changes in aging; Raz et al., 2005). In their longitudinal study examining volume changes in brain regions as a function of age, Raz et al. (2005) found negative correlations between age and hippocampal volume ($r = -0.50$), and between age and lateral prefrontal cortex volume ($r = -0.59$). Other processes such as alteration of synaptic spines also affect these regions with aging (Morrison & Hof, 1997). Whether or not age-related neuroanatomical and physiological changes in these brain regions are causing the functional changes reported in the literature, proper assessment of MTL/memory functions and FL/executive functions[1] is essential when conducting aging research given the heightened vulnerability of these functions in older adults.

Indeed, many studies have shown decline in episodic memory in older compared to young adults (Balota, Dolan, & Duchek, 2000; Craik, Anderson, Kerr, & Li, 1995; McDaniel, Einstein, & Jacoby, 2008; Zacks, Hasher, & Li, 2000) but results vary depending on whether performance is measured using free recall, cued recall, or recognition (e.g., Zacks et al., 2000). Nevertheless, memory difficulties are among the most common complaints in aging individuals (e.g., Jonker, Geerlings, & Schmand, 2000; Tannenbaum, Mayo, & Ducharme, 2005), and memory is one of the most frequently assessed cognitive functions in cognitive aging research. Similarly, a decline in executive functions and working memory is one of the most robust effects of aging on cognitive functioning (e.g., Daniels, Toth, & Jacoby, 2006), affecting everyday functioning abilities (Vaughan & Giovanello, 2010). There is, however, some variation across results in aging studies: some report a drastic decline while others report a mild change, and some have even observed equivalent performances between young and older adults (e.g., see Bryan & Luszcz, 2000, for a review of sensitivity of executive tasks to aging changes).

There are different possible reasons for these discrepancies in the research literature. One reason may be related to cognitive screening of older adults in study samples. We now know that dementia develops over decades and is likely preceded by a phase called mild cognitive impairment (Blennow, de Leon, & Zetterberg, 2006; Petersen, Stevens, Ganguli, Cummings, & DeKosky, 2001). Recently, significant advances have been made relative to this prodromal phase, namely in the development of more sensitive screening measures, such as the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), to improve identification of older adults with mild cognitive impairment. More specifically, the MoCA includes more sub-tests assessing executive functions than does the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). This more recent screening test has been validated in several languages and found to have greater sensitivity and reliability in detecting individuals with mild cognitive impairment than the MMSE for which ceiling effects have been reported, making it hard to distinguish normal aging from mild cognitive decline (de Jager, Hogervorst, Combrinck, & Budge, 2003; Hoops et al., 2009; Nasreddine et al., 2005). However, this further suggests that previous aging studies using only the MMSE to rule out dementia in healthy older adults may have included some individuals with mild cognitive impairment in their study sample. Consequently, this may have resulted in an over-estimation of age effects in some cases (Arsenault-Lapierre, Whitehead, Belleville, Massoud, & Chertkow, 2011).

Another reason for variation in results may be differences in neuropsychological tests used to measure episodic memory and executive functions across studies. There are several standardized tests available to measure MTL/memory and FL/executive functions for which inconsistent sensitivity to age-related cognitive decline have been reported (Bryan & Luszcz, 2000).

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Furthermore, because of time constraints, a limited number of tests may be used. However, many studies have shown that single tests do not always correlate with experimental data as expected. Hence, use of multiple tests to capture more variance is desirable, especially in light of the evidence showing that MTL/memory and FL/executive functions are likely subserved by different cognitive processes. For example, Miyake, Friedman, Emerson, Witzki, and Howerter (2000), through statistical analyses, have provided evidence for the non-unitary nature of executive functions. By selecting a broad range of tests targeting the same function, the examiner is more likely to detect subtle cognitive changes related to normal aging.

In line with this view, Glisky, Polster, and Routhieaux (1995) proposed using composite scores to index MTL/memory and FL/executive functions respectively. The rationale behind composite scores is that several measures of a given function are more likely to reflect the total variance in the cognitive processes specifically associated with that function than is variance associated with any single measure. The authors first selected a series of standardized tests (four tests measuring episodic memory and five tests measuring executive functions) based on the theoretical concepts they are assumed to measure. As Glisky and Kong (2008) clearly indicated in their study:

> The memory tests were selected to tap basic retention or consolidation processes traditionally thought to depend on MTLs and to be minimally influenced by strategic factors that might be contributed by the FLs. The FLs tests, on the other hand, were clearly not tests of long-term memory but were thought to tap executive control processes, perhaps those associated with working memory. (p. 811)

Importantly, an exploratory principal factor analysis was performed to determine whether the selected test scores grouped according to the two expected factors. As predicted, results showed that the first factor was composed of the four scores on tests assumed to measure episodic memory, and the second factor was made up of the five scores on tests associated with executive functions. Based on these findings, and those later validated in an overall sample of 375 older adults and 96 young adults, which served as control participants, Glisky et al. (Glisky & Kong, 2008; Glisky, Rubin, & Davidson, 2001) proposed using composite scores of these tests (mean *z*-scores) to properly index MTL/memory and FL/executive functions.

Since their inception, the MTL/memory and FL/executive functions indexes have been used in many aging studies to shed light on various cognitive processes assumed to be related to changes in either one or both of the functions. These indexes help to quantify even subtle variations in these functions across participants, enabling correlational analyses or orthogonal categorizations of participants based on level of performance (e.g., high vs. low FL/executive functioning). We performed a search using the Web of Science database (webofknowledge.com) and Google Scholar for the period of 1995 to July 15, 2012, with the Glisky et al. (1995) paper cited in reference, and found 242 experimental articles and 28 doctoral dissertations. To further estimate how frequently the MTL/memory and/or FL/executive functions indexes had been used in aging research, we manually reviewed these documents. We found 36 articles and eight doctoral dissertations in which the MTL/memory and/or FL/executive functions indexes had been calculated to assess cognitive functions in older adults. Widespread use of a recognized index is valuable as it provides the possibility of directly comparing results across studies. A few studies have also used the indexes in patients (e.g., Anderson et al., 2008; Anderson, Guild, Cyr, Roberts, & Clare, 2012), suggesting the indexes be used in clinical evaluation. Overall, this informal review suggests increasing usage of the MTL/memory and/or FL/executive functions indexes in aging research to measure cognitive changes associated with normal aging.

To the best of our knowledge, validation of the MTL/memory and FL/executive functions indexes using factor analyses has been reported in a total of nine studies, eight of which involve English-speaking populations (Chan & McDermott, 2007; Glisky & Kong, 2008; Glisky et al., 1995; Glisky et al., 2001; Henkel, Johnson, & De Leonardis, 1998; McCabe, Roediger, McDaniel, & Balota, 2009; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Rubin, Van Petten, Glisky, & Newberg, 1999), and one in a Hebrew-speaking population (Vakil, Raz, & Levy, 2010). Because age-related changes are known to specifically affect memory and executive functions, it is important to develop reliable measures of these functions and extend them to non-English-speaking populations as well. Given the popular use of the MTL/memory and FL/executive functions indexes in the aging research literature, validation of these indexes in French-speaking young and older adults is necessary before their use in aging studies. Although the neuropsychological tests involved in these indexes have all been standardized in French, some language- and culture-based differences remain between French and English versions. For example, in the Verbal Fluency Test, not only do the letters differ between French and English versions ("P, T, L" in French; Fontaine & Joubert, 2010; F, A, S in English; Spreen & Benton, 1977) but also, the duration of each test differs (90 sec in French and 60 sec in English). Another example is the Wechsler Memory Scale-III

(Wechsler, 2000); the stories in the French-Canadian version are not a simple literal translation from English to French but have been culturally adapted by using French names and Canadian cities.

