REY AUDITORY-VERBAL LEARNING TEST: STRUCTURE ANALYSIS

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One of the major advantages of the Rey Auditory-Verbal Learning Test (AVLT) is its multiple measures of learning and memory. This study evaluated empirically whether the different scores are, in fact, not merely different expressions of a single factor, but, rather, measures of different memory domains. The Rey AVLT was administered to 146 normal subjects. Factor analyses produced one, two, or three factors depending on the combination of scores included in the analysis and on the criteria used to determine the number of factors. The basic factors identified were acquisition and retention. The latter can be subdivided further into storage and retrieval, thus yielding a total of three factors.

One of the major advantages of the Rey Auditory-Verbal Learning Test (AVLT) is that it simultaneously provides several measures of learning and memory (Lezak, 1983; Query & Megran, 1983; Ryan, Rosenberg, & Mittenberg, 1984; Wiens, McMinn, & Crossen, 1988). Among these measures are immediate and delayed recall, learning rate, recognition, proactive and retroactive interference, primacy, and recency. These scores are affected differentially by age, intelligence, and type of population (Query & Berger, 1980; Query & Megran, 1983; Wiens et al., 1988). Vakil, Blachstein, and Hoofien (1991) suggested executing an additional trial of the Rey AVLT in order to test memory for temporal order. The authors found that this measure differentiates between control and closed head injury groups.

Memory impairment can assume many different forms; the affected brain area determines impaired and preserved aspects of memory (Squire, 1982). Such considerations highlight the advantage of a test such as the Rey AVLT, which can yield different scores that reflect different memory indices, as compared with a test that provides only a global score. Conceptually, