Journal of Clinical and Experimental Neuropsychology

ISSN: 1380-3395 (Print) 1744-411X (Online) Journal homepage: www.tandfonline.com/journals/ncen20

Factor analyses across lifespan: based on composite scores derived from the Rey – Auditory Verbal Learning Test (AVLT)

Eli Vakil, Haya Blachstein & Zohar Elyoseph

To cite this article: Eli Vakil, Haya Blachstein & Zohar Elyoseph (26 Sep 2025): Factor analyses across lifespan: based on composite scores derived from the Rey – Auditory Verbal Learning Test (AVLT), Journal of Clinical and Experimental Neuropsychology, DOI: 10.1080/13803395.2025.2565217

To link to this article: https://doi.org/10.1080/13803395.2025.2565217

Published online: 26 Sep 2025.

JOURNAL OF CLINICAL AND EXPERIMENTAL NEUROPSYCHOLOGY
https://doi.org/10.1080/13803395.2025.2565217

Routledge
Taylor & Francis Group

Factor analyses across lifespan: based on composite scores derived from the Rey – Auditory Verbal Learning Test (AVLT)

Eli Vakil[a], Haya Blachstein[a] and Zohar Elyoseph[b]

[a]Department of Psychology and Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel; [b]School of Counseling and Human Development, The Faculty of Education, The University of Haifa, Haifa, Israel

ABSTRACT

Objective: The goal of this study, by using factor analyses, was to reveal the structure of the interrelations between the various total and composite scores generated by the Rey AVLT. A second goal was to address the question: does this structure remain constant across the lifespan?
Method: This study consists of three phases: In Phase I, six total scores were submitted to Exploratory Factor Analysis (EFA) conducted on the entire sample ($n = 1471$) with an age range of 8–91. In Phase II, EFA was conducted on seven composite scores – five process scores and two total scores, applied to the entire sample. In Phase III, the same scores were then submitted to separate Confirmatory Factor Analysis for five age cohorts (8–12, 13–17, 20–29, 30–59, & 60–91).
Results: In Phase I, when total scores were used, unconstrained rotation yielded a single factor. Only under constraining to a three-factorial model did Learning, Storage, and Retrieval emerge. In Phase II, when process scores were used, under unconstrained rotation, a three-factorial model, Learning, Storage, and Retrieval, emerged. The results in Phase III confirmed that the three-factor model shows a developmental trajectory throughout the lifespan. Furthermore, the factors' loading parameters were found to be similar across all age groups.
Conclusions: This study has major theoretical and clinical/diagnostic implications. On the theoretical level, it confirmed that there are three distinct memory processes underlying the Rey AVLT: Learning, Storage, and Retrieval. Furthermore, these processes remain constant across the entire age range, 8–91 years old. On a clinical level, the current results could lead the diagnostician to a conceptually driven diagnosis by pinpointing the exact impaired or preserved memory process, based on the constellation of the various Rey AVLT scores, according to the factor on which they are loaded.

ARTICLE HISTORY
Received 30 December 2024
Accepted 18 September 2025

KEYWORDS
Verbal memory; factor analysis; lifespan; Rey AVLT

The Rey-Auditory Verbal Learning Test (AVLT) (Rey, 1964) is one of the most frequent learning and memory tests used among neuropsychologists (Butler et al., 1991; Rabin et al., 2016). The norms of this test have been published in several countries and several languages (see Lezak et al., 2012). The major reason for its popularity is that several memory scores can be generated from this test, which are assumed to reflect different aspects of verbal learning and memory. Various measures (e.g., Trials 1, 5, 6, & 7) of the test were found to be very sensitive to age-related changes (Burke & Light, 1981; Light, 1991; Vakil & Blachstein, 1997; Vakil et al., 1998) and to different brain pathologies, such as individuals suffering from traumatic brain injury (Blachstein et al., 1993; Silberg et al., 2016), Alzheimer's disease (Estévez-González et al., 2003), Mild Cognitive Impairment (MCI) (Fernaeus et al., 2014), Parkinson's disease (Siciliano et al., 2017), ADHD (Vakil et al., 2012), Schizophrenia (Grimes et al., 2017) and Depression (Günther et al., 2004)

Most normative studies are reported on total scores of the test, such as immediate memory (Trial 1), learning (Trial 5), delayed recall and recognition (Trials 8 & 9, respectively) (Geffen et al., 1990; Vakil & Blachstein, 1997; Vakil et al., 1998). Process scores differ from total scores by providing a greater understanding about how a total score was obtained. For example, Trial 5 could be viewed as reflecting the cumulative effect of the five learning trials, although it is confounded with the baseline of immediate memory (Trial 1). Thus, two individuals with the same score on Trial 5 might reflect different learning rates, due to their different immediate memory. The same problem emerges when viewing Trial 8 as reflecting delayed recall. If the baseline of the number of words recalled before the delay is not considered, then Trial 8, reflecting the delay effect on memory, is confounded with baseline performance. Hence, in an attempt to obtain a better understanding of the total scores, some researchers have generated "process" scores (Vakil et al., 2010; Weitzner et al.,

CONTACT Eli Vakil vakile@biu.ac.il Department of Psychology, Bar-Ilan University, Ramat-Gan 52900, Israel

2020). Vakil et al. (2010) published norms on the most frequently used composite scores (total & process scores): Total learning: a score which is the sum of the first five learning trials; Learning rate is reflected by subtracting Trial 1 from Trial 5. Proactive interference: results from subtracting List B scores from the Trial 1 score; Retroactive interference: results from subtracting Trial 7 scores from Trial 5 scores; Retention: produced by subtracting Trial 8 scores from Trial 5 scores; and Retrieval efficiency: by subtracting delayed recall score (Trial 8) from delayed recognition score (Trial 9).

Kaplan and colleagues (Kaplan, 1988) introduced the "Boston Process Approach" to neuropsychological assessment, emphasizing the importance of analyzing performance at the level of cognitive processes underlying each test, rather than the total scores of the test. The validity of these composite scores has been demonstrated on developmental data. Some of these measures (Total Learning and Corrected Total Learning scores) were found to be the most developmentally sensitive measures in both children's and adults' samples, as well as for gender (female more sensitive than male participants) (Karakaş et al., 2022; Vakil et al., 2010).

Factor analysis of the composite scores generated from the Rey AVLT, including total and process scores, could represent more accurately the orthogonal factors constructing the test, and the underlying memory and learning processes. Several factor analysis studies conducted on the Rey AVLT have been reported previously. However, in some of these studies, scores from other memory tests were added to the Rey AVLT scores for the analysis. Ryan et al. (1984) added to the factor analysis the Paired Associates and Logical Memory subtest scores from the Wechsler Memory Scale (WMS). Moses (1989) added to their analysis the scores of Benton's Visual Retention Test (BVRT). It is difficult to learn about the structure that comprises the Rey AVLT, from such studies that are included in their factor analysis scores from other memory tests.

Five factor analysis studies have exclusively utilized Rey AVLT scores. Vakil and Blachstein (1993) examined 146 healthy adults (19–46 years) and identified one-factor (memory), two-factor (Retention, learning), or three-factor models (Learning, Storage, & Retrieval), corresponding to information processing models (Ellis & Hunt, 1983; Huppert & Piercy, 1978). First, it should be noted that all scores that entered the factor analysis are only Rey AVLT total scores. Second, the age range is very limited (19–46), thus not including either children or older adults. Baños et al. (2005) studied 221 patients with spinal cord injury (15–83 years) and extracted three factors: General verbal learning, Auditory attention, and Inaccurate recall. The difficulty with this study is that 45.2% of their samples report loss of consciousness, suggesting brain injury involvement. Weitzner et al. (2020) analyzed 718 healthy individuals (16–85 years), identifying three factors: Memory, Attention/Learning, and Inaccurate memory. Dassanayake et al. (2020) employed a hybrid Rey AVLT/CVLT version (using semantically categorized words) with 561 adults (19–85 years), yielding a two-factor structure (Retention, Learning) similar to Vakil and Blachstein's model. Finally, Karakaş et al. (2022) conducted Confirmatory Factor Analysis with 600 adults (20–74 years), using composite scores, producing three factors: Learning, Retention, and Retrieval. Methodological limitations across studies include using primarily total scores, restricted age ranges excluding children, and sample characteristics potentially limiting generalizability.

Several studies conducted factor analysis on a similar multiple-trial word-list test, such as the California Verbal Learning Test (CVLT) (Donders, 2008; Delis et al., 1987, 1988). Notwithstanding the similarities between the Rey AVLT and the CVLT (e.g., multiple learning trials of a word list, interference list, delayed recall, and recognition) there are some significant differences between the tests (e.g., the words in the CVLT are semantically related, an additional trial of cued recall). Therefore, comparison of the results of these two tests should be made cautiously.

Prior to discussing the similarities and differences in the factors found across all five studies, it should be emphasized that there are two issues which make this comparison very challenging: First, the choice of scores extracted from the Rey-AVLT (e.g., total & process scores) to be included in the analysis, obviously has an effect on which factors would emerge. Secondly, different researchers might have used different terms to label similar factors or contracts. In three out of the five factor analysis studies (Dassanayake et al., 2020; Karakaş et al., 2022; Vakil & Blachstein, 1993) the process score of Learning rate, a Learning factor emerged have been used. In all five studies, when total scores of individual trials and/or of Total learning were entered, they formed an independent factor of Storage. Less consistency was noticed regarding the third factor. Dassanayake et al. (2020) found only two factors. Studies included errors in the analysis (e.g., repetitions, intrusions, phonetic and semantic false alarms in the recognition trial) (Baños et al., 2005; Karakaş et al., 2022; Weitzner et al., 2020). A third factor emerged combining recognition and errors. In the study by Vakil and Blachstein (1993), which did not include errors, the third factor was Retrieval, loaded by the recognition score.

The memory processes or model that we are attempting to determine whether it is captured by the Rey AVLT, are based on an information processing perspective, that distinguishes between a three-stage model of declarative memory (Ellis & Hunt, 1983; Huppert & Piercy, 1978; Squire, 1982; Wright et al., 2009). The first is Learning, or Acquisition, the stage that reflects the acquisition of the material learned. The second stage is Storage or Consolidation, in which information is stored and saved for the third stage – Retrieval. At this stage, the information is pulled up and becomes available to the person.

As reviewed above, there are a limited number of factor analysis studies with the Rey AVLT. Furthermore, in some of these studies, scores from other than the Rey AVLT were added to the analysis (e.g., Moses, 1989; Ryan et al., 1984). Another limitation observed in previous analyses is the relatively small sample size (e.g., Baños et al., 2005, n = 221; Vakil & Blachstein, 1993, n = 146) and limited age range. The small sample size limited the possibility of evaluating the changes in the cognitive structure of the Rey AVLT across the lifespan. In addition, most scores submitted to factor analysis in previous studies were primarily total scores.

In this study, factor analysis is conducted on a large normative sample of 1471 healthy individuals (Vakil & Blachstein, 1997; Vakil et al., 1998). This large sample size, covering the entire lifespan, enables us to compare the performance of five age cohorts: Young children (8–12 years, n = 503); middle childhood and adolescence (13–17, n = 440); young adulthood (20–29, n = 117); adulthood (30–59, n = 204); and old age (60–91, n = 207). Several studies have demonstrated a curvilinear trajectory (an inverted U-shape) across the lifespan of memory functioning. This is evident from normative studies on various memory tests, in which increased performance is observed until the age of 30, and then stability followed by a gradual but relatively slow decrease in performance until about the age of 60, followed by a more accelerated decrease in performance (e.g., Donders, 2008 re: CVLT; Blachstein & Vakil, 2016, Blachstein & Vakil, 2022; Vakil & Blachstein, 1997; Vakil et al., 1998, 2010 re: Rey AVLT). Donders (A, 2008) conducted a factor analysis on the CVLT II standardization sample. The authors noted that the factorial structure for the older group was less robust than in the two younger groups. This study highlights the importance of examining the effect of age on the test's structure. Delis et al. (2003) raised the difficulty of applying factor analysis findings conducted on a neurotypical population, to populations with memory impairments such as Alzheimer's disease. The researchers showed that factors that were stable in a normal population did not necessarily remain so in a population with brain pathology. Brain changes throughout the lifespan (i.e., brain maturation in the early stages and deterioration in the later stages) are well documented (Raz et al., 2005). Therefore, Delis et al.'s cautionary remark is also relevant when testing the entire lifespan, because the factors in one age cohort would not necessarily hold for a different age cohort. Thus, the question addressed by conducting factor analyses on the various age cohorts is whether in addition to the quantitative changes in memory observed across the lifespan, the relationship between the different cognitive processes underlying the test also changes or remains stable.

This study is also unique in the choice of scores derived from the Rey AVLT that were applied to the analysis. Unlike most of the previous studies that used primarily total scores of the Rey AVLT (Baños et al., 2005; Vakil & Blachstein, 1993; Weitzner et al., 2020), in the present study we used two total scores (Immediate memory & Total learning) and five process scores (Learning rate, Proactive and Retroactive interference, Retention, and Retrieval efficiency). Note, however, that the process scores could have been calculated as ratio scores rather than difference scores. For example, although Retrieval efficiency could be calculated as Delayed recall/Recognition rather than Recognition-Delayed recall, we chose the difference scores, to be consistent with the normative data of the composite scores previously published (Vakil et al., 2010). The only two total scores applied to the factor analysis are Immediate memory (Trial 1), which reflects immediate memory, and Total learning.

Numerous studies have demonstrated that the seven scores we selected for analysis were found to be highly sensitive to the effects of age on memory and for differential diagnosis between various neurological and psychological disorders. The Total learning score has been shown to predict cognitive decline risk (Andersson et al., 2006). Research demonstrates that the Learning rate score effectively distinguishes between patients diagnosed with Alzheimer's disease (AD) and those with Parkinson's disease (Tierney et al., 1994), as well as between AD and MCI (Zhu & Sun, 2024). The Retention score has proven valuable in identifying progression from individuals with subjective memory complaints to those with AD (Estévez-González et al., 2003). Studies show that Immediate memory combined with Total learning scores can distinguish between individuals with MCI and depression (Cankaya et al., 2024), identify MCI-to-dementia progression (Dawidowicz et al., 2021), differentiate between non-AD MCI and AD-MCI (Salvadori et al., 2024), distinguish between dementia, Subjective Cognitive Impairment, MCI, and healthy controls (Almkvist, 2025), and differentiate patients with schizophrenia from controls (Grimes et al., 2017). Furthermore, these two scores together with the Retention score effectively differentiate healthy elderly individuals from those with MCI/AD (Messinis et al., 2016). Finally, these three scores, along with Learning rate and Retrieval Efficiency, have been shown to predict decade-long MCI-to-dementia conversion (Dawidowicz et al., 2021).

We trust that analyzing the cognitive composition of the Rey AVLT with total and process scores, would have significant theoretical and clinical implications.

This study consists of three phases: In Phase I, the aim is to replicate and validate the stability of the previously identified factor structure derived from total scores Vakil and Blachstein (1993). The previous factor analysis study was conducted on a relatively small sample ($n = 146$) and with a limited age range (19–46 years). To this end, Exploratory Factor Analysis (EFA) was conducted on the entire sample ($n = 1471$) with wide age range of 8–91, on six frequently used total scores – the same scores originally used in the Vakil and Blachstein (1993) study, scores also commonly used in clinical settings (Lezak et al., 2012).

In Phase II, EFA was conducted on seven composite scores – five process scores and two total scores, applied on the entire sample. Although there is a theoretical basis for predicting a three factors model: Learning, Storage, and Retrieval (Ellis & Hunt, 1983; Huppert & Piercy, 1978; Squire, 1982; Wright et al., 2009), as also indicated in the previous EFA (Vakil & Blachstein, 1993), we decided to begin, as in Phase I, with EFA in order to examine which scores would load onto which factors. Only then did we proceed to Phase III where we conducted Confirmatory Factor Analysis (CFA) on each of the five age cohorts (8–12, 13–17, 20–29, 30–59, & 60–91), enabling the examination of the effect of age on the identified factor structures. Together, these three phases enable us to reveal the structure and interrelations between the various total and composite scores generated from the Rey AVLT. Furthermore, these analyses enable us to address the question: does this factorial structure remain constant across the lifespan?

Method

The entire sample

The data of the present study are taken from our published normative raw data of the Hebrew version of the Rey AVLT, for children (Vakil et al., 1998), adults (Vakil & Blachstein, 1997), and composite scores for children and adults (Vakil et al., 2010). It should be noted that although the adults' and children's norms were published in two separate papers, the test form of the Rey AVLT was identical in the two groups, which enabled the comparison of memory performance of the five age cohorts.

Participants

The children's data consisted of a sample of 943 children (487 boys and 456 girls), ranging from 8 to 17 years of age. The children's sample was recruited from 14 public schools in central Israel (i.e., the greater Tel-Aviv area). The normative sample was chosen from public schools in the middle range of a scale used by The Israeli Ministry of Education, by which all public schools are ranked. Furthermore, children who were identified by their teachers with exceptionally high or low academic achievement were not included. Also excluded were children diagnosed with learning disabilities, attention disorders, or those requiring special assistance in school. Also included in the sample were 124 children (63 boys and 61 girls) from different locations in the country that according to a preliminary analysis did not differ from the rest of their relative age group in the mean sample on any parameter and were merged into it. Hebrew was the native language for all the children in the sample.

The adults' data were collected from a sample of 528 participants (257 males and 271 females), ranging from 20 to 91 years old. All the adult participants were Israeli citizens for at least 10 years and spoke Hebrew fluently. All the participants were volunteers, most of them responded to advertisements placed at Bar-Ilan University (Israel). All the older adult participants, when tested, were alert and oriented to time and place. Based on self-report, participants with a history of learning disabilities, alcohol, drug abuse, or neurological or psychiatric illness were excluded (for more details about the participants, see Vakil et al., 1998; Vakil & Blachstein, 1997, for children and adult populations, respectively).

The entire sample is composed of 1471 participants (age, $M = 25.72$, $SD = 21.38$; education, $M = 8.82$, $SD = 4.33$). The sample included 744 males (age, $M = 24.84$, $SD = 20.65$; education, $M = 8.75$, $SD = 4.34$) and 727 females (age, $M = 26.81$, $SD = 22.09$; education, $M = 8.88$, $SD = 4.36$). Age and years of education were not significantly different between males and females ($F(1, 1470) = 2.53$, $p = .11$, $\eta^2 = .002$; $F(1, 1470) = .33$, $p = .56$, $\eta^2 = .001$, respectively). The Psychology Department of the Bar-Ilan University Institutional Review Board approved the project, and all participants volunteered for the experiment, and provided written informed consent.

Five age cohorts

Demographic characteristics of the five age group cohorts are presented in Table 1.

In these age cohorts, there is a similar ratio of males/females. Children's education is by age, while a significant difference was found for the mean years of education of the three adult groups $F(2, 525) = 11.93$, $p < .001$. A follow-up analysis using the Duncan procedure indicated that the two younger groups differed from the older group. A large proportion of the Israeli population arrived in the country as immigrants. Many of the older adults immigrated as children, and they had to interrupt their studies and go to work. Thus, for the older group, formal education does not reflect their potential education. Within the age groups, education did not differ by gender.

Tests and procedure

Children and adults participated voluntarily and were tested individually. The children were tested in a room allocated for this purpose in their own schools during school hours, and adults were tested either in their senior citizens' home in a room allocated for this purpose, or in the memory and amnesia laboratory at the university. The examiners in this project were 14 undergraduate psychology majors at Bar-Ilan University, who were trained to administer and score the tests. All participants were told that they could stop at any time if they wished to do so.

The Rey AVLT: The Hebrew version of the Rey AVLT was used (Vakil & Blachstein, 1997, 1998, 2010) translation from English word-for-word equivalents with minor adaptations. Administration was standard, as described by Lezak et al. (2012). It consisted of 15 common nouns, which were read to the participants at a rate of one word per second, in five consecutive trials (Trials 1 through 5); each reading was followed by a free recall task. In List B, an interference list of 15 new common nouns was presented, followed by a free recall of these new nouns. In Trial 7, without additional reading, the participants were again asked to recall the first list. Twenty minutes later, a delayed recall (Trial 8) was followed by delayed recognition (Trial 9). In this trial, participants were given a list of 50 words (15 from the first list, 15 from the second, and 20 new common nouns) and were asked to identify the 15 words of List A.

Phase I

Total scores analysis with entire sample (n = 1471)

To investigate the factorial structure of the Rey AVLT in the 1471 participant sample, six total scores were subjected to EFA using JASP software (version 0.16.1.0): Immediate memory (Trial 1), Best learning (Trial 5), Proactive interference score list B (Trial 6), Retroactive interference score list A (Trial 7), Delayed memory (Trial 8), and Recognition (trial 9). Two total scores were excluded from this analysis, Total learning score, to avoid a repeated representation of Trial 1 and Trial 5, and Temporal order score, since it is not frequently used.