The objective of this study was to validate the MTL/memory and FL/executive functions indexes in a French-speaking population of young and older adults for future use in aging studies. To do so, we used a similar methodology as initially proposed by Glisky et al. (1995) by performing a principal component analysis on neuropsychological data. In all but one case, we also used an updated version of the neuropsychological tests included in the indexes. Additionally, we performed a bootstrap principal component analysis in order to assess the reliability of results using 1,000 re-samples. We predicted that two factors would be found, one with expected tests representing MTL/memory functions and the other with expected tests representing FL/executive functions. Furthermore, we predicted that the bootstrap factor analysis would show that the two factors are reliable.

Method

Participants

A total of 114 native French-speaking Canadian participants were recruited for this study: 34 young adults and 80 healthy older adults. Young adults were recruited on the Université de Montréal campus, and older adults were recruited from the community through posted advertisements. All participants were right-handed. Exclusion criteria for older adults were (a) impaired performance on the MoCA test (Nasreddine et al., 2005; performance < 26/30) and (b) significant depressive symptoms as measured by the Geriatric Depression Scale (GDS-15; Sheikh & Yesavage, 1986; score > 5/15). Exclusion criteria for young adults included significant depressive symptoms as measured by the Beck Depression Inventory-II (BDI-II; Beck, Rial, & Rickets, 1974; score > 14/63). Exclusion criteria for all participants included performance on neuropsychological tests under 1.5 standard deviation from age- and education-matched norms, history of traumatic brain injury, stroke or other cerebrovascular disorder, diabetes, neurological disorder, psychiatric illness, alcohol abuse, and general anaesthesia (Caza, Taha, Qi, & Blaise, 2008) within the past year.

Based on these criteria, 14 older adults were excluded for the following reasons: eight individuals fell below the cut-off score on the MoCA (Nasreddine et al., 2005); two individuals scored above the cut-off on the GDS-15 (Sheikh & Yesavage, 1986); two older adults performed under 1.5 standard deviation of normative scores for their age and education on two neuropsychological tests used in the indexes; one individual had diabetes; and one participant dropped out. In the young group, one adult was excluded from the study due to a score above the cut-off on the BDI-II (Beck, Rial, & Rickets, 1974), and a second young adult was excluded because she performed below a 1.5 standard deviation of normative scores for her age and education on two neuropsychological tests used in the indexes. With these exclusions, a total of 98 individuals participated in this study: 66 healthy older adults aged between 60 and 80 years, and 32 young participants aged between 19 and 35 years. Demographic characteristics of participants are summarized in Table 1. This study was approved by the Research and Ethics Committee of the Institut universitaire de gériatrie de Montréal, and all participants gave informed consent. Participants for this study took part in different ongoing studies in N. Caza's laboratory comparing young and older adults; all participants were tested individually over three sessions that lasted from 1.5 to 2 hours each.

Materials and Procedures

A French version of the eight neuropsychological tests[2] associated with MTL/memory functions (three tests)

Table 1: Demographic, cognitive, and psychological variables of participants

Variable	Young Adults ($n = 32$)	Older Adults ($n = 66$)	p-value (t-test)	Effect size (Cohen's d)
Age (years)	25.03 (4.32)	68.61 (4.49)	< .001	9.89
Education (years)	16.53 (2.06)	16.49 (3.73)	n.s.	0.01
Mill Hill (/34)	24.31 (4.10)	28.66 (3.03)	< .001	1.21
MoCA (/30)	–	27.74 (1.36)		
GDS (/15)	–	1.70 (1.59)		
BDI-II (/63)	4.11 (3.05)	–		

Mean and standard deviations (in parentheses) are provided for each variable.
BDI-II = Beck Depression Inventory-II
GDS = Geriatric Depression Scale
Mill Hill = Mill Hill Vocabulary Test
MoCA = Montreal Cognitive Assessment

and FL/executive functions (five tests) were selected for validation based on the work by Glisky et al. (1995, 2001) and Glisky and Kong (2008). The MTL/memory functions measures included the total score on the Logical Memory I test and the total score on the Verbal Paired Associates I test, both from the French-Canadian version of the Wechsler Memory Scale-III (Wechsler, 2000), as well as the Long-Delay Cued Recall score from the French version of the California Verbal Learning Test (CVLT; Poitrenaud, Deweer, Kalafat, & Van Der Linden, 2007). As previously mentioned, these tests are assumed to reflect retention or consolidation processes associated with MTL regions with limited influence from strategic factors. The FL/executive functions measures included the total score on the Mental Arithmetic test from the French-Canadian version of the Wechsler Adult Intelligence Scale-III (Wechsler, 1997), the total score of the Mental Control test and the total score of the Backward Digit Span from the Memory for Digits test, both from the French-Canadian version of the Wechsler Memory Scale-III (Wechsler, 2000), the total number of categories achieved on the Wisconsin Card Sorting Test-64 Card Version (WCST-64; Kongs, Thompson, Iverson, & Heaton, 2000), and the total number of words for the letters P, T, and L (the Verbal Fluency Test; Fontaine & Joubert, 2010). These tests are assumed to involve different executive processes, including mental flexibility, inhibition, monitoring, planning, and working memory. Administration of these eight neuropsychological tests in order to obtain the two indexes generally required between 1 hour, 45 minutes to 2 hours, 15 minutes.

Data Analyses

All statistical analyses were carried out using IBM SPSS statistics software version 17.0.1. To determine whether the aforementioned eight French neuropsychological tests represented two factors reflecting MTL/memory and FL/executve functions, respectively, we performed a principal component analysis using the total number of participants (n = 98). A series of regression analyses was first conducted to remove the variance attributed to age from each test; this allowed us to capture the contribution of MTL/memory and FL/executive functions independent of age. Second, as can be seen in Table 1, a vocabulary effect was found between young and older adults: the latter performed better than the former on the Mill Hill Vocabulary test (Gérard, 1983). This vocabulary effect was thus further examined in order to determine if it had influenced performance on each neuropsychological test. Correlational analyses indicated that performance on the Mill Hill test was only associated with the Verbal Fluency Test (positive correlation in both groups). Hence, to determine whether vocabulary level influenced the observed age effect on the Verbal Fluency Test, Mill Hill scores were used as a co-variate in a regression analysis between age and performance on the Verbal Fluency Test. Results indicated that vocabulary did not influence the age effect on the Verbal Fluency Test, and, therefore, this variable was not statistically controlled in the following analyses.

Guided by previous studies in the literature, the eight standardized residual scores were submitted to a forced two-factor principal component analysis. An oblique rotation was first performed to verify correlations between factors. In line with Tabachnick and Fidell's (2007) recommendation for using varimax rotation (correlation coefficient between factors should be under .3), the two factors were found to be only weakly correlated with each other (r = .18). Only score loadings on a factor at least equal to .32 and factors with eigenvalues greater than 1 were considered significant (Tabachnick & Fidell, 2007).

Additionally, a non-parametric bootstrap principal component analysis (e.g., Diaconis & Efron, 1983) was conducted across 1,000 re-samples using the residual scores from the eight neuropsychological tests to assess reliability of the findings from our sampled population (Thompson, 1994; Zientek & Thompson, 2007). This method consists of performing analyses with 1,000 re-samples drawn with replacement from the original sample (n = 98), with each re-sample being the same size as the original sample. For example, the first re-sample could be composed of the first 97 participants with participant number one being drawn twice; the second re-sample could be composed of the first 95 participants, with participants numbered 54, 76, and 91 all drawn twice and participant number 1 never drawn; and so on for 1,000 re-samples. Based on Zientek and Thomson (2007), the ratio of the mean of factor loadings and standard errors (which acts like a t statistic) was then compared to the critical t value for n = 98 (t = 2; report to classic Student's t-distribution).

Results

Factor Analysis

The mean level of performance on each of the individual neuropsychological tests for young and older adults along with the effect sizes are shown in Table 2. Raw scores on six of the eight tests showed a medium to large age effect between groups, consistent with the literature, which further justifies use of residual scores in the regression analyses to remove age effects from the factor analysis. Importantly, loadings extracted from the varimax rotation indicated two factors with score loadings greater than .32 and eigenvalues greater than

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Table 2: Raw Scores on neuropsychological tests for young and older adults

Scores	Young Adults ($n = 32$)	Older Adults ($n = 66$)	p-value (t-test)	Effect size (Cohen's d)
Logical Memory I[a] (/50)	33.94 (8.03)	29.02 (5.40)	.001	0.72
Paired Associates I[b] (/32)	27.25 (3.41)	21.92 (5.93)	< .001	1.10
California Verbal Learning Test[c] (/16)	15.06 (1.22)	14.00 (2.3)	< .05	0.56
Mental Arithmetic[b] (/22)	14.97 (2.99)	14.67 (2.71)	ns	0.11
Mental Control[b] (/40)	30.41 (3.88)	27.91 (4.54)	< .01	0.59
Backward Digit Span[b] (/14)	9.03 (2.32)	6.98 (2.43)	< .001	0.86
Wisconsin Card Sorting-64[d] (/6)	4.25 (1.27)	3.08 (1.33)	< .001	0.90
Verbal Fluency[e]	49.88 (10.96)	51.77 (11.15)	ns	0.17
California Verbal Learning [f] (/16)	14.75 (1.44)	13.86 (2.02)	< .05	0.51

* **Mean and standard deviations (in parentheses) are provided for each variable.**
[a] **Total score (story A + story B1)**
[b] **Total score**
[c] **Long-Delay Cued Recall (older adults $n = 63$; data for 3 older adults went missing due to experimentor error)**
[d] **Number of categories achieved**
[e] **Total number of words generated with letters P, T, L**
[f] **Score for the immediate cued recall**

1 (see Table 3). As predicted, residual scores presumed to be associated with MTL/memory functions loaded on one factor (Factor 2) and scores presumed to be associated with FL/executive functions loaded on a second factor (Factor 1), with both factors explaining 44.5 per cent of the total variance. The mean inter-item correlations for MTL/memory and FL/executive functions factors were .26 and .24, respectively, which is within the proposed optimal range (Briggs & Cheek, 1986).

Table 3: Loadings extracted from the varimax rotation

Scores	Factor 1	Factor 2
Mental Arithmetic[a]	.632	.141
Mental Control[b]	.651	–.075
Backward Digit Span[c]	.698	.111
Wisconsin Card Sorting Test-64[d]	.420	.376
Verbal Fluency[e]	.653	.001
Logical Memory I[f]	–.066	.544
Paired Associates I[g]	.215	.700
CVLT[h]	.028	.796
Eigenvalues	2.23	1.33

* **Scores submitted to factor analysis are standardized residual scores from regression between age and neuropsychological test.**
[a] **Total score on the Mental Arithmetic test (/22)**
[b] **Total score of the Mental Control test (/40)**
[c] **Total score of the Backward Digit Span from the Memory for Digits test (/14)**
[d] **Total number of categories achieved on the Wisconsin Card Sorting Test-64 (/6)**
[e] **Total number of words for the letters P, T, and L**
[f] **Total score on the Logical Memory I test (/50)**
[g] **Total score on the Verbal Paired Associates I test (/32)**
[h] **Long-Delay Cued Recall score from the California Verbal Learning Test (/16)**

Bootstrap Analysis

Means of factor loadings and standard errors (*SE*s) from the bootstrap analysis using 1,000 re-samples are reported in Table 4. Of importance here are the ratios that were calculated by dividing the bootstrap factor loadings by the *SE*s (Boots./SE). Results showed that all five ratios of test loadings on the first factor were above two and that the ratios of two of the three test loadings on the second factor were above two, suggesting relative stability of data in all but one test loading (Logical Memory I test).

Bootstrap analysis also allows one to obtain eigenvalues for the two factors in each of the 1,000 re-samples from which mean (and *SE*) eigenvalues can be calculated (presented in Table 4). A 95% confidence interval (CI) of the eigenvalues was thus calculated for each factor. Results showed that the eigenvalues from our original sample for the FL/executive functions factor (eigenvalue = 2.33, CI [1.91, 2.71]) and for the MTL/memory functions factor (eigenvalue = 1.33, CI [1.21, 1.73]) are within the CI.

Discussion

The findings from this study provide the first validation in a French-speaking population of two indexes that measure critical cognitive functions in aging. Our literature review suggests that a significant number of research laboratories use the composite scores initially suggested by Glisky et al. (1995) to index MTL/memory and FL/executive functions in young and older adults. This study adds to existing literature by extending the use of the MTL/memory and FL/executive functions indexes to French-speaking populations for aging research.

Table 4: Sample and bootstrap factor loadings with ratio of mean bootstrap factor loadings and standard errors

Scores[a]	Factor 1			Factor 2		
	Sample[b]	Boots.[c] (*SE*)[d]	Boots.[c]/*SE*	Sample	Boots. (*SE*)	Boots./*SE*
Mental Arithmetic[e]	.632	.869 (.204)	4.26	.141	.187 (.411)	0.45
Mental Control[f]	.651	.932 (.113)	8.25	–.075	–.07 (.337)	–0.21
Backward Digit Span[g]	.698	.921 (.140)	6.59	.111	.157 (.328)	0.49
Wisconsin Card Sorting Test-64[h]	.420	.745 (.242)	3.08	.376	.504 (.365)	1.38
Verbal Fluency[i]	.653	.904 (.179)	5.05	.001	.033 (.388)	0.09
Logical Memory I[j]	–.066	.108 (.413)	0.26	.544	.750 (.508)	1.48
Paired Associates I[k]	.215	.468 (.255)	1.84	.700	.806 (.257)	3.14
CVLT[l]	.028	.242 (.292)	0.89	.796	.904 (.195)	4.64
Eigenvalues	2.23	2.30 (0.21)		1.33	1.43 (0.13)	

[a] **Variables from factor analysis**
[b] **Factor loadings from our sample *n* = 98**
[c] **Mean bootstrap factor loadings**
[d] ***SE* = standard error; since SDs are averaged across 1,000 re-samples, SDs in bootstrap act like SEs.**
[e] **Total score on the Mental Arithmetic test (/22)**
[f] **Total score of the Mental Control test (/40)**
[g] **Total score of the Backward Digit Span from the Memory for Digits test (/14)**
[h] **Total number of categories achieved on the Wisconsin Card Sorting Test-64 (/6)**
[i] **Total number of words for the letters P, T, and L**
[j] **Total score on the Logical Memory I test (/50)**
[k] **Total score on the Verbal Paired Associates – I test (/32)**
[l] **Long-Delay Cued Recall score from the California Verbal Learning Test (/16)**

We used several criteria to validate the indexes in French-speaking individuals. First, a relatively large sample of participants were included in this validation study compared with the initial study published by Glisky et al. (1995; n = 48 participants, but who have since increased their sample size). Second, we used more stringent criteria to rule out cognitive impairment in older adults than all previous validation studies, by using the MoCA test (Nasreddine et al., 2005) rather than the MMSE (Folstein et al., 1975). In our study, this resulted in a 10 per cent rejection rate on the basis of the MoCA test alone.

In line with the literature suggesting that episodic memory and executive functions are especially vulnerable to aging, performance on the majority of the neuropsychological tests revealed an age effect. Interestingly, mean performances on two executive functions measures (i.e., Mental Arithmetic and Verbal Fluency Tests) did not differ between young and older adults. These findings may be related to the more stringent cognitive screening criteria used to include older participants in our study. Another possibility is that these tests might not be very sensitive measures of executive changes in aging, as others have also shown (Glisky & Kong, 2008; McCabe et al., 2009). For example, Glisky and Kong (2008) found that older adults out-performed young adults in the Mental Arithmetic test. Similarly, several lines of evidence suggest that verbal abilities remain relatively stable over time whereas vocabulary capacities sometimes increase with age (Park & Gutchess, 2002).

As predicted, we found two factors. These factors explained 44.5 per cent of the total variance, a finding that is comparable to that reported by Glisky et al. (46% in the 1995 paper, 48.5% in the 2001 paper) and by Glisky & Kong (2008; 44.3%; Elizabeth Glisky, personal communication, November 17, 2012). Overall, these findings suggest that the French and English versions of the standardized neuropsychological tests measure similar processes associated with MTL/memory and FL/executive functions, despite cultural and methodological differences. Of note, the removal of the Visual Paired Associates II test (Wechsler, 1987) compared to Glisky's original test battery had limited impact on the grouping of variables, and may reduce testing time.

