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Memory score discrepancies by healthy middle-aged and older individuals: The contributions of age and education

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Abstract

The aim of this study was to examine discrepancies between immediate/delayed recall and recall/working memory in middle-aged and older persons by age and education. Participants were 322 healthy individuals from the community who were stratified into three age and three education groups. Immediate and delayed recall distributions of WMS-III Logical Memory (LM) scores approximated normal curves, and LM savings scores showed a significant, but small, effect of age. LM (immediate, delayed) and Letter-Number Sequencing (LNS) discrepancies varied as a function of age and education. The difference between LM and LNS was not significant in the younger and less educated participants, but increased with age in the most educated group, and in the oldest group LNS exceeded LM (immediate and delayed). The results indicate deterioration in encoding and retrieval, rather than storage, with age, and show a differential, but small, effect of age and education on the memory measures. Working memory was resistant to age-related decline relative to immediate and delayed recall in the oldest, most educated group. Delayed recall–working memory discrepancy is relatively stable with age and education and may be a useful index of the onset of memory pathology across different ages and levels of education.(*JINS*, 2009, *15*, 963–972.)

Keywords: Intraindividual variability, Aging, Demographic, Immediate recall, Delayed recall, Working memory

INTRODUCTION

Statistically significant differences between single or index scores are frequent in standardization samples. The distributions of IQ and index scores of the Wechsler Adult Intelligence Scale-Revised (WAIS-R), the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III), and the Wechsler Memory Scale-Third Edition (WMS-III) have revealed very frequent statistically significant differences between pairs of scores (Matarazzo & Prifitera, 1989; The Psychological Corporation, 1997). Large and frequent intraindividual variability has also been observed in the cognitive performance of normal adults over a broad range of tests, including tests with little skewness and kurtosis (Schretlen, Munro, Anthony, & Pearlson, 2003). Thus, a statistically significant difference between a pair of scores may also be clinically meaningful depending on the frequency (base rate) of the difference in the normal population (Hawkins & Tulsky, 2003; Matarazzo & Herman, 1984).

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A variety of factors have been associated with test score differences. Discrepancies between test scores increase slightly with advancing age (Schretlen et al., 2003), are somewhat more common with higher levels of IQ (Hawkins & Tulsky, 2003), and increase with memory pathology (Hultsch, MacDonald, Hunter, Levy-Bencheton, & Straus, 2000; Jacobson, Delis, Salmon, & Bondi, 2002) and poorer overall cognitive performance (Schretlen et al., 2003). Furthermore, the *direction* of test score differences, that is, the tendency for one score to be predominantly superior to the other within segments of the sample varies as a function of IQ. Full Scale IQ (FSIQ) stratified base-rate data from the standardization sample showed a superiority of General Memory Index (GMI) over FSIQ at lower IQ levels (< 80), but a superiority of FSIQ over GMI at higher IQ levels (120+). FSIQ exceeded GMI in just 16.1% of cases in the individuals with FSIQ lower than 80, but exceeded GMI in 86.6% of cases with IQ of 120 and over (Hawkins & Tulsky, 2001).

An implication of this base-rate data is that the unstratified differences method of determining the rarity of a discrepancy between two test scores and its statistical significance will be very frequently misleading. The direction and size of the discrepancy are not uniform, and the tendency for one index score to be lower or higher than another depends on IQ level or any strong correlate of IQ, such as education (Hawkins & Tulsky, 2001).

The discrepancy between primary and secondary memory in particular may offer clinically useful information, because the two measures show different patterns of deterioration with age and memory pathology. Initial encoding and retrieval, rather than more rapid forgetting, account for the deterioration in memory with increasing age, based on the standardization sample from the WMS-III. Assuming that immediate recall reflects encoding and retrieval, and delayed recall reflects initial encoding indirectly and storage and retrieval of the information that was initially encoded, the finding of comparable aging effects for immediate and delayed recall suggest that the age-related decline is attributed to deterioration in encoding and retrieval more than storage (Haaland, Price, & LaRue, 2003). On the other hand, memory pathology is associated with rapid forgetting of information, that is, a deficit in storage. A decline in episodic memory is an important early predictor of Alzheimer's Disease (AD), whereas primary memory is relatively unaffected in the early stages of the disease (Albert, Moss, Tanzi, & Jones, 2001; Chen et al., 2000; Linn et al., 1995; Masur, Sliwinski, Lipton, Blau, & Crystal, 1994; Tierney et al., 1996) and may remain relatively stable with disease progression (Bennett et al., 2002). Because primary memory functions are expected to be relatively resistant to decline in very early AD or Mild Cognitive Impairment (MCI) and episodic memory, especially delayed recall of verbal information, shows the greatest decline (Chen et al., 2000; Grundman et al., 2004), a significant discrepancy between primary memory and delayed recall may signal the onset of impairment.

There is limited information about size and direction of discrepancies between delayed recall and working memory in normal aging. Stratification of the WAIS-III/WMS-III discrepancy scores by IQ over the entire age range showed some differences in the direction of the discrepancy: at lower FSIQ levels (< 80) a Working Memory Index (WMI)–Auditory Memory Index (AMI) discrepancy of 13 exceeded that seen in 85% of the cases, whereas at higher FSIQ levels (120+) a WMI–AMI discrepancy of 13 exceeded that seen in 75% of the cases (Hawkins & Tulsky, 2003). However, the AMI is a composite of both immediate and delayed recall scores of Logical Memory and Paired Associates (Wechsler, 1997) and thus does not provide a pure measure of delayed recall.

The first aim of this study was to examine the distributions of auditory immediate and delayed recall in healthy middle-aged and older persons, in order to replicate the results of Haaland et al. (2003) of age-related decline in encoding and retrieval, rather than storage. It was predicted that large discrepancies between immediate and delayed recall would be rare in nonpathological aging. The second and main aim of the study was to determine the rarity, size, and direction of within-individual discrepancies between secondary memory and working memory in healthy middle-aged and older persons, stratified by age and education. Secondary and working memory measures may show different patterns of decline with age, so examining the direction of discrepancies over the entire age range may conceal important differences that characterize older people's performance. Because the WMI consists of tasks from two different modalities, the auditory (Letter-Number Sequencing) and visual (Spatial Span), and higher correlation is expected between tasks within a single modality (Hawkins & Tulsky, 2003), the auditory modality was selected. Based on the findings of the stratification of the WAIS-III/WMS-III discrepancy scores, it was predicted that greater working memory than secondary memory would be somewhat more frequent and/or larger in persons of high education. The recall measures (immediate, delayed) were examined separately in relation to working memory.

METHOD

Participants

A total of 322 nonpaid volunteers living independently in the community were evaluated. All were native Greek speakers, between the ages of 47 and 88, with 140 men (43.5%) and 182 women (56.5%). All participants were recruited by the researcher and her assistants through personal contact and by word of mouth. Participants had no reported history of neurological, psychiatric disorder, or memory difficulties, as determined from a semi-structured interview, and were not taking any psychotropic medication that would suggest neuropsychiatric disorder. Participant data was obtained in compliance with regulations of the University of Athens and the Helsinki Declaration.

There were significantly more women than men ($\chi^2 = 5.48$, $p < .05$), but the two groups did not differ significantly in age, $F(1, 320) = 0.37$, $p > .5$. Men had significantly more years of education than women, but the effect size was small, $F(1, 320) = 18.18$, $p < .001$, $\eta^2 = .05$. Demographics for the sample are presented in Table 1 along with means, standard deviations, minimum, and maximum values on the neuropsychological measures.

Instruments

Participants were administered a battery of tests that included three subtests of a Greek adaptation of WMS-III (Wechsler, 1997) by Economou and Papageorgiou for research purposes (Economou, Papageorgiou, & Karageorgiou, 2006). No Greek standardization exists for WMS-III. The subtests were Logical Memory I (LM I), Logical Memory II (LM II), and Letter-Number Sequencing (LNS). Logical Memory I consists of the immediate repetition from memory of two brief stories read by the examiner, with the second story read and repeated a second time. Logical Memory II involves the retelling of the two stories from Logical Memory I after a delay of about 20 minutes. Letter-Number Sequencing, a measure of working memory, involves the repetition of an

Table 1. Demographic and psychometric characteristics of the sample

	Men	Women	Total
	Mean (*SD*) min – max (*n* = 140)	Mean (*SD*) min – max (*n* = 182)	Mean (*SD*) min – max (*n* = 322)
Age	64.95 (9.01) 47 – 88	64.31 (9.48) 50 – 88	64.59 (9.27) 47 – 88
Education (years)	12.07 (4.53)** 0 – 23	10.05 (3.97) 0 – 22	10.93 (4.33) 0 – 23
LM I	35.77 (12.71) 6 – 69	34.66 (11.93) 5 – 67	35.15 (12.27) 5 – 69
LM-II	19.71 (8.79) 0 – 41	19.82 (9.15) 0 – 40	19.77 (8.98) 0 – 41
LNS	8.11 (3.12)* 0 – 14	7.41 (2.82) 0 – 15	7.71 (2.97) 0 – 15
Savings score	74.92 (19.31) 0 – 138	77.28 (21.17) 0 – 159	76.25 (20.38) 0 – 159

Note. The wide range in education, from 0 to 23 years, reflects a diverse sample in terms of educational background and socioeconomic status. In Greece it is not unusual for older persons, especially women, to have had 6 years of education or less. The maximum number of 23 years is that of a medical doctor.
$^*p < .05$; $^{**}p < .001$.

auditorily presented combination of numbers and letters so that the numbers are repeated first in ascending order, and the letters next in alphabetical order. Scoring of WMS-III followed the WMS-III guidelines.

Procedures and Test Measures

The participants were tested in their own homes in a single session. They were administered the tests in a fixed order in individual sessions lasting approximately one hour.

The memory measures (LM I, LM II, LNS) were *z*-transformed before entering the statistical analyses. Two difference measures were computed from the *z*-transformed scores by subtracting LNS from LM I, and LNS from LM II. Additionally, the LM savings score was calculated from the raw scores using the following equation: (LM II/LM I Story A + second recall of LM I Story B) X 100.

RESULTS

Distributions of the Memory Measures and Savings Score

The distribution of LM I raw scores was slightly positively skewed and platykurtic (skewness: .31, kurtosis: –.11), with 15.5% of the sample producing scores lower than 1 *SD,* and 17.7% of the sample producing scores greater than 1 *SD*. When the cut-off was increased to 1.5 *SD*s, the percentages were 3.7% and 5.6%, respectively. Similarly, the distribution of LM II raw scores was slightly positively skewed and platykurtic (skewness: .18, kurtosis: –.61), with 15.3% of the sample producing scores lower than 1 *SD,* and 16.5% of the sample producing scores greater than 1 *SD*. When the cut-off was increased to 1.5 *SD*s, the percentages were 5.3% and 6.9%, respectively. The distribution of LM savings scores was slightly negatively skewed and leptokurtic (skewness: –.37, kurtosis: 1.94), with 15.6% of the sample producing savings scores lower than 1 *SD,* and 13.4% of the sample producing savings scores greater than 1 *SD*. When the cut-off was increased to 1.5 *SD*s, the percentages were 6.5% and 2.8%, respectively.

The sample was stratified into three age groups by dividing it into thirds: Age group 1: 47–58 years, Age group 2: 59–68 years, and Age group 3: 69–88 years. The sample was also stratified into three groups in terms of education: Education group 1: ≤ 6 years, Education group 2: 7–12 years, and Education group 3: 13+ years. The means and *SD*s of the three memory measures, LM I, LM II, and LNS, by age and education, are provided in Table 2. As the table shows, there were no floor effects in the oldest, lowest-education group, or ceiling effects in the youngest, highest-education group.

To examine the effects of age on the savings score, a one-way analysis of variance (ANOVA) was conducted with Age group as the independent variable. Although there was a significant reduction in savings scores with age, the effect size was small, $F(2, 319) = 8.83$, $p < .0001$, $\eta^2 = .05$. The histogram of LM savings scores is shown in Figure 1.

The distributions of the two difference measures (LM I – LNS and LM II – LNS) had normal skewness and were platykurtic (skewness: –.04, kurtosis: –.67 and skewness: .02, kurtosis: –.48, respectively). The examination of LM I – LNS differences revealed that 17.1% of the sample produced scores with LNS greater than LM I by 1 *SD,* and 17.1% of the sample produced scores with LNS smaller than LM I by 1 *SD*. When the cut-off was increased to 1.5 *SD*s, the percentages were 7.8% and 9%, respectively. The examination of LM II – LNS differences revealed that 16.2% of the sample

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Table 2. Descriptive information of the three memory measures by age and education

	Education			
Age	0–6 years Mean (*SD*)	7–12 years Mean (*SD*)	13+ years Mean (*SD*)	Total Mean (*SD*)
LM I (range: 0–75)				
47–58 years	29.64 (10.48)	38.39 (9.20)	45.92 (11.59)	38.64 (12.10)
59–68 years	26.66 (9.41)	38.35 (10.50)	42.98 (11.58)	36.99 (12.41)
69–88 years	25.63 (8.19)	28.33 (8.34)	37.33 (11.74)	29.82 (10.47)
Total	27.08 (9.31)	35.28 (10.43)	42.38 (12.01)	35.15 (12.27)
LM II (range: 0–50)				
47–58 years	17.04 (8.53)	22.00 (8.30)	27.67 (8.02)	22.63 (9.19)
59–68 years	13.66 (5.70)	22.48 (7.85)	25.44 (7.27)	21.25 (8.50)
69–88 years	13.15 (6.84)	14.31 (5.89)	20.07 (8.61)	15.48 (7.61)
Total	14.41 (7.19)	19.78 (8.27)	24.68 (8.41)	19.77 (8.98)
LNS (range: 0–21)				
47–58 years	6.11 (2.41)	8.46 (2.15)	10.11 (1.92)	8.40 (2.64)
59–68 years	4.93 (1.79)	8.70 (2.35)	9.17 (2.94)	7.88 (3.03)
69–88 years	4.98 (2.50)	6.81 (2.39)	9.50 (2.43)	6.86 (3.03)
Total	5.29 (2.32)	8.03 (2.42)	9.58 (2.50)	7.71 (2.97)

produced scores with LNS greater than LM II by I *SD,* and 17.4% of the sample produced scores with LNS smaller than LM II by 1 *SD*. When the cut-off was increased to 1.5 *SD*s, the percentages were 6.2% and 8.1%, respectively.

Discrepancies between Recall and Working Memory by Age and Education

Tables 3a and 3b provide base rates for LM I > LNS and LM II > LNS by ≥ 1 *SD* by age and education groups. The tables show a drop in discrepancy base rates when recall exceeds working memory by ≥ 1 *SD*, which is prominent in the oldest, most educated group. Thus, it is rare for that group to show higher recall (immediate or delayed) than working memory by ≥ 1 *SD*.

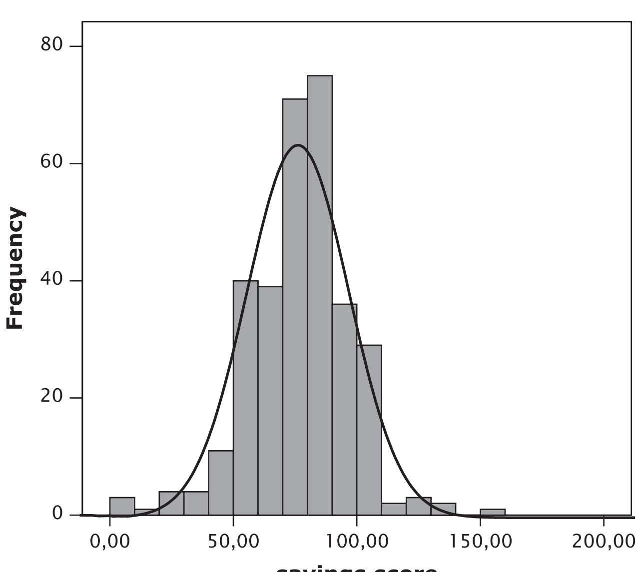

Fig. 1. Savings score distribution in the sample.

The relationships between the memory measures, the difference measures, age, and education were explored in correlations, shown in Table 4. LM I, LM II, and LNS correlated negatively with age and positively with education, as expected, with the correlations with age being lower than the correlations with education. LM II showed the highest correlation with age and LNS the highest correlation with education. The correlations between the difference measures and the demographic variables were much lower than the correlations between the memory measures and the demographic variables. The negative correlations of the difference measures with education show that the higher the education, the lower the LM score compared to the LNS score.

To further examine the effects of age and education for the memory measures, three univariate ANOVAs were conducted, with each of the memory *z* scores (LM I, LM II, LNS) as dependent variables and Age (3 groups) and Education (3 groups) as fixed factors. With LM I as a dependent variable, there was a main effect of Age, $F(2, 313) = 15.49$, $p < .0001$, partial $\eta^2 = .09$, and a main effect of Education,

Table 3a. Discrepancy base rates of sample with LM I > LNS by ≥ 1 *SD* by age and education

	Education			
Age	0–6 years	7–12 years	13+ years	Total
47–58 years	21.4%	17.1%	25.0%	21.0%
	n = 28	*n* = 41	*n* = 36	*n* = 105
59–68 years	20.7%	15.0%	24.4%	20.0%
	n = 29	*n* = 40	*n* = 41	*n* = 110
69–88 years	14.4%	13.9%	3.3%	11.2%
	n = 41	*n* = 36	*n* = 30	*n* = 107
Total	18.4%	15.4%	18.7%	17.4%
	n = 98	*n* = 117	*n* = 107	*n* = 322

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Table 3b. Discrepancy base rates of sample with LM II > LNS by ≥ 1 *SD* by age and education

	Education			
Age	0–6 years	7–12 years	13+ years	Total
47–58 years	28.6% $n = 28$	19.5% $n = 41$	19.4% $n = 36$	21.9% $n = 105$
59–68 years	24.1% $n = 29$	20.0% $n = 40$	19.5% $n = 41$	20.9% $n = 110$
69–88 years	14.6% $n = 41$	11.1% $n = 36$	3.3% $n = 30$	10.3% $n = 107$
Total	21.4% $n = 98$	17.1% $n = 117$	15.0% $n = 107$	17.7% $n = 322$

$F(2, 313) = 52.78$, $p < .0001$, partial $\eta^2 = .25$. Comparisons of Age group 1 (47–58 years) with Age group 2 (59–68 years) and Age group 3 (69–88 years) showed that LM I was significantly higher for Age group 1 than Age group 3 ($p < .0001$). Comparisons of Education group 1 (0–6 years) with Education group 2 (7–12 years) and Education group 3 (13+ years) showed that LM I was significantly lower for Education group 1 than Education group 2 ($p < .0001$), and Education group 1 than Education group 3 ($p < .0001$). Similarly, with LM II as a dependent variable, there was a main effect of Age, $F(2, 313) = 20.29$, $p < .0001$, partial $\eta^2 = .12$, a main effect of Education, $F(2, 313) = 42.48$, $p < .0001$, partial $\eta^2 = .21$, but also an Age x Education interaction, $F(4, 313) = 2.52$, $p = .041$, partial $\eta^2 = .03$. Comparisons of Age group 1 with Age group 2 and Age group 3 showed that LM II was significantly higher for Age group 1 than Age group 3 ($p < .0001$). Comparisons of Education group 1 with Education group 2 and Education group 3 showed that LM II was significantly lower for Education group 1 than Education group 2 ($p < .0001$), and Education group 1 than Education group 3 ($p < .0001$). With LNS as a dependent variable, there was a main effect of Age, $F(2, 313) = 6.01$, $p = .003$, partial $\eta^2 = .04$, a main effect of Education, $F(2, 313) = 82.54$, $p < .0001$, partial $\eta^2 = .35$, and an Age x Education interaction, $F(4, 313) = 2.51$, $p = .042$, partial $\eta^2 = .03$. Comparisons of Age group 1 with Age group 2 and Age group 3 showed that LNS was significantly higher for Age group 1 than Age group 2 ($p = .055$), and Age group 1 than Age group 3 ($p = .001$). Comparisons of Education group 1 with Education group 2 and Education group 3 showed that LNS was significantly lower for Education group 1 than Education group 2 ($p < .0001$), and Education group 1 than Education group 3 ($p < .0001$).

Figures 2 and 3 show the means of LM I z scores *versus* LNS z scores, and LM II z scores *versus* LNS z scores by Age and Education groups. The Figures show the expected decline of LM I, LM II, and LNS as a function of age and education. The LM I – LNS and LM II – LNS differences were explored with two univariate ANOVAs, with each of the difference measures as dependent variables, and Age group and Education group as fixed factors. With LM I – LNS as a dependent variable, there was a main effect of Age, $F(2, 313) = 3.08$, $p = .047$, partial $\eta^2 = .02$, and a marginal main effect of Education, $F(2, 313) = 2.68$, $p = .07$, partial $\eta^2 = .02$. The difference between LM I and LNS was marginally greater in Age group 3 relative to Age group 1 ($p = .058$), was greater in Education group 2 relative to Education group 1 ($p = .031$), and was marginally greater in Education group 3 relative to Education group 1 ($p = .066$). Thus, the LM I – LNS difference marginally increased in terms of age and education, with LNS being greater than LM I in the oldest, most educated group. With LM II – LNS as a dependent variable there was a main effect of Age, $F(2, 313) = 5.21$, $p = .006$, partial $\eta^2 = .03$, and a main effect of Education, $F(2, 313) = 4.77$, $p = .009$, partial $\eta^2 = .03$. The difference between LM II and LNS was greater in Age group 3 relative to Age group 1 ($p = .007$), was greater in Education group 2 relative to Education group 1 ($p = .008$), and was greater in Education group 3 relative to Education group 1 ($p = .007$). Thus, the LM II – LNS difference also increased in terms of age and education, with LNS being greater than LM II in the oldest, most educated group.

Two univariate ANOVAs for each Education group further explored the roles of age and education in the difference scores. LM I – LNS and LM II – LNS reached significance only for Education group 3 (LM I – LNS, $F(2, 104) = 3.84$, $p = .03$, $\eta^2 = .07$, and LM II – LNS, $F(2, 104) = 6.73$, $p = .002$, $\eta^2 = .12$). *Post-hoc* (Bonferroni) comparisons showed that LM I – LNS was significantly greater in Age group 3 relative to Age group 2 ($p = .03$), and LM II – LNS was significantly greater in Age group 3 relative to Age group 1 ($p = .01$), and Age group 3 relative to Age group 2 ($p = .003$). Thus, as the Figures show, the difference measures increased as a function of age for the most educated (13+ years) group, with LNS exceeding LM I and LM II in the oldest group.

Table 4. Correlations between age, education, and memory scores

	Age (years)	Education (years)	LNS
LM I	–.34**	.52**	.60**
LM II	–.39**	.47**	.58**
LNS	–.26**	.63**	
LM I – LNS	–.08	–.12*	
LM II – LNS	–.14*	–.17*	

Note. *$p < .05$; **$p < .0001$.

DISCUSSION

The distributions of immediate and delayed recall raw scores approximate symmetrical bell curves and show that large deviations from the mean are relatively uncommon in the present sample. The percent of scores falling below 1.5 *SD*s from the mean is close to the expected 6.7% of individuals who comprise a normal distribution. Consequently, large differences from the mean of LM savings scores are also relatively uncommon in the sample and the LM savings score means of three age groups (Age group 1: 81, Age group 2: 78,

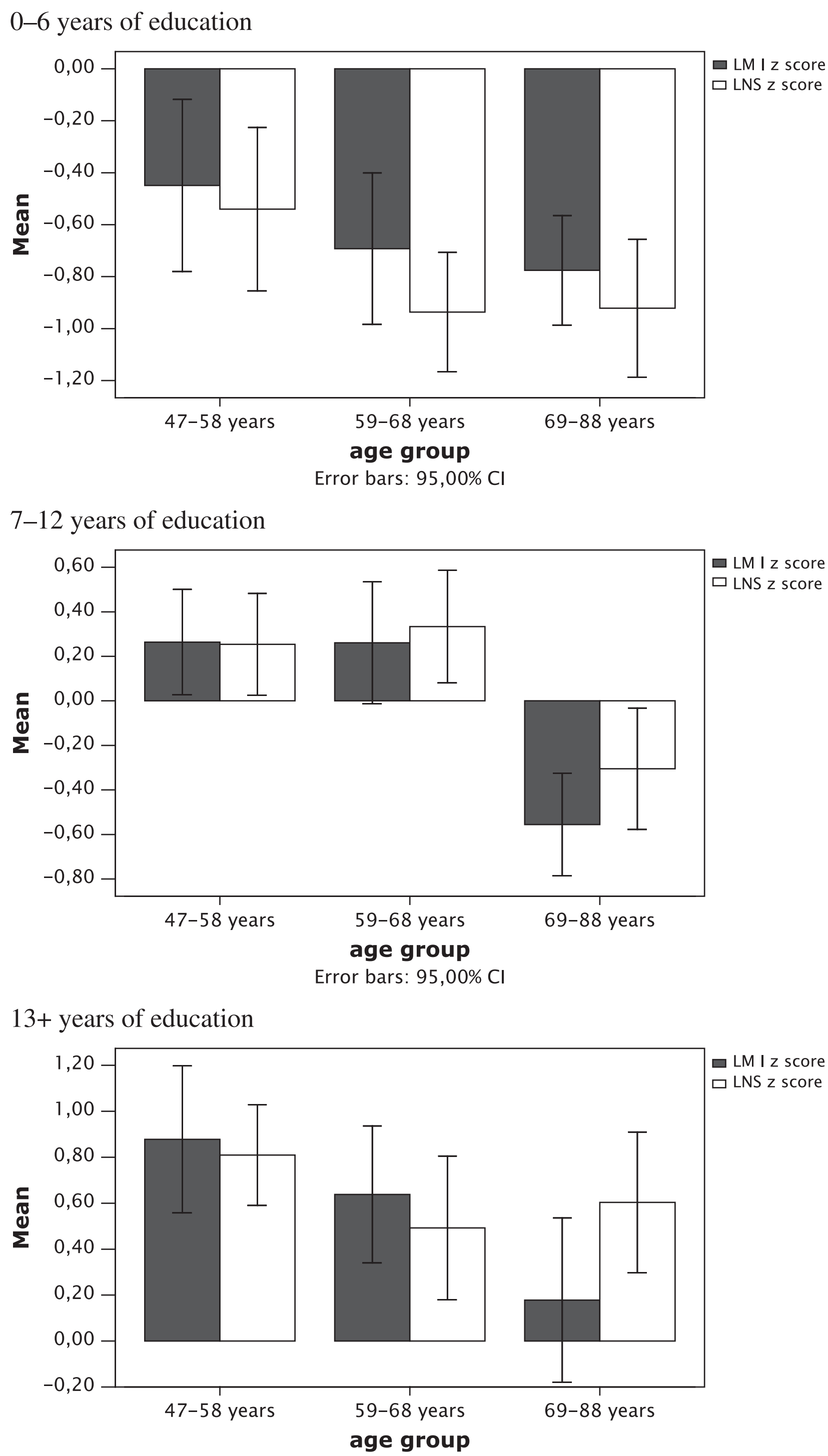

Fig. 2. LM I *versus* LNS as a function of age and education.

Age group 3: 70) fall well within the means of the WMS-III standardization sample (Wechsler, 1997) for the equivalent age groups. The results therefore indicate that the recall performance of this sample of healthy middle-aged and older individuals is close to what would be expected from the normal distribution, and are consistent with the findings of age-related decline observed in a memory measure related to acquisition and early retrieval of information and not in a measure of memory retention in a sample of older, community-dwelling persons (Small, Stern, Tang, & Mayeux 1999). The significant, but small, effect size of age-related decline in LM savings scores in the present sample is close to the effect size of the Delay x Age interaction of LM scores of the WMS-III standardization sample (Haaland et al., 2003), underscoring deterioration predominantly in encoding and retrieval, rather than storage, with age.

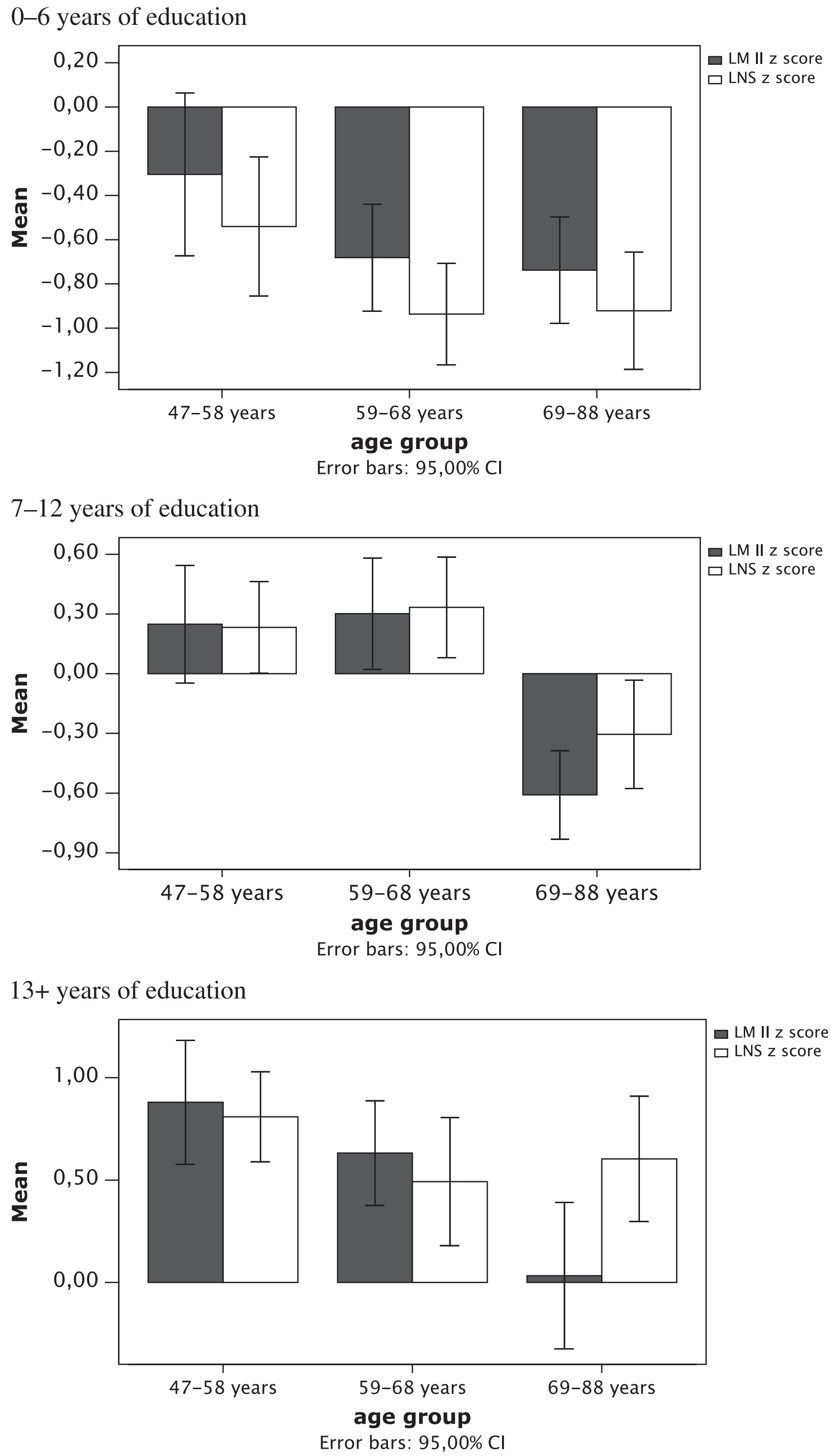

Fig. 3. LM II *versus* LNS as a function of age and education.

Both recall and working memory correlate with age and education, as expected, with correlations with education being stronger than correlations with age. In adults, developmental changes with age are smaller than developmental changes from early childhood to adulthood and likely reflect decline in cognitive abilities resulting from a variety of causes, both pathological and intrinsic to aging itself. Education, on the other hand, has ubiquitous effects on test performance, especially in samples with a wide range of educational backgrounds (Mungas, Reed, Haan, & González, 2005; Mungas, Reed, Tomaszewski Farias, & DeCarli, 2009). Education showed a complex relationship to age-related cognitive decline, as measured by different tests, and moderated the effects of age-related decline in a memory task, recall of words, in a large sample spanning a wide age and educational range (Ardila, Ostrosky-Solis, Rosselli, & Gómez, 2000). In this sample, education moderated working memory more than immediate and delayed recall. The nonsignificant or very small correlations of the difference measures with age are consistent with the findings of Park et al. (2002), who showed identical trajectories of age-related decline for working memory and long-term memory in a sample of 345 people from 20 to 92 years of age, and suggest that working memory mediates considerable variance in long-term memory.

When the sample was stratified by age and education, the percentage of cases exhibiting a superiority of recall (immediate and delayed) over working memory by ≥ 1 *SD* tended to decline with education, especially in the oldest, most educated group, indicating that higher recall than working memory is rare for that group. Discrepancy magnitude as a function of age and education corroborated these findings. Whereas the younger (Age groups 1 and 2) and less educated (Education groups 1 and 2) participants had similar recall and working memory scores, the most educated participants (Education group 3) showed an increase in the difference between recall and working memory as a function of age, and in the oldest group, working memory exceeded immediate and delayed recall. The size of the difference between recall (immediate and delayed) and working memory in this group was approximately 0.5 *SD*.