Results and discussion

The dataset met the criteria for factor analysis, as indicated by Bartlett's test of sphericity $\chi2(15) = 4004.20$, $p < .001$. The maximum likelihood factor analysis with a cutoff point of .40 and Kaiser's criterion of eigenvalues greater than 1 (see Braeken & Van Assen, 2017) yielded a dominant single factor (eigenvalue = 3.372) accounting for 56.20% of the total variance. Despite the large sample size, this outcome of a single factor closely parallels the structure observed in our previous study (Vakil & Blachstein, 1993) suggesting a robust general memory factor when relying on total scores. As in the previous study, the scree plot (Cattell, 1966) indicated, after a first break, two minor components (eigenvalues = .87 & .73) and since our interest was mainly in the structure of the model, in line with the previous study, a three-factor solution was extracted using Equamax rotation, which accounted for 82.88% of the variance.

As presented in Table 2, it can be noted that the pattern of loadings across the three factors closely replicates the structure found in Vakil and Blachstein (1993). The first factor which contains Best learning,

Table 1. Means and *SD* of age and education stratified by age cohorts.

	Age group cohorts														
	8–12			13–17			20–29			30–59			60–91		
		Age	Educ		Age	Educ		Age	Educ		Age	Educ		Age	Educ
Male	*n* = 258	9.97 (1.38)	4.07 (1.37)	*n* = 229	14.98 (1.33)	8.99 (1.34)	*n* = 57	24.74 (2.65)	13.61 (1.57)	*n* = 108	42.72 (8.73)	13.34 (2.95)	*n* = 92	70.15 (7.08)	12.90 (3.48)
Female	*n* = 245	9.96 (1.39)	4.02 (1.37)	*n* = 211	14.97 (1.39)	8.99 (1.41)	*n* = 60	24.27 (2.40)	13.85 (1.54)	*n* = 96	44.63 (7.79)	14.05 (2.48)	*n* = 115	69.63 (7.57)	12.16 (3.12)
Total	*n* = 503	9.97 (1.38)	4.04 (1.37)	*n* = 440	14.97 (1.36)	8.99 (1.37)	*n* = 117	24.50 (2.52)	13.74 (1.55)	*n* = 204	43.62 (8.34)	13.68 (2.76)	*n* = 207	69.86 (7.34)	12.49 (3.30)

Table 2. Factor loadings for the three-factor solution from exploratory factor analysis of six total scores.

		Factor	
Score	Learning	Storage	Retrieval
Immediate Memory (Trial1)	0.74	0.12	0.32
Best Learning (Trial 5)	0.29	0.17	0.82
Proactive Interference (Trial 6)	0.88	0.09	0.14
Retroactive interference (Trial 7)	0.25	0.21	0.86
Delayed Memory (Trial 8)	0.26	0.23	0.86
Recognition (Trial 9)	0.10	0.98	0.17
% of total variance (rotated)	25.93%	18.49%	38.46%

Loadings > 0.4 are in bold.

Retroactive interference, and Delayed memory was referred to as Retrieval. The second factor which contains Immediate memory and Proactive interference was referred to as Learning/Short Term Memory, and the third factor, which contains Recognition, was referred to as the Storage factor. It is important to note that even within this expanded sample, when no rotational constraints were imposed, a single dominant factor emerged. Therefore, this result underscores the importance of investigating in Phase II whether, with the process scores, we can extract a more differentiated memory representation from a theoretical perspective that is also much more clinically useful.

Phase II

Process and total scores with entire sample analysis (n = 1471)

To investigate the factorial structure of the Rey AVLT in the 1471 participant sample, seven composite scores were subjected to EFA using JASP software (version 0.16.1.0). Five of the seven are process scores: Learning rate score computed as Trial 5 minus Trial 1, Proactive interference score computed as Trial 1 minus List B, Retroactive interference score computed as Trial 5 minus Trial 7, Retention score computed as Trial 5 minus Trial 8, and Retrieval efficiency score computed as Trial 9 minus Trial 8. The remaining two are total scores: Total learning score computed as the sum of Trials 1 through 5, and Immediate memory (Trial 1).

Results and discussion

Bartlett's test of sphericity $\chi2(21) = 5847.98$, $p < .001$, indicated that correlation structure is adequate for factor analyses. The maximum likelihood factor analysis with a cutoff point of .40 and the Kaiser's criterion of eigenvalues greater than 1 (see Braeken & Van Assen, 2017) yielded a three-factor solution as the best fit for the data, accounting for 72.2% of the variance, with two-factor and one-factor solutions accounting only for 27% and 51% of the variance, respectively. The three-factor analysis results indicate that the first factor accounted for 27% of the explained variance, followed by a second factor contributing 24%, and a third factor explaining 21% of the variance. According to the Scree test, this three-factor solution yielded eigenvalues above 1, suggesting a good model fit. The results of the factor analysis are presented in Figure 1 and factor loadings are presented in Table 3.

The first factor that contains the scores of Total learning and Immediate memory (both loaded positively), and Retrieval efficiency (loaded negatively), represent memory capacity, and can therefore be

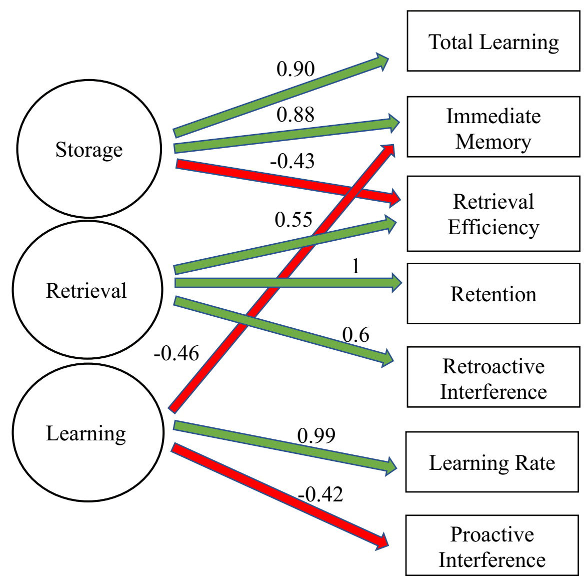

Figure 1. Path diagram of exploratory factor analysis of the entire sample ($n = 1474$). A green or red arrow represents a positive or negative relationship, respectively. Note: the factors in this figure are ordered according to the factors loading (i.e., Storage, Retrieval & Learning), whereas throughout the text and the tables, the factors are ordered according to an information processing approach (i.e., Learning, Storage & Retrieval).

Table 3. Factor loading from exploratory factor analysis of two total scores and five process scores.

		Factor	
Score	Learning	Storage	Retrieval
Immediate Memory	**−0.460**	**0.880**	0.092
Learning Rate	**0.991**	−0.080	0.084
Total Learning	0.130	**0.897**	0.191
Retrieval Efficiency	−0.257	**−0.428**	0.552
Proactive Interference	**−0.425**	0.294	0.007
Retention	0.103	−0.121	**0.997**
Retroactive Interference	0.175	−0.109	**0.598**

Loadings > 0.4 are in bold.

referred to as the Storage factor. From the theoretical perspective of information processing, this would be the second phase (as presented in the following tables). The second factor that contains the scores of Retention, Retrieval efficiency, and Retroactive interference (all loaded positively), can therefore be referred to as the Retrieval factor, which would be the third phase from an information processing perspective. The third factor that contains the scores of Learning rate (positively loaded), Proactive interference, and Immediate memory (Trial 1) (both loaded negatively), can therefore be referred to as the Learning factor, which would be the first phase from an information processing perspective.

We further evaluated the three-factor solution and the specific structure of each factor using oblique rotation (specifically, Promax). The results corroborated the factorial structure observed in the orthogonal analysis. Notably, both analyses yielded consistent outcomes, not only in terms of the number of factors but also in the composition of variables within each factor. This consistency across different rotation methods strengthens the reliability of our factor structure.

Phase III

Process and total scores with five age cohorts (8–12, 13–17, 20–29, 30–59, & 60–91)

Following the findings in Phase II in which we found that in the full sample analysis, a three-factor model provides a good explanation for the data. In this phase, the three-factor model was further examined with the same scores as in the previous phase, by using CFA in the five age cohorts. To examine whether the three-factor model that emerged in the analysis of the entire sample is stable over the age groups, we used the factor structure performed on the full sample (EFA), and performed CFA on each age group (8–12, 13–17, 20–29, 30–59, 60–91) separately (see Table 4).

Results and discussion

A good CFI fit of 0.84–0.96 was found across all age groups. In addition, both the Fit measures (Comparative Fit Index – CFI; Root Mean Square Error of Approximation – RMSEA; Parsimony Normed Fit Index – PNFI; Tucker-Lewis Index – TLI) and the factor loadings parameters were found to be similar across the age groups. The similarity in configural invariance regarding the factors structure, and metric invariance regarding the factor's loadings, indicates that the three-factor model is stable throughout the lifespan. In conclusion, we found that the three-factor model seems stable across the five age groups.

Factor scores across age groups

To examine whether any of the three-factor scores changes across ages, we calculated a factor score for each participant [for example: Storage = (z Total Learning * Total Learning factor loading) + (z Immediate memory * Immediate memory factor loading) + (z Retrieval Efficiency * Retrieval Efficiency factor loading)/3)]. Comparison between the five age groups of the three-factor score was analyzed using One-Way ANOVA. As presented in Figure 2, significant differences were found in the scores of the three factors throughout the five age groups [Storage ($F(4, 1470) = 66.3$, $p < 0.001$); Retrieval ($F(4, 1470) = 16.0$, $p < 0.001$); Learning ($F(4, 1470) = 5.8$, $p < 0.001$)]. The results indicate that the three-factor scores exhibit sensitivity to age-related changes, with the Storage factor

Table 4. Age group Confirmatory Factor Analysis.

Index	8–12, $n = 503$			13–17, $n = 440$			20–29, $n = 117$			30–59, $n = 204$			60–91, $n = 207$		
Baseline test [(df), $\chi 2$, p]	(9) 256.54*			(9) 152.50*			(9) 44.01*			(9) 44.38*			(9) 163.04*		
CFI	0.86			0.91			0.93			0.96			0.84		
RMSEA	0.23			0.19			0.18			0.14			0.29		
PNFI	0.37			0.39			0.39			0.41			0.36		
TLI	0.67			0.8			0.85			0.91			0.62		
Factor number	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Immediate Memory	−0.88	0.98		−0.79	0.78		−0.75	0.76		−0.72	0.59		−0.53	0.79	
Total Learning		1			1			1			1			1	
Learn	1			1			1			1			1		
Proactive interference	−0.63			−0.59			−0.38			−0.67			−0.47		
Retroactive Interference			0.46			0.39			0.27			0.64			0.44
Retention			1			1			1			1			1
Retrieval Efficiency		−0.56	0.38		−0.44	0.33		−0.44	0.49		−0.23	0.48		−0.37	0.35

Factor 1 = Learning, Factor 2 = Storage, Factor 3 = Retrieval.
*$p < 0.0001$.
CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation; PNFI = Parsimony Normed Fit Index; TLI = Tucker-Lewis Index.

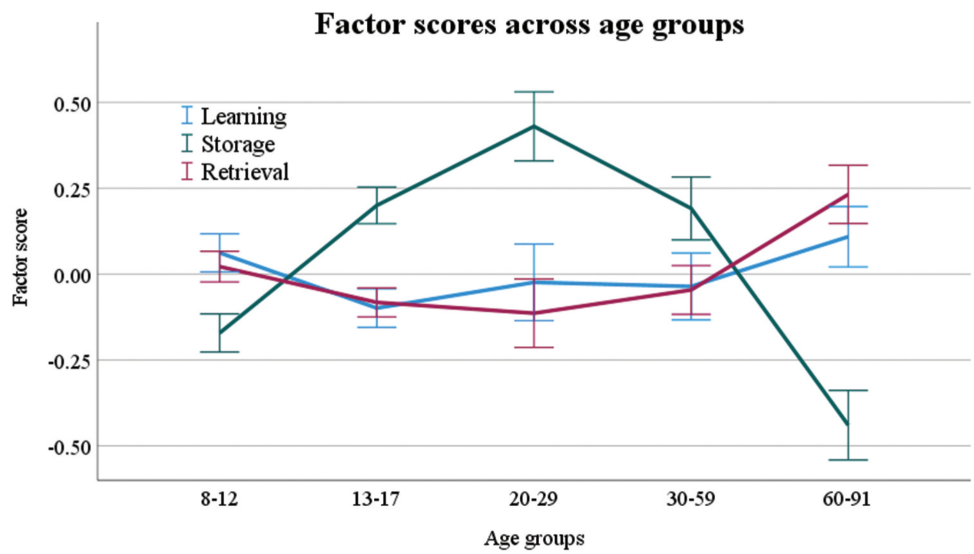

Figure 2. Mean and *SD* of the three factors scores (Storage, Retrieval, and learning.) across age groups (8–12, 13–18, 20–30, 30–60, 60–91).

demonstrating the highest degree of sensitivity. Moreover, the findings reveal that the quality of memory across the three factors varies across different age groups, while the fundamental factorial structure of memory remains stable across the lifespan.

General discussion

The Rey AVLT is frequently used as a learning and memory test (Butler et al., 1991; Rabin et al., 2016). The sensitivity of this test is probably because numerous measures could be generated from this test, tapping various learning and memory processes (Geffen et al., 1990; Vakil & Blachstein, 1997; Vakil et al., 1998). The challenge clinicians are facing, when trying to characterize the memory impairment of a population (e.g., patients with TBI, Parkinson's disease or Schizophrenia), is which memory processes are exactly reflected by each measure/score?

The purpose of this study was first to take this investigation a step further, by conducting EFA that would reveal the interrelations between the various scores, empirically indicating which ones tap a similar or different underlying memory process. The current study was conducted on a very large sample ($n = 1471$) with a wide age range (8–91), including seven scores that are commonly used clinically (two total scores and five process scores) derived only from the Rey AVLT.

The results of Phase I replicated the results of our previous factor analysis study (Vakil & Blachstein, 1993) which was conducted on a smaller sample and a more restricted age range. Six total scores were subjected to EFA yielded a dominant single memory factor accounting for 56.20% of the total variance. When a three-factor solution was extracted – Learning, Storage, and Retrieval, using Equamax rotation, 82.88% of the variance was accounted for.