Most loadings for each test were large, suggesting that correlations across tests under one factor were high (Comrey & Lee, 1992). In other words, all measures can be considered very good measures of each factor, with the CVLT (Poitrenaud et al., 2007) having the largest loading score. On the practical side, however, the Long-Delay Cued Recall measure from the CVLT used in the MTL/memory functions index is also the most time-consuming test from the battery (it can take up to 40 minutes to obtain this score because of the 20-minute delay). Keeping in mind the use of these indexes in aging research, we set out to examine whether the immediate cued recall measure (performed before the long delay but immediately after presentation of the interference list B) could be used instead to reduce testing time. Although delayed recall

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tasks have been found to be most sensitive, even to subtle memory impairment (e.g., in individuals with mild cognitive impairment [MCI]), we assume that interference may be as detrimental as time on memory performance. Indeed, in their review, Belleville, Sylvain-Roy, de Boysson, and Ménard (2008) reported studies showing that interference (both proactive and retroactive) reduced retention in people with MCI. Further evidence for similar processes between immediate and Long-Delay Cued Recall is provided by statistical analyses showing that the two scores were highly correlated ($r = .844$; $p < .0001$).[3] Therefore, validation of the two factors reflecting MTL/memory and FL/executive functions with residual scores using immediate cued recall from the CVLT is provided in Table 5. This small modification to the original indexes might be of interest to researchers assessing MTL/memory and FL/executive functions for which time is an issue (also see Table 2 for performances on the immediate cued recall).

The smallest loading score obtained was for the WCST-64 (Kongs et al., 2000). Although our score is comparable to the one reported in Glisky et al. 1995 paper (.410) and Glisky & Kong (2008) paper (.425), it is important to note that similar loadings were obtained for the two factors in our study (.420 for the FL/executive functions factor and .376 for the MTL/memory functions factor), both of which were above the .32 criterion (Tabachnick & Fidell, 2007). The most likely explanation for the discrepancy between our findings and those of Glisky et al. is that we used different versions of the WCST (Hart, Kwentus, Wade, & Taylor, 1988; Kongs et al., 2000). Glisky et al. (1995; 2001 and Glisky and Kong (2008) used 72 cards that are unambiguous with respect to category, whereas we used the "classic" version with ambiguous cards. This latter version is more difficult and likely to involve additional executive processes that may have affected the loadings.

Interestingly, in their review, Nyhus and Barceló (2009) found evidence of impairment on the WCST (e.g., number of categories achieved, number of perseverative errors) in both frontal- and non-frontal-damaged patients, including those with lesions to the hippocampus. Moreover, these authors reported evidence of a widespread neural network involvement in this task. Hence, although the loading score for the WCST-64 (Kongs et al., 2000) is higher for the FL/executive functions factor than for the MTL/memory functions factor, this finding suggests that this test version shares a common variance with both FL/executive and MTL/memory functions. Thus, one may wish to remove this test from the FL/executive functions index. Table 6 provides the loading scores from the factor analysis without the WCST-64 (Kongs et al., 2000).

The bootstrap factor analysis performed using residual scores from the eight neuropsychological tests is a powerful method to estimate the sampling distribution

Table 5: Loadings extracted from the varimax rotation with immediate cued recall instead of Long-Delay Cued Recall from the California Verbal Learning Test*

Scores	Factor 1	Factor 2
Mental Arithmetic[a]	.557	.281
Mental Control[b]	.637	–.002
Backward Digit Span[c]	.680	.123
Wisconsin Card Sorting Test-64[d]	.429	.386
Verbal Fluency[e]	.697	–.078
Logical Memory I[f]	–.153	.723
Paired Associates I[g]	.262	.554
CVLT[h]	.085	.724
Eigenvalues	2.25	1.30

