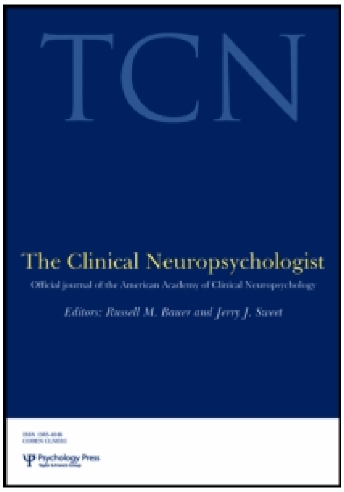

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NORMATIVE DATA FOR COMPOSITE SCORES FOR CHILDREN AND ADULTS DERIVED FROM THE REY AUDITORY VERBAL LEARNING TEST

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Norms on seven composite scores derived from the Rey Auditory Verbal Learning Test (AVLT) are reported here. These scores reflect a variety of verbal memory processes: learning, interference, retention over time, and retrieval efficiency. The norms are based on 943 children ranging in age from 8 to 17 years, divided into 10 age cohorts, and 528 adults, ranging in age from 21 to 91 years, divided into 6 age cohorts. Overall, the learning measures were the most sensitive to age. The most significant changes in memory as measured with these composite scores took place in the very young and very old age groups. These changes may be attributable to frontal lobe maturation in youth and deterioration in old age. Female participants show superiority over male participants on various verbal memory measures. These norms on the composite scores are primarily expected to serve the clinician in the process of memory assessment by supplementing the existing norms on individual trials of the Rey AVLT.

Keywords: Verbal memory; Rey AVLT; Developmental norms.

INTRODUCTION

Learning and memory processes are frequently compromised in a wide range of acquired and developmental insults to the central nervous system; therefore their evaluation is central in any neuropsychological assessment. Several tests are currently used in neuropsychology, measuring various aspects of learning and memory. Some of the tests such as the California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan, & Ober, 1994), the Rey Auditory Verbal Learning Test, (AVLT) (Rey, 1964), and the Buschke Selective Reminding Test (Buschke & Fuld, 1974) use word lists with several learning trials, and test recall at different time intervals. The use of word lists (as opposed to story recall) enables the assessment of memory with limited/reduced effects of associations or context (Lezak, Howieson, & Loring, 2004). Furthermore, since these tests are supra-span tasks, assessment

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of organizational and encoding strategies is possible (Helms, 2000). Repeated presentations of word lists and their successive testing at various time intervals allow the analysis of different learning process components, such as acquisition, retention, retrieval, and interference (Ivnik et al., 1992).

The Rey AVLT (Rey, 1964) is a word-list multiple-trials test frequently used in neuropsychological batteries. This test is differentially sensitive to the effects of age and gender (Vakil, Blachstein, & Sheinman, 1998), intelligence (Bolla-Wilson, & Bleecker, 1986), psychiatric condition (Addington, van Mastrigt, & Addington, 2003), and brain trauma (Vakil, Blachstein, Rochberg, & Vardi, 2004). One of the advantages of the Rey AVLT is that a variety of verbal memory measures may be derived from it. The simultaneous comparison of performance on several measures allows for a more comprehensive characterization of verbal memory than with a single measure.

The Rey AVLT procedure consists of five learning trials of the same word list followed by an interference list (Trial 6). In Trial 7 the participant is asked to recall the first list again. After a delay, participants are once more asked to recall the first list (Trial 8) followed by a recognition task (Trial 9).

In neuropsychological assessment an attempt is made to analyze performance at the level of the cognitive processes underlying each test (Kaplan, 1988). As mentioned above, one of the advantages of the Rey AVLT is that several such cognitive processes can be extracted from it. However, scores of individual trials do not necessarily reflect a ‘‘pure’’ cognitive process. The isolation of a discrete cognitive process is not a trivial challenge, and requires further analysis. One way of addressing this challenge is by computing a composite score from several trials in order to extract a purer index of a particular cognitive process. It should be noted that some composite scores cannot be considered as reflecting a ‘‘pure’’ process, but rather aggregate several trials presumably sharing a similar process (e.g., see later ‘‘Total Learning’’ score). Composite scores reflecting a range of verbal memory processes extracted from the Rey AVLT have been reported previously in the literature, some as normative data and some as scores used in a particular study to distinguish between different patient groups (see below).

ACQUISITION/LEARNING MEASURES

The Rey AVLT provides a unique opportunity to assess the process of acquisition. Several composite scores have been reported in the literature to measure the learning process based on the first five learning trials of the Rey AVLT.

Total learning

The total number of words recalled over the first five trials reflects the individual's ability to accumulate words across repeated learning trials. This score is obtained by adding up all five trials of List A (Strauss, Sherman, & Spreen, 2006; Vakil & Blachstein, 1997). Norms for this measure were previously published for children and adults. However, unlike the present study that covers a broad age range (8–91) for both genders, each of the previous studies covered only a segment of this age range (Crossen & Wiens, 1994; Forrester & Geffen, 1991; Geffen, Butterworth, & Geffen, 1994; Geffen, Moar, O'Hanlon, Clark, & Geffen, 1990; Ivnik et al., 1990; Nielsen, Knudsen, & Daugbjerg, 1989; Ryan, Geisser, Randall, & Georgemiller, 1986; Schmidt, 1996; Van den Burg & Kingma, 1999; Wiens, McMinn, & Crossen, 1988). (Note that the present norms of this measure, for adults only, were previously cited in Strauss et al., 2006, p. 801). Total learning on the Rey AVLT was found to be deficient in a variety of patient groups (Atchison et al., 2004, for traumatic brain injury; Katai, Maruyama, Hashimoto, & Ikeda, 2003, for Parkinson's disease; Nordlund et al., 2007, for Alzheimer's disease and mild cognitive impairment, MCI).

Corrected total learning

Ivnik et al. (1992) have suggested a modification of the Total Learning score described above. Their claim is that, in order to get an uncontaminated estimate of the individual's actual improvement over trials, it is important not only to correct for the initial memory span, but to correct it for *all* five learning trials. The formula suggested by them is: The total number of words recalled in the five learning trials minus five times the number of words recalled in the first trial. Norms for this index were published by Ivnik et al. (1990) for ages 55–97. To the best of our knowledge, no study comparing clinical groups on this measure has been published.

Learning rate

This measure involves subtracting the first learning trial from the number of words recalled in the fifth learning trial, which is usually also the best learning trial. This score parsimoniously reflects the learning rate unconfounded by immediate learning. The most commonly used computational method is the aforementioned Trial 5 minus Trial 1 (Helms, 2000; Lezak et al., 2004; Mitrushina, Boone, Razani, & D'Elia, 2005; Vakil & Blachstein, 1993; Vakil et al., 1998). An alternative method is dividing Trial 5 by Trial 1 (Vakil & Blachstein, 1997).

The only normative data published were for the first measure (Trial 5 minus Trial 1). Norms were published in different studies with an overall spread of ages ranging from 19 to 85 years old (Cohen, personal communication, cited in Mitrushina et al., 2005, p. 845; Mitrushina, Satz, Chervinsky, & D'Elia, 1991; Query & Megran, 1983; Wiens et al., 1988). The Learning Rate score might be very informative, since patients with MCI (Bröder, Herwig, Teipel, & Fast, 2008) and aging individuals (Henkel, 2008) show slower rate of learning and improvement in tasks of memory and repeated learning.

INTERFERENCE MEASURES

In memory tasks with several presentations, reduced performance may be caused by various types of interference. Assessment of memory interference is very important, since it is common among diverse age groups and clinical syndromes. Children who are learning-disabled and have attention deficit hyperactivity (ADHD) display sensitivity to distraction, and interference and intrusions during various tasks (Palladino, 2006; Patton & Offenbach, 1978). Patients suffering from multiple sclerosis also show increased sensitivity to memory interference (Thornton & Raz, 1997). Two interference measures can be extracted from the Rey AVLT: proactive and retroactive.

Proactive interference

This interference occurs when previously learned material negatively affects the acquisition or recall of new information (Hedden & Park, 2001; Vakil, 2005). On the Rey AVLT it is expressed as impaired learning of a new list (List B Trial 6) after an earlier learning of List A. This measure can be obtained by comparing Trial 6 to the first learning trial (Trial 1), either Trial 6 minus Trial 1 (Helms, 2000; Strauss et al., 2006), or Trial 1 minus Trial 6 (Lezak et al., 2004; Vakil & Blachstein, 1997). It is also possible to divide Trial 6 by Trial 1 or vice versa (Vakil & Blachstein, 1997). Such difference or ratio scores provide a measure of the net effect of proactive interference. Normative data have not been yet published on this score.

Age and brain trauma affect the individual's susceptibility to proactive interference, which declines during middle childhood and early adolescence (Kail, 2002), and increases again in old age (Ikier, Yang, & Hasher, 2008). Patients with frontal lobe lesions show heightened susceptibility to proactive interference and intrusions on memory tests (Turner, Cipolotti, Yousry, & Shallice, 2007).

Retroactive interference

This interference occurs when subsequent material negatively affects the recall of previously learned material (Hedden & Park, 2001). On the Rey AVLT it is measured by the recall of List A (Trial 7) after learning the distractor list, List B (Trial 6). This measure can be obtained by comparing Trial 7 and Trial 5 (Trial 7 minus Trial 5 or vice versa) (Vakil & Blachstein, 1997). This comparison provides information regarding interference effects comparing recall before (Trial 5) and after exposure to the distracting list (Trial 7). No normative data were presented.

DELAYED MEASURES (RETENTION/FORGETTING MEASURES)

Forgetting rate and retention

The Rey AVLT allows for the assessment of long-term retention and forgetting rate, by testing the recall of List A after a 20-minute delay interval. A more accurate estimate of retention and forgetting can be obtained by comparing this delayed recall (List A Trial 8) with the last learning trial or the best learning trial. Several measures have been proposed to reflect the forgetting rate. Strauss et al. (2006) used Trial 8 minus Trial 5, while others have used Trial 8 divided by Trial 5 (Helms, 2000; Vakil & Blachstein, 1997); or Trial 5 minus Trial 8 (Vakil & Blachstein, 1997). Alternatively, delayed recall may be compared to the last recall trial (List A Trial 7): Trial 8 minus Trial 7 (Mitrushina et al., 2005) or Trial 8 divided by Trial 7 (Forrester & Geffen, 1991). All these scores represent the amount of material retained over a 20-minute interval, taking into account the final learning of the individual prior to the delay. No normative data for these measures have been published. Long-term retention has been found to be deficient in various disorders (as measured by Trial 8) (Gainotti, Marra, & Villa, 2001, for MCI and Alzheimer's disease; Günther, Holtkampa, Jolles, Herpertz-Dahlmanna, & Konrad, 2004, for depression; Katai et al., 2003, for Parkinson's disease).

RECOGNITION AND RETRIEVAL MEASURES

Retrieval efficiency

As noted above, in memory assessment it is extremely important to separate encoding/storage failures from retrieval failures. The latter can be obtained by comparing recognition (List A Trial 9) with the last learning trial (Trial 5) or with the last recall trial (Trial 8). Difference or ratio scores can be computed (Vakil & Blachstein, 1997; Vakil et al., 2004). No normative data have been published for either of these retrieval measures. Retrieval difficulties are common among several diagnostic groups (Bröder et al., 2008, for MCI; Gainotti et al., 2001, for Alzheimer's disease; Thornton & Raz, 1997, for MS; Turner et al., 2007, for frontal lobe damage; Vakil et al., 2004, for children with head trauma).

THE PRESENT STUDY

The primary purpose of the present study is to serve the clinician by presenting norms of the major composite measures of the Rey AVLT discussed earlier, covering in the same framework a broad age range (8–91 years). It is our expectation that such norms will assist the clinician in the assessment of verbal memory, reporting performance in terms of impaired or preserved memory processes. In addition, some of the measures might help the clinician in formulating a more refined diagnosis. As mentioned above, several memory processes are especially deficient in certain disorders. It is also of interest to determine whether some of these measures are more sensitive than others to age and developmental changes.

In our previous reports (e.g., Vakil & Blachstein, 1997), we found no advantage of ratio scores over difference scores in differentiating age groups. In addition, difference scores are more intuitively understood than ratio scores. Therefore we have decided in the present study to present only the more frequently used difference scores.

METHOD

The data analyzed in the present study are the normative children's and adults' Rey AVLT data published by Vakil et al. (1998) and Vakil and Blachstein (1997).

Participants

The children's data were collected from a sample of 943 children (487 boys and 456 girls). The age range of the sample population was 8 to 17 years, divided into 10 age cohorts. The children's sample for the study was recruited from a population of children in 14 public schools in central Israel (i.e., the greater Tel Aviv area). The Israeli Ministry of Education uses a scale by which all public schools are ranked according to five criteria: parents' income, parents' education, family size, proportion of immigrants in the school, and distance from a major city. The children participating in the normative study were from public schools ranked in the middle range of this scale. Children diagnosed with learning disabilities or attentional deficit disorder, were excluded from the sample. Also, teachers were asked not to refer children with exceptionally high or low academic achievement. All children were tested within a range of 3 months before or after their birthday. Hebrew is the native language of all the children in the sample. The total of about 100 children in each age group consisted of about 20 children from four to six different schools.

An additional 124 children (63 boys and 61 girls) in the same age groups from different parts of the country were tested on a voluntary basis, fulfilling the same selection criteria as the former group. Based on a preliminary analysis, since this group did not differ from the rest of the sample on any parameters, the two samples were merged. For more details about the participants, see Vakil et al. (1998).

The adult data were collected from a sample of 528 participants (257 men and 271 women). The age range of the sample population was 21 to 91 years, divided into six age cohorts (of 10 years each), with the exception of the oldest group, which included participants between the ages of 70 and 91 years. Mean education, as measured by years of schooling, was 13.73, 14.25, 13.42, 13.42, 12.62, and 12.55, respectively for the six age cohorts. The educational difference between the groups reached significance, $F(5, 527) = 4.99$, $p < .001$. Follow-up analysis indicates that the difference between the youngest adult groups (mean years of education = 13.99) and the oldest groups (12.58) is the source of the significant difference. This is probably due to the fact that many of the elderly were immigrants and in those days did not have an opportunity to receive higher education. Thus, in this case, it is reasonable to assume that it does not necessarily reflect lower cognitive abilities. As reported in our original adult norms paper (Vakil et al., 1997, p. 358): "All participants met the criteria for living in Israel for at least 10 years, and spoke Hebrew fluently. In fact, most of the participants lived in the country much longer than 10 years." The younger participants were volunteers who responded to advertisements placed at Bar Ilan University (Israel) and other public places. The older participants were recruited either from among students attending a special lecture series for elderly people offered at Bar Ilan University, or from several senior citizens' community centers, serving the population in the central region of Israel. The senior citizens participants were referred by social workers who judged them as non-demented, and as active and independent, cooperative, and communicative. All of the elderly participants were alert and oriented to time and place when tested. Based on their own report they were in good health, and none of them had a history of alcohol, drug abuse, or neurological or psychiatric illness (for more details see Vakil & Blachstein, 1997). In both child and adult samples the majority of the participants cooperated fully, and the number of drop-outs was negligible.

Tests and procedure

The Rey AVLT. The Hebrew version of the Rey AVLT was used (Vakil et al., 1998). Administration was standard, as described by Lezak et al. (2004). The test consists of 15 common nouns, which were read to the participants at the rate of one word per second, in five consecutive trials (Trials 1 through 5); each reading was followed by a free recall task. In trial 6 an interference list of 15 new common nouns was presented, followed by free recall of these new nouns. In Trial 7, without an additional reading, participants were again asked to recall the first list. Twenty minutes later, and again without an additional reading, participants were once again asked to recall the first list (Trial 8). Next, in Trial 9, they were given a list of 50 words (15 from the first list, 15 from the second list, and 20 new common nouns), and were asked to identify the 15 first-list words.

RESULTS

Table 1 presents the measures analyzed in the present study. The means (and *SD*) of these measures are presented separately for children and adults (by gender) in Tables 2–3 and 4–5, respectively. ANOVA, followed up by Duncan procedure as a post-hoc analysis, was used in order to test the sensitivity of each composite score to age.

Total learning

This score changed significantly with age in the children's sample, $F(9, 923) = 27.04$, $p < .001$, $\eta^2 = .21$, and in the adult sample, $F(5, 516) = 55.09$, $p < .001$, $\eta^2 = .35$. Beginning at age 8, the amount of recall changed at each of the

Table 1 Measures used in the study

Calculation of the measure	Measure name	Process
Sum of Trials 1 through 5	Total Learning	Acquisition/Learning
The total of the five learning trials minus (5 multiplied by List A Trial 1)	Corrected Total Learning	
Trial 5 minus Trial 1	Learning Rate: Last Trial vs First Trial	
Trial 1 minus Trial 6	Proactive Interference	Interference
Trial 5 minus Trial 7	Retroactive Interference	
Trial 5 minus Trial 8	Retention: Delayed Recall vs Final Learning Trial	Retention/Forgetting
Trial 9 minus Trial 8.	Retrieval Efficiency	Retrieval/Recognition

Table 2 Boys: Means and standard deviations of the composite memory scores for each age group

Measure	8 ($n=51$)	9 ($n=51$)	10 ($n=56$)	11 ($n=55$)	12 ($n=45$)	13 ($n=42$)	14 ($n=42$)	15 ($n=61$)	16 ($n=47$)	17 ($n=37$)
Total Learning	43.59	46.76	49.27	52.76	52.89	53.45	53.88	55.39	53.42	53.00
	(7.92)	(7.33)	(7.11)	(6.92)	(6.65)	(7.74)	(7.06)	(7.61)	(6.46)	(6.73)
Corrected Total	13.09	18.33	17.75	18.76	18.89	17.02	18.28	18.10	17.57	18.13
	(7.88)	(7.13)	(5.99)	(6.83)	(6.37)	(6.78)	(6.57)	(6.03)	(6.20)	(6.76)
Learning Rate	4.51	6.02	5.48	5.58	6.11	5.00	5.69	5.51	5.47	5.30
	(2.42)	(2.27)	(1.64)	(2.05)	(1.97)	(2.02)	(1.73)	(1.95)	(1.90)	(1.97)
Proactive Interference	1.04	0.33	0.71	0.71	0.40	1.26	0.45	0.52	0.85	0.57
	(2.14)	(1.88)	(1.73)	(2.03)	(2.24)	(2.26)	(1.89)	(2.23)	(2.18)	(2.18)
Retroactive Interference	1.69	2.23	1.89	1.07	1.67	1.12	1.86	1.24	1.30	1.19
	(2.00)	(2.09)	(1.70)	(1.33)	(2.11)	(1.88)	(1.85)	(1.87)	(1.47)	(1.41)
Retention	1.63	1.84	1.59	1.09	1.20	0.81	1.86	1.39	1.30	1.46
	(1.67)	(1.93)	(1.84)	(1.86)	(1.96)	(1.42)	(1.97)	(1.68)	(1.65)	(1.52)
Retrieval Efficiency	4.76	3.41	3.64	2.78	2.69	2.76	3.31	2.36	2.64	2.94
	(2.24)	(3.46)	(2.14)	(1.98)	(1.84)	(1.88)	(2.06)	(1.74)	(2.01)	(2.86)

Total Learning = sum of Trials 1 through 5; Corrected Total = the total of the five learning trials minus (5 multiplied by trial 1); Learning Rate = Trial 5 minus Trial 1; Proactive Interference = Trial 1 minus Trial 6; Retroactive interference = Trial 5 minus Trial 7; Retention = Trial 5 minus Trial 8; Retrieval Efficiency = Trial 9 minus Trial 8.

Table 3 Girls: Means and standard deviations of the composite memory scores for each age group

Measure	8 ($n=49$)	9 ($n=49$)	10 ($n=54$)	11 ($n=48$)	12 ($n=45$)	13 ($n=41$)	14 ($n=45$)	15 ($n=43$)	16 ($n=43$)	17 ($n=39$)
Total Learning	44.53	49.10	52.59	55.04	55.15	53.78	55.62	57.58	54.60	56.36
	(9.22)	(7.19)	(7.07)	(7.20)	(5.66)	(7.18)	(5.65)	(8.11)	(7.41)	(6.03)
Corrected Total	15.44	19.31	18.33	18.37	18.82	18.29	17.84	16.88	16.81	18.02
	(7.02)	(5.89)	(7.05)	(6.22)	(6.42)	(6.09)	(5.32)	(6.41)	(6.86)	(5.55)
Learning Rate	5.26	6.33	5.70	5.56	5.69	5.71	5.58	5.00	5.53	5.36
	(2.44)	(1.81)	(2.17)	(2.07)	(1.94)	(1.79)	(1.64)	(1.74)	(2.00)	(1.68)
Proactive Interference	1.22	0.37	0.52	1.14	0.62	0.68	1.04	0.81	1.14	1.13
	(1.87)	(1.85)	(2.46)	(1.79)	(1.99)	(1.99)	(1.70)	(2.72)	(2.23)	(2.03)
Retroactive	1.90	1.59	1.44	1.35	1.73	1.78	1.24	1.12	1.70	1.15
Interference	(2.36)	(1.86)	(1.60)	(1.95)	(1.74)	(1.56)	(1.35)	(1.90)	(1.63)	(1.75)
Retention	1.63	1.53	1.46	1.21	1.35	1.32	0.89	0.98	1.21	0.92
	(2.07)	(1.90)	(1.73)	(1.57)	(1.60)	(1.54)	(1.40)	(1.83)	(1.35)	(1.51)
Retrieval Efficiency	4.14	3.35	2.96	2.98	2.55	2.68	1.75	2.00	2.28	2.10
	(3.81)	(2.97)	(3.09)	(1.97)	(2.75)	(1.92)	(2.65)	(1.76)	(1.65)	(3.22)

Total Learning = sum of Trials 1 through 5; Corrected Total = the total of the five learning trials minus (5 multiplied by Trial 1); Learning Rate = Trial 5 minus Trial 1; Proactive Interference = Trial 1 minus Trial 6; Retroactive interference = Trial 5 minus Trial 7; Retention = Trial 5 minus Trial 8; Retrieval efficiency = Trial 9 minus Trial 8.

following age groups: age 9, age 10, and age 11. After age 11 there were no more significant changes. In comparison to ages 20–29 the amount of recall is reduced at ages 30–39, remaining stable from age 30–59, and then deteriorates at ages 60–69 and again at ages 70–91.

Table 4 Men: Means and standard deviations of the composite memory scores for each age group

Measure	20–29 ($n = 57$)	30–39 ($n = 39$)	40–49 ($n = 42$)	50–59 ($n = 27$)	60–69 ($n = 48$)	70–91 ($n = 44$)
Total Learning	56.68	54.51	54.29	50.82	46.79	41.48
	(6.12)	(8.85)	(9.23)	(5.82)	(8.92)	(7.23)
Corrected Total Learning	18.09	18.10	17.38	18.22	16.17	15.00
	(6.00)	(6.31)	(6.43)	(6.69)	(6.14)	(5.31)
Learning Rate	6.14	5.79	5.33	5.89	5.25	5.55
	(1.56)	(1.88)	(2.08)	(2.50)	(2.18)	(1.97)
Proactive Interference	0.37	0.61	0.98	0.96	0.62	0.93
	(2.27)	(2.23)	(2.27)	(1.85)	(1.70)	(1.40)
Retroactive Interference	1.19	1.59	1.19	1.93	2.17	3.14
	(1.77)	(1.91)	(1.66)	(2.05)	(2.21)	(1.91)
Retention	1.26	1.61	1.38	1.89	2.25	2.86
	(1.78)	(2.15)	(1.56)	(2.08)	(2.57)	(2.15)
Retrieval Efficiency	2.09	2.15	2.86	2.70	3.79	4.27
	(1.98)	(3.56)	(2.15)	(2.93)	(2.70)	(3.88)

Total Learning = sum of Trials 1 through 5; Corrected Total = the total of the five learning trials minus (5 multiplied by Trial 1); Learning Rate = Trial 5 minus Trial 1; Proactive Interference = Trial 1 minus Trial 6; Retroactive Interference = Trial 5 minus Trial 7; Retention = Trial 5 minus Trial 8; Retrieval Efficiency = Trial 9 minus Trial 8.

Table 5 Women: Means and standard deviations of the composite memory scores for each age group

Measure	20–29 ($n = 60$)	30–39 ($n = 24$)	40–49 ($n = 44$)	50–59 ($n = 28$)	60–69 ($n = 67$)	70–91 ($n = 48$)
Total Learning	59.48	58.04	55.41	55.86	50.21	42.29
	(6.29)	(5.86)	(7.83)	(6.37)	(8.92)	(9.50)
Corrected Total Learning	20.07	20.12	17.23	19.96	17.89	16.04
	(7.00)	(6.05)	(7.58)	(5.38)	(6.46)	(6.83)
Learning Rate	6.27	6.29	5.43	6.14	5.87	5.44
	(1.97)	(1.88)	(2.55)	(1.65)	(1.86)	(2.26)
Proactive Interference	0.60	0.58	1.32	0.53	1.30	0.69
	(2.34)	(1.77)	(2.42)	(1.97)	(2.06)	(2.46)
Retroactive Interference	1.27	0.75	1.48	1.39	2.15	2.54
	(1.73)	(1.19)	(1.91)	(1.62)	(2.24)	(2.34)
Retention	1.28	1.12	1.36	1.21	1.61	2.60
	(2.35)	(1.26)	(1.83)	(1.64)	(2.07)	(1.91)
Retrieval Efficiency	1.48	2.04	2.04	2.21	2.25	3.85
	(2.34)	(2.09)	(2.62)	(2.06)	(2.49)	(2.99)

Total Learning = sum of Trials 1 through 5; Corrected Total = the total of the five learning trials minus (5 multiplied by Trial 1); Learning Rate = Trial 5 minus Trial 1; Proactive Interference = Trial 1 minus Trial 6; Retroactive Interference = Trial 5 minus Trial 7; Retention = Trial 5 minus Trial 8; Retrieval Efficiency = Trial 9 minus Trial 8.

Corrected total learning

Age effect reached significance in the children's sample, $F(9, 923) = 4.09$, $p < .001$, $\eta^2 = .04$. A significant difference was found in the children's sample between age 8 and all other children aged 9–17. Age effect reached significance in the adult sample as well, $F(5, 516) = 4.58$, $p < .001$, $\eta^2 = .04$. Age groups 20–39 and 50–59 were significantly different from ages 60–69, but no significant differences were found either between age group 40–49 and the younger age groups (20–39) or the older age group (60–69).

Learning rate: Last trial vs first trial (Trial 5 minus Trial 1)

Age effect reached significance only for the children's sample, $F(9, 923) = 3.10$, $p < .001$, $\eta^2 = .03$. This effect is due to the difference between age 8 and age groups 9, 10, 12, 14, and 16 years.

Proactive interference (Trial 1 minus Trial 6)

This score was not sensitive to age, either in the young or in the adult age groups.

Retroactive interference (Trial 5 minus Trial 7)

This score was significantly different only in the adult sample, $F(5, 516) = 10.27\, p < .001$, $\eta^2 = .09$. This effect is due to the difference between age groups 20–49 and 60–69. Age group 50–59 was not significantly different either from the younger age groups (20–49) or from the older age group (60–69). However, age group 70–91 was significantly different from all the other age groups.

Retention: Delayed recall vs final learning trial (Trial 5 minus Trial 8)

This score was sensitive only to the changes in the older age sample, $F(5, 516) = 6.94$, $p < .001$, $\eta^2 = .06$. The source of this effect is the difference between age groups 20–69 and ages 70–91.

Retrieval efficiency (Trial 9 minus Trial 8)

This score was sensitive to age in both age groups: children, $F(9, 923) = 6.90$, $p < .001$, $\eta^2 = .06$, and adults, $F(5, 516) = 8.48$, $p < .001$, $\eta^2 = .08$. In the children's sample a difference exists between age 8 vs all other children's ages, and age groups 9 and 10 vs age groups 15 and 16. The other children's age groups did not differ. In the adult sample significant differences were found between age groups 20–29 and 60–69, and between ages 70–91 and all other adult age groups.

Gender differences exist on the following measures: Total Learning: Boys: 51.35 ± 7.99; Girls: 53.25 ± 8.04, $F(9, 923) = 17.88$, $p < .001$, $\eta^2 = .02$; Adult men: 50.89 ± 9.49; Adult women: 52.98 ± 9.81, $F(5, 516) = 15.10$, $p < .001$, $\eta^2 = .03$; Retrieval Efficiency: Boys: 3.13 ± 2.35; Girls: 2.71 ± 2.75, $F(9, 923) = 7.62$, $p < .01$, $\eta^2 = .01$; Adult men: 2.98 ± 2.99; Adult women: 2.31 ± 2.60, $F(5, 516) = 7.20$, $p < .01$, $\eta^2 = .01$; Corrected Total Learning: Adult women: 18.35 ± 6.83; Adult men: 17.10 ± 6.17, $F(5, 516) = 5.64$, $p < .05$, $\eta^2 = .01$. The interaction of Age by Gender did not reach significance for any of the measures in either the children's or the adult groups.

DISCUSSION

The purpose of the present study is to present norms of composite measures of the Rey AVLT discussed earlier, covering a broad age range (8–91 years). Our approach in the present report is process oriented. The goal is to present and discuss performance in terms of the latent cognitive processes that it reflects. It is expected that such norms will assist the clinician in the assessment process, reporting performance in terms of impaired or preserved verbal memory processes. In addition, some of the measures might help the clinician in formulating a more refined diagnosis. The fact that these composite norms are based on the Hebrew version of the Rey AVLT raises the question of whether these norms could be generalized to other languages, particularly English. In order to address this issue the present composite scores were compared to published English norms. For the adults' sample we compared two simple measures (Trials 1 and 5) and two composite measures (Total learning and Corrected total learning) of five published American and Australian norms (Geffen et al., 1990; Ivnik et al., 1990; Mitrushina et al., 1991; Wiens et al., 1988) to our norms. This comparison (when age range was comparable) revealed that our norms fall within a third of a standard deviation (in both directions) of the other published norms for all compared measures. For the children's sample we compared two simple measures (Trials 1 and 5) and one composite measure (Total learning) of the Australian children's norms, published by Forrester and Geffen (1991). Only three age cohorts are comparable (9–10, 11–12, 14–15). Quite consistently, our scores were about one standard deviation higher than those of Forrester and Geffen. This suggests that for adults the present results are applicable to tests administered in English, but for children it has to be applied more cautiously.

As can be noticed in the norms tables there are some measures (Proactive interference, Retroactive interference, Retention, Retrieval efficiency) with a large standard deviation. This might limit the clinical usefulness of these measures. Nevertheless, the norms still provide valuable information to the clinician. They tell the clinician that a wide range of scores on a particular measure are within the normal range of performance. Therefore, when a score exceeds the boundaries of the normal range, the conclusion of impaired process could be made more decisively.

Several significant findings were found in the analyses. Compared to all measures used in this study, the Total learning and Corrected total learning scores were found to be the most developmentally sensitive measures in both children's and adult samples. Furthermore, female participants obtained a higher score than male participants on this measure. All other measures were much less sensitive to the effect of age. It is possible that the fact that this score is composed of the *sum* of five learning trials increases its sensitivity in contrast to the "pure" scores, which are composed by *subtraction* between trials. This might reflect a trade-off between the sensitivity of a measure (at least to age) and its "purity". However, although the "pure" measures are less sensitive to age effects, when they do detect impairment, they may be better interpreted. Thus, both types of measures have advantages and could be seen as complementary in the evaluation process. The learning process requires continuous effortful and strategic encoding and retrieval, which is associated with the functioning of the frontal lobes (Tulving, 2002; Wallis, 2007). The developmental changes associated with age, discussed below, could explain why the learning measures were so sensitive to age.

Of the interference measures, Proactive interference did not change across the children's and adult samples. The sensitivity to Retroactive interference was found to rise at age 60, and again at age 70. It has been suggested that memory interference is caused by deficits of inhibition, over-activation of irrelevant memory items, response competition and deficits of source monitoring (Hedden & Park, 2001, 2003; Howe, 2004; Kail, 2002). Therefore, resisting the effects of memory interference requires efficient and intact effortful mechanisms of retrieval monitoring and inhibition. In a previous report on the same children's sample we have reported changes in attention tasks up to age 11 (Vakil, Blachstein, Sheinman, & Greenstein, 2009). It is suggested that maturation and deterioration of frontal lobe functioning are related to the attentional and present memory findings.

The above-mentioned effortful memory processes have been associated with the frontal lobes: these lobes have been implicated/involved in memory processes, specifically working and episodic memory encoding and retrieval, in addition to inhibitory and attentional functions, also termed "executive functions" (Tulving, 2002; Wallis, 2007). Relationships between prefrontal activity and executive functions have been found in several studies (see Yurgelun-Todd, 2007). For example, frontal lobe lesions have been found to increase an individual's sensitivity to memory interference (Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995). Synaptic density and gray matter develop and increase during development, and the last areas to mature are the prefrontal and lateral temporal areas. It is argued that the last areas to mature mediate such functions as complex language, attention, inhibition, and executive functions (Amos & Casey, 2006). Gray matter volume in frontal areas reaches a peak at ages 10–12 years; it then undergoes pruning after adolescence (Blakemore, 2008; Blakemore & Choudhury, 2006; Bunge & Wright, 2007). Executive functions deteriorate with age, accompanied by a decline in the prefrontal area volume (Head, Rodrigue, Kennedy, & Raz, 2008). Indeed, reduction of gray matter in advanced age is evident especially in frontal areas (Galluzzi, Beltramello, Filippi, & Frisoni, 2008). The above-mentioned neural changes might also account for the poor retention and rapid forgetting from Trial 5 to Trial 8, which occurs after age 69. Less-efficient executive control processes might be related to increased interference, thereby reducing recall after a 20-minute interval.

Regarding retrieval efficiency, the discrepancy between Trial 8 (recall without retrieval cues) and Trial 9 (recognition with retrieval cues) is greatest at age 8, which is different from all children's age groups, and differs also among age groups 9, 10, and ages 15–16. This discrepancy score rises again at age 60 and again at age 70. In both samples the discrepancy is greater among male as compared to female participants. Retrieval difficulties are common in old age, probably due to less efficient retrieval strategies, or deficits in the use of effortful memory processes, all related to dysfunction of the frontal lobes (Cohn, Emrich, & Moscovitch, 2008; Jennings & Jacoby, 1993; Turner et al., 2007). Therefore offering retrieval cues greatly enhances memory performance in these ages, indicating the existence of retrieval failure (as opposed to storage failure). Similar changes take place in childhood, where older children improve their memory search and use more efficient retrieval strategies (Kobasigawa, 1974). Theses results highlight the importance of using recognition, in addition to recall, testing methods, in order to estimate more precisely the memory functions of young children and elderly individuals.

It has been frequently established that female participants show superiority over male participants in various verbal memory tests and measures (see Lowe, Mayfield, & Reynolds, 2003). This difference is also evident in our study.

In summary, this report provides norms for a broad range of age groups for a variety of composite verbal memory scores derived from the Rey AVLT. Regarding age differences, it appears that there are roughly five age cohorts that can be distinguished, based on the age comparisons: Very young (8 years); middle childhood and adolescence (9–17); young adulthood (20–29); adulthood (30–59); and old age (60 and above). At each of these age cohorts, a significant change takes place at least with some of the measures tested in the present study. Some of these changes may be attributable to neural maturational and deteriorative changes, as discussed above.

Regarding the composite measures reported in the present study, it seems that there are four developmentally sensitive measures, each reflecting a major cognitive process essential for adaptive everyday functioning: Measures of cumulative learning ability (Sum of all Learning Trials), retention of learned material over a time period (Trial 5 minus Trial 8), sensitivity to retroactive interference and the ability to resist distraction (Trial 5 minus Trial 7) and retrieval efficiency, the ability to perform memory search efficiently (Trial 9 minus Trial 8).

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