In Phase II, three factors emerged from the EFA, which we labeled as Learning, Storage, and Retrieval. As described in the Introduction, this three-factor model is consistent with theoretical models presenting similar basic memory processes (Ellis & Hunt, 1983; Huppert & Piercy, 1978; Squire, 1982; Wright et al., 2009). The first factor is Learning, which is primarily composed of the Learning Rate score that reflects the difference between immediate memory and the number of words recalled following five learning trials (Trial 5). The second score is Proactive Interference, which is loaded negatively on this factor. This score reflects the difference between the number of words recalled on the first trial of the first list, and the number of words recalled on the second list (which followed five repeated learning trials of the first list). The finding that this score is negatively loaded suggests that smaller proactive interference is an indication of a better learning capacity. The third score also loaded on this factor is Immediate memory. The fact that this score is negatively loaded suggests that less words recalled on the first trial would be associated with a better learning rate. This could be viewed as an artifact, simply because if the number of words recalled on the first trial is low, there is a wider range for learning (up to 15 words), whereas if the number of words recalled on the first trial is high, then the additional words to be learned are limited, and this ceiling effect could mistakenly be interpreted as a low learning rate.

The second factor, Storage, is composed of Total learning (highest positively loaded eigen value), which reflects the number of words accumulated and retained across the five learning trials. The second score also positively loaded is Immediate memory, which reflects the number of words recalled in the first trial. Immediate memory could be viewed as the baseline of the storage on which more words will be acquired through the next four learning trials. The third score is Retrieval Efficiency, which is loaded negatively on this factor. It is not intuitively clear why this score is loaded on this factor. A possible explanation is that this score reflects the gap between delayed recall (Trial 8) and delayed recognition (Trial 9). Thus, the higher the score it would reflect a retrieval difficulty, because many words were not recalled, but were recognized. This is consistent with the finding that Retrieval efficiency is positively loaded on the Retrieval factor. However, on the storage factor, it is loaded negatively, suggesting that the lower the score, the more it reflects the actual storage capacity.

The third factor, Retrieval, is composed of the Retention score (highest loading), which reflects the difference between delayed retrieval, compared to number of words recalled prior to the delay. There is a need to clarify why the Retention score is loaded in the Retrieval factor. It appears that this score reflects an individual's ability to retrieve words after a delay, in comparison to the number of words retrieved prior to the delay. Retrieval Efficiency is also positively loaded, and the rationale for it being loaded on this factor is explained above. The third score loaded on this factor is Retroactive Interference, which is the cost of the interfering list expressed as the difference between number of words recalled prior to the interference (Trial 5) and the number of words following the interference (Trial 7). Thus, the higher score reflects more sensitivity to retroactive interference, indicating a retrieval difficulty as in the previous scores. Note, too, that in all three scores loading on this factor, the larger the number the more deficient is the performance (i.e., retrieval).

It is important to note that scores could be loaded on different factors as a function of the other scores that are submitted into the analysis. For example, Immediate memory score (Trial 1) loaded on Attention factor when submitted with Trial 6 (list B) (Baños et al., 2005; Donders, 2008; Weitzner et al., 2020), or Acquisition (Dassanayake et al., 2020) or "Learning and Memory" (Karakaş et al., 2022) as a function of the other total scores submitted. Similarly, Retention score (Trial 5 minus Trial 8) in the present study loaded on Retrieval, when submitted along with another delayed memory score (Trial 7-Trial 8), both loaded on the Retention factor (Karakaş et al., 2022).

The EFA on the entire sample confirmed the structure and the basic memory processes (Learning, Storage, & Retrieval) underlying the Rey AVLT and is consistent with the theoretical model we presented in the Introduction (Ellis & Hunt, 1983; Huppert & Piercy, 1978; Squire, 1982; Wright et al., 2009). These findings are consistent with previous factor analyses conducted on the Rey AVLT (Karakaş et al., 2022; Vakil & Blachstein, 1993).

When comparing the results of Phase I and those of Vakil and Blachstein (1993) which were based on total scores, to the results of Phase II, primarily based on process scores, it is interesting to note that the total scores under unconstrained rotation yielded a single factor. Only under constraining to a three-factorial model did Learning, Storage, and Retrieval emerge. In contrast, in Phase II, with the process scores and two total scores, the three-factorial model, Learning, Storage, and Retrieval emerged under unconstrained rotation. A possible interpretation for the difference between the Total scores (yielding primarily a single factor) and the Process scores (yielding primarily three factors) is that the latter are conceptually driven and calculated in a way that minimizes the dependence between the Total scores from which they are composed (e.g., the Learning rate score is calculated by subtracting Trial 1 from Trial 5). This in our opinion led to more differentiated factors when the process scores were submitted to EFA.

The question further addressed was whether despite the well documented fact that memory Learning functioning across the lifespan has a curvilinear trajectory (CVLT; Blachstein & Vakil, 2016, Donders, 2008re: 2022; Vakil & Blachstein, 1997; Vakil et al., 1998, 2010 re: Rey AVLT), this structure remains constant across the entire age range. To this end, CFA was conducted on five age cohorts (8–12, 13–17, 20–29, 30–59, and 60–91). The results showed that the three-factor model structure is stable throughout the lifespan and was found across all age groups. Given the rapid developmental changes' characteristic of childhood, which can influence the structure of factors differently, the youngest participant group was divided into two subgroups: 8–10 years and 11–12 years. CFA conducted separately for each subgroup revealed similar model fit indices, suggesting developmental stability of the constructs during this age range.

The CFI analysis across age groups reveals a distinctive developmental trajectory in the fit of the three-factor memory model throughout the lifespan. The model demonstrates moderate fit in childhood (CFI = .86 for ages 8–12), progressively improves through adolescence (CFI = .91 for ages 13–17) and young adulthood (CFI = .93 for ages 20–29), reaches peak fitness in middle adulthood

(CFI = .96 for ages 30–59), before showing a significant decline in older age (CFI = .84 for ages 60–91). These findings suggest that while the three-factor model of memory (Learning, Storage, and Retrieval) optimally characterizes cognitive functioning during adult years when performance is at its peak, it less accurately captures memory processes at the extremes of the age spectrum – in early childhood and in old age – when performance is at its lowest level. Therefore, we can conclude that although age affects the number of words recalled or recognized, age does not substantively affect the basic relations between the various components and memory processes measured by the Rey AVLT.

Another interesting finding is that while the fundamental factorial structure of memory remains stable across the lifespan, the three-factor scores exhibit sensitivity to age-related changes, with the Storage factor demonstrating the highest degree of sensitivity (see Figure 2). Thus, in addition to the theoretical implications of this finding, the clinical implications are that the interpretation of profile of results on the Rey AVLT, could remain the same across the lifespan, while the factor scores (primarily that of Storage) are sensitive to age change. Furthermore, a deviation from the robust finding of the factors underlying the Rey AVLT could by itself serve as a sensitive indication of an impairment or pathology. Therefore, it is recommended to replicate these factor analyses in the various populations in which their performance on the Rey AVLT was found to be impaired. A selective impairment in a particular factor could better characterize the impairment of that population, whether it is a learning, storage, or retrieval deficit. An additional recommendation for future research is to conduct a separate factor analysis across life span with total scores and compare the results to the factor analyses utilizing the process scores. Such a comparison could offer an insight into the diagnostical value of the different types of memory scores derived from the Rey-AVLT. Similarly, previous normative studies reported that the performance of females was superior to that of males across all age groups (Vakil & Blachstein, 1997; Vakil et al., 1998). It would be interesting to investigate in future studies whether there are influences with different factor structure effects.