The results indicate that working memory is resistant to age-related decline relative to immediate and delayed recall in the most educated group. A similar pattern of results was observed in a community sample of healthy middle-aged and older persons comparing California Verbal Learning Test (CVLT) delayed recall performance and LNS. The difference between delayed recall – LNS correlated with neither age nor education in the whole sample. When the sample was divided into two age groups, which did not differ in education, there was a negative correlation of the difference score with education in the older group: the higher the education, the larger the discrepancy between delayed recall and LNS, in favor of LNS (Economou, 2006).

Indirect support for the differential effect of education on the memory measures is found in the WMS-III sample, which shows some variation in the frequency of the discrepancy between Working Memory – Auditory Memory as a function of FSIQ, a strong correlate of education. Working Memory exceeded Auditory Memory in 37% of the sample with FSIQ < 80, but exceeded Auditory Memory in 52% of the sample with FSIQ 120+. For FSIQ < 80, a Working Memory Index-Auditory Memory discrepancy of 13 points was seen in less than 15% of the WMS-III weighted sample, whereas for FSIQ 120+, a discrepancy of 13 points was seen in less than 25% of the sample (Hawkins & Tulsky, 2003). The recall and working memory trajectories of the WMS-III standardization sample (ages 20 to 85), as a function of age and education, also reveals a pattern consistent with the findings. The age-corrected *z* scores of Auditory Immediate and Auditory Delayed Memory showed identical trajectories as a function of education, and similarly, the education-corrected *z* scores of Auditory Immediate and Auditory Delayed Memory showed identical trajectories as a function of age. However, the age-corrected WMI showed a steeper increase as a function of education than either Auditory Immediate or Auditory Delayed Memory, especially in the highest education group (16+ years) (Heaton, Taylor, & Manly, 2003). Because the WMI is a mixed auditory and visual index, and no stratification by both age and education was employed, the findings are not directly comparable; nevertheless, they indicate differential patterns of change in working memory and recall as a function of education.

The differential effect of FSIQ or education on a pair of scores reflects the typical modest correlation between the contrasted scores, combined with the fact that one of the contrasted pair usually correlates more strongly with FSIQ than the other (Hawkins & Tulsky, 2003). In the present sample, working memory was modestly associated with immediate and delayed recall and correlated more strongly with education than either recall measure. Working memory is strongly related to intelligence, a correlate of education. The assignment of attention to the contents of short-term memory comprises working memory, which is connected to the controlled processing of information. Consequently, working memory is essential for the mental activities that are assumed to be basic to intelligence (Schweizer & Moosbrugger, 2004), and working memory variables have been shown to strongly influence fluid intelligence (Salthouse, Pink, & Tucker-Drob, 2008). The findings are consistent with the view that cognitive reserve is mediated through education or IQ and that education or socio-economic status might serve as proxies for reserve (Stern, 2002).

The main issue in discrepancy analysis is whether a given discrepancy is associated with a clinical condition. Although highly desirable, measures that show relatively infrequent variability in normal individuals, but large dissociations in pathology, are rare. Indexes that are modestly associated in normal individuals, but are differentially affected by pathology, may be more useful clinically than indexes that are more strongly correlated, but show little discrepancy, with pathology (Hawkins & Tulsky, 2003). There is limited research on the differential sensitivity of discrepancies between pairs of scores to different pathological conditions. The distinction between Working Memory and episodic memory (both auditory and visual) was striking in a very small sample of Korsakoff's syndrome patients, who showed no impairment in working memory, but was much smaller in a sample of AD patterns (Heaton et al., 2003). Discrepancies between auditory memory, especially delayed recall, and working memory may not be of very high sensitivity in detecting AD, given the pervasive nature of the deficits; however, they may be more sensitive to earlier stages of the disease, when the deficits are relatively more selective (Hawkins & Tulsky, 2003). A comparison of WMS-III Working – Delayed Memory differences in a small sample of patients and controls revealed better Working than Delayed Memory in the MCI patients, but the opposite pattern in the healthy elderly comparison group (Economou et al., 2006), in support of this hypothesis.

The main limitation of this study is the possible presence of individuals with unrecognized memory decline among the older, more educated participants, which might account for the better working memory than recall in this group. Higher levels of education may provide a cognitive reserve that delays the onset of cognitive symptoms (Stern, 2002) or their detection (Tuokko, Garrett, McDowell, Silverberg, & Kristjansson, 2003). In such an event, differences between recall and working memory might reflect the influence of underlying brain pathology and age-related diseases in this group. Although the rarity of large deviations from the mean in the present sample makes such a possibility less likely, it cannot be ruled out.

In conclusion, the discrepancy between recall and working memory varies as a function of both age and education. The discrepancy was, however, only evident in the older, more educated participants, and the effect size was small. Because delayed recall – working memory discrepancy does not show much change in nonpathological aging, shows a small effect of education, and may be differentially affected by memory impairment, it makes a potentially useful index of the onset of memory pathology across different ages and levels of education.

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