*** Scores submitted to factor analysis are standardized residual scores from regression between age and neuropsychological test.**
[a] Total score on the Mental Arithmetic test (/22)
[b] Total score of the Mental Control test (/40)
[c] Total score of the Backward Digit Span from the Memory for Digits test (/14)
[d] Total number of categories achieved on the Wisconsin Card Sorting Test-64(/6)
[e] Total number of words for the letters P, T, and L
[f] Total score on the Logical Memory I test (/50)
[g] Total score on the Verbal Paired Associates I test (/32)
[h] Immediate cued recall score from the California Verbal Learning Test (/16)

Table 6: Loadings extracted from the varimax rotation without the WCST-64*

Scores	Factor 1	Factor 2
Mental Arithmetic[a]	.619	.134
Mental Control[b]	.674	–.045
Backward Digit Span[c]	.739	.167
Verbal Fluency[d]	.638	–.028
Logical Memory I[e]	–.049	.577
Paired Associates I[f]	.226	.709
CVLT[g]	.032	.797
Eigenvalues	2.04	1.33

*** Scores submitted to factor analysis are standardized residual scores from regression between age and neuropsychological test.**
[a] Total score on the Mental Arithmetic test (/22)
[b] Total score of the Mental Control test (/40)
[c] Total score of the Backward Digit Span from the Memory for Digits test (/14)
[d] Total number of words for the letters P, T, and L
[e] Total score on the Logical Memory I test (/50)
[f] Total score on the Verbal Paired Associates I test (/32)
[g] Long-Delay Cued Recall score from the California Verbal Learning Test (/16)

and assess reproducibility of the factors found in the original sample (Thompson, 1994; 1995). Of importance here, our results suggest stability across re-samples for seven out of eight tests. Stability, in turn, suggests that seven neuropsychological tests are most probably correctly linked to their respective factor. Results for one test, Logical Memory I (Wechsler, 2000), however, suggest that this variable might not be stable across re-samples. For example, residual scores on this test may have sometimes loaded on the FL/executive functions factor rather than the MTL/memory functions factor because of participants composing the re-samples, raising the hypothesis that it may not be exclusively measuring the MTL/memory function when put in a factor analysis with the seven other tests used in this study. Future studies are needed to clarify this issue.

Some limitations of the present study are worth noting. First, because data for this study were taken from ongoing aging studies on memory, we pooled two populations of young and older adults together to increase sample size but did not include middle-aged participants. However, we did remove the age effect by using residual scores from regression analyses. Similarly, the only other group difference found in our sample was performance on the Mill Hill Vocabulary Test, which had no influence on the age effects found in neuropsychological performances. Second, only the minimal number of participants needed to run a factor analysis were included in this study (Tabachnick & Fidell, 2007). However, we did use a greater number of participants than the original study by Glisky et al. (1995), and we have supported our findings with a subsidiary bootstrap analysis to assess reliability of our findings. Third, the bootstrap method has its limitations: it is an internal reproducibility method, and external reproducibility remains the most dependable method to test reliability of results (Thompson, 1994).

In conclusion, this study validates for the first time the use of MTL/memory and FL/executive functions indexes to help monitor cognitive changes in French-speaking populations. It also provides normative data to calculate composite z-scores for older individuals in order to index their MTL/memory and FL/executive functions, using a more recent version of most tests than the original indexes. In light of the well-documented age effects in episodic memory and executive functions (Craik & Salthouse, 2000), these indexes have gained in popularity in aging research and their use may now be extended to French-speaking adults.

Notes

1 We acknowledge that there is not necessarily a direct mapping between region and function; however, given the reported associations between impaired functions in patients with focal brain lesions, the terms MTL functions and memory functions are used interchangeably; the same reasoning is applied to FL functions and executive functions.

2 The Visual Paired Associates II test from the Wechsler Memory Scaled-Revised (Wechsler, 1987) is part of the original battery from Glisky et al. (1995) but was not used in our study since findings from our laboratory and others (e.g., Anderson et al., 2008) have showed celling effects in healthy controls which greatly reduces variability.

3 Correlations were performed on residual scores (n = 98).

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