In conclusion, this study has major theoretical as well as clinical/diagnostical implications. On a theoretical level, this study confirmed that underlying the Rey AVLT there are three distinct memory and learning processes: Learning, Storage, and Retrieval. These factors are consistent with theoretical models of memory in terms of information processing (Ellis & Hunt, 1983; Huppert & Piercy, 1978; Squire, 1982). Furthermore, these underlying processes remain constant across the entire age range, from 8 to 91 years old. However, the factor scores are sensitive to age, primarily the Storage factor. On a clinical level, the current results could lead the diagnostician to a conceptually driven diagnosis, to pinpoint the exact memory process (i.e., Learning, Storage, or Retrieval) impaired or preserved based on the constellation of the various Rey AVLT scores, according to the factor on which they are loaded. A practical method could be to focus on the composite scores, mostly representing the factor with the highest loading. For example, looking at the Learning Rate score as the best representative of Learning, the Total Learning score as the best representative of Storage, and the Retention score as the best representative of Retrieval. Finally, generalization from these findings to populations with memory impairment should be done cautiously, as previously demonstrated by Delis et al. (2003).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Farber Alzheimer's Center Foundation. This sponsor had no role in writing the review or in making the decision to submit the article for publication.

References

Almkvist, O., Rennie, A., Westman, E., Wallert, J., & Ekman, U. (2025). Methods for assessment of Rey auditory verbal learning test performance in memory clinic patients and healthy adults-at the cross-roads of learning theory and clinical utility. *The Clinical Neuropsychologist*, *39*(2), 424–438. https://doi.org/10.1080/13854046.2024.2384616

Andersson, C., Lindau, M., Almkvist, O., Engfeldt, P., Johansson, S. E., & Eriksdotter Jönhagen, M. (2006). Identifying patients at high and low risk of cognitive decline using Rey auditory verbal learning test among middle-aged memory clinic outpatients. *Dementia and Geriatric Cognitive Disorders*, *21*(4), 251–259. https://doi.org/10.1159/000091398

Baños, J. H., Elliott, T. R., & Schmitt, M. (2005). Factor structure of the Rey auditory verbal learning test in adults with spinal cord injury. *Rehabilitation Psychology*, *50*(4), 375–380.. https://doi.org/10.1037/0090-5550.50.4.375

Blachstein, H., & Vakil, E. (2016). Verbal learning across the life span: An analysis of the components of the learning curve. *Aging, Neuropsychology & Cognition*, *23*(2), 133–153. https://doi.org/10.1080/13825585.2015.1063579

Blachstein, H., & Vakil, E. (2022). Life span strategy implementation in verbal learning: Size and type of cluster adoption. *Aging, Neuropsychology & Cognition*, *29*(6), 965–984.. https://doi.org/10.1080/13825585.2021.1946472

Blachstein, H., Vakil, E., & Hoofien, D. (1993). Impaired learning in patients with closed-head injuries: An analysis

of components of the acquisition process. *Neuropsychology*, *7*(4), 530–535. https://doi.org/10.1037/0894-4105.7.4.530
Braeken, J., & Van Assen, M. A. (2017). An empirical Kaiser criterion. *Psychological Methods*, *22*(3), 450–466. https://doi.org/10.1037/met0000074
Burke, M. D., & Light, L. L. (1981). Memory and aging: The role of retrieval process. *Psychological Bulletin*, *90*(3), 513–546. https://doi.org/10.1037/0033-2909.90.3.513
Butler, M., Retzlaff, P. D., & Vanderploeg, R. (1991). Neuropsychological test usage. *Professional Psychology, Research and Practice*, *22*(6), 510–512.. https://doi.org/10.1037/0735-7028.22.6.510
Cankaya, S., Yalciner, B., Yilmaz, M. K., & Yulug, B. (2024). Differentiating MCI from depression through verbal memory scores. *Alzheimer's & Dementia: Translational Research & Clinical Interventions*, *10*(1), e12448. https://doi.org/10.1002/trc2.12448
Cattell, R. B. (1966). The scree test for the number of factors. *Multivariafe Behavioral Research*, 1,245–276.
Dassanayake, T. L., Hewawasam, C., Baminiwatta, A., Samarasekara, N., & Ariyasinghe, D. I. (2020). Sex-, age-and education-adjusted norms for the WHO/UCLA version of the Rey auditory verbal learning test for Sinhala-speaking Sri Lankan adults. *The Clinical Neuropsychologist*, *34*(sup1), 127–142.. https://doi.org/10.1080/13854046.2020.1829069
Dawidowicz, L., Ash, L., Korczyn, E., D, A., Andelman, F., Levy, S., & Elkana, O. (2021). Can the RAVLT predict deterioration from MCI to dementia? Data from long term follow up. *Experimental Aging Research*, *47*(4), 347–356.. https://doi.org/10.1080/0361073X.2021.1898182
Delis, D. C., Freeland, J., Kramer, J. H., & Kaplan, E. (1988). Integrating clinical assessment with cognitive neuroscience: Construct validation of the California Verbal Learning Test. *Journal of Consulting & Clinical Psychology*, *56*(1), 123–130.. https://doi.org/10.1037/0022-006X.56.1.123
Delis, D. C., Jacobson, M., Bondi, M. W., Hamilton, J. M., & Salmon, D. P. (2003). The myth of testing construct validity using factor analysis or correlations with normal or mixed clinical populations: Lessons from memory assessment. *Journal of the International Neuropsychological Society*, *9*(6), 936–946. https://doi.org/10.1017/S1355617703960139
Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *California verbal learning test research edition manual*. The Psychological Corporation.
Donders, J. A (2008). Confirmatory factor analysis of the California verbal learning test-second edition (CVLT-II) in the standardization sample. *Assessment*, *15*(2), 123–131. [PubMed: 18187398] https://doi.org/10.1177/1073191107310926
Ellis, H. C., & Hunt, R. R. (1983). *Fundamentals of human memory and cognition*. Wm. C. Brown Publishers, c 1989.
Estévez-González, A., Kulisevsky, J., Boltes, A., Otermín, P., & García-Sánchez, C. (2003). Rey verbal learning test is a useful tool for differential diagnosis in the preclinical phase of Alzheimer's disease: Comparison with mild cognitive impairment and normal aging. *International Journal of Geriatric Psychiatry*, *18*(11), 1021–1028.. https://doi.org/10.1002/gps.1010
Fernaeus, S. E., Östberg, P., Wahlund, L. O., & Hellström, Å. (2014). Memory factors in Rey AVLT: Implications for early staging of cognitive decline. *Scandinavian Journal of Psychology*, *55*(6), 546–553.. https://doi.org/10.1111/sjop.12157
Geffen, G., Moar, K. J., O'hanlon, A. P., Clark, C. R., & Geffen, L. B. (1990). Performance measures of 16-to 86-year-old males and females on the auditory verbal learning test. *The Clinical Neuropsychologist*, *4*(1), 45–63.. https://doi.org/10.1080/13854049008401496
Grimes, K. M., Zanjani, A., & Zakzanis, K. K. (2017). Memory impairment and the mediating role of task difficulty in patients with schizophrenia. *Psychiatry and Clinical Neurosciences*, *71*(9), 600–611. https://doi.org/10.1111/pcn.12520
Günther, T., Holtkamp, K., Jolles, J., Herpertz-Dahlmann, B., & Konrad, K. (2004). Verbal memory and aspects of attentional control in children and adolescents with anxiety disorders or depressive disorders. *Journal of Affective Disorders*, *82*(2), 265–269. https://doi.org/10.1016/j.jad.2003.11.004
Huppert, F. A., & Piercy, M. (1978). Dissociation between learning and remembering in organic amnesia. *Nature*, *275*(5678), 317–318. https://doi.org/10.1038/275317a0
Kaplan, E. (1988). A process approach to neuropsychological assessment. In T. Boll & B. K. Bryant (Eds.), *Clinical neuropsychology and brain function: Research, measurement, and practice*. American Psychological Association, 129–167.
Karakaş, S., Erdoğan Bakar, E., Doğutepe, E., Can, H., & Kaskatı, T. (2022). Differentiation of memory processing stages and effect of demographic variables with alternative scoring approaches to the Rey auditory verbal learning test. *Journal of Clinical and Experimental Neuropsychology*, *44*(2), 109–133. https://doi.org/10.1080/13803395.2022.2080186
Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (2012). *Neuropsychological assessment* (5th ed.). Oxford University Press.
Light, L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review in Psychology*, *42*(1), 333–376. https://doi.org/10.1146/annurev.ps.42.020191.002001
Messinis, L., Nasios, G., Mougias, A., Politis, A., Zampakis, P., Tsiamaki, E., Malefaki, S., Gourzis, P., & Papathanasopoulos, P. (2016). Age and education adjusted normative data and discriminative validity for Rey's auditory verbal learning test in the elderly Greek population. *Journal of Clinical and Experimental Neuropsychology*, *38*(1), 23–39. https://doi.org/10.1080/13803395.2015.1085496
Moses, J. A. (1989). Replicated factor structure of Benton's tests of visual retention, visual construction and visual form discrimination. *International Journal of Clinical Neuropsychology*, *11*(1), 30–37.
Rabin, L. A., Paolillo, E., & Barr, W. B. (2016). Stability in test-usage practices of clinical neuropsychologists in the United States and Canada over a 10-year period: A follow-up survey of INS and NAN members. *Archives of Clinical Neuropsychology*, *31*(3), 206–230. https://doi.org/10.1093/arclin/acw007
Raz, N., Lindenberger, U., Rodrigue, K. M., Kennedy, K. M., Head, D., Williamson, A., Dahle, C., Gerstorf, D., & Acker, J. D. (2005). Regional brain changes in aging healthy adults: General trends, individual differences and modifiers. *Cerebral Cortex*, *15*(11), 1676–1689. https://doi.org/10.1093/cercor/bhi044
Rey, A. (1964). *L'examen clinique en psychologie*. Presses Universitaires de France.

Ryan, J. J., Rosenberg, S. J., & Mittenberg, W. (1984). Factor analysis of the Rey auditory verbal learning test. *International Journal of Clinical Neuropsychology*, *6*, 239–341.

Salvadori, N., Torrigiani, E. G., Paoletti, F. P., Chipi, E., Montanucci, C., Verderosa, C., Parnetti, L., Fruttini, D., & Parnetti, L. (2024). Predictive value for cerebrospinal fluid Alzheimer's disease profile of different measures of verbal episodic memory in patients with MCI. *Scientific Reports*, *14*(1), 12235. https://doi.org/10.1038/s41598-024-62604-z

Siciliano, M., De Micco, R., Trojano, L., De Stefano, M., Baiano, C., Passaniti, C., De Mase, A., Russo, A., Tedeschi, G., & Tessitore, A. (2017). Cognitive impairment is associated with Hoehn and Yahr stages in early, de novo Parkinson disease patients. *Parkinsonism & Related Disorders*, *41*, 86–91. https://doi.org/10.1016/j.parkreldis.2017.05.020

Silberg, T., Ahonniska-Assa, J., Levav, M., Eliyahu, R., Peleg-Pilowsky, T., Brezner, A., & Vakil, E. (2016). The effect of age-at-testing on verbal memory among children following severe traumatic brain injury. *Child Neuropsychology a Journal on Normal & Abnormal Development in Childhood & Adolescence*, *22*(5), 600–617. https://doi.org/10.1080/09297049.2015.1028348

Squire, L. R. (1982). The neuropsychology of human memory. *Annual Review of Neuroscience*, *5*(1), 241–273. https://doi.org/10.1146/annurev.ne.05.030182.001325

Tierney, M. C., Nores, A., Snow, W. G., Fisher, R. H., Zorzitto, M. L., & Reid, D. W. (1994). Use of the Rey auditory verbal learning test in differentiating normal aging from Alzheimer's and Parkinson's dementia. *Psychological Assessment*, *6*(2), 129–134. https://doi.org/10.1037/1040-3590.6.2.129

Vakil, E., & Blachstein, H. (1993). Rey auditory verbal learning test: Structure analysis. *Journal of Clinical Psychology*, *49*(6), 883–890. https://doi.org/10.1002/1097-4679(199311)49:6<883::AID-JCLP2270490616>3.0.CO;2-6

Vakil, E., & Blachstein, H. (1997). Rey AVLT: Developmental norms for adults and the sensitivity of different memory measures to age. *The Clinical Neuropsychologist*, *11*(4), 356–369. https://doi.org/10.1080/13854049708400464

Vakil, E., Blachstein, H., & Sheinman, M. (1998). Rey AVLT: Developmental norms for children and the sensitivity of different memory measures to age. *Child Neuropsychology*, *4*(3), 161–177. https://doi.org/10.1076/chin.4.3.161.3173

Vakil, E., Blachstein, H., Wertman-Elad, R., & Greenstein, Y. (2012). Verbal learning and memory as measured by the Rey-auditory verbal learning test: ADHD with and without learning disabilities. *Child Neuropsychology*, *18*(5), 449–466. https://doi.org/10.1080/09297049.2011.613816

Vakil, E., Greenstein, Y., & Blachstein, H. (2010). Normative data for composite scores for children and adults derived from the Rey auditory verbal learning test. *The Clinical Neuropsychologist*, *24*(4), 662–677. https://doi.org/10.1080/13854040903493522

Weitzner, D. S., Pugh, E. A., Calamia, M., & Roye, S. (2020). Examining the factor structure of the Rey auditory verbal learning test in individuals across the life span. *Journal of Clinical and Experimental Neuropsychology*, *42*(4), 406–414. https://doi.org/10.1080/13803395.2020.1741517

Wright, M. J., Woo, E., Schmitter-Edgecombe, M., Hinkin, C. H., Miller, E. N., & Gooding, A. L. (2009). The item-specific deficit approach to evaluating verbal memory dysfunction: Rationale, psychometrics, and application. *Journal of Clinical and Experimental Neuropsychology*, *31*(7), 790–802. https://doi.org/10.1080/13803390802508918

Zhu, W. H., & Sun, Z. G. (2024). Process approach in memory assessment of patients with Alzheimer's disease and mild cognitive impairment: A review. *zhongguo yi xue ke xue yuan xue bao. Acta Academiae Medicinae Sinicae*, *46*(2), 242–246. https://doi.org/10.3881/j.issn.1000-503X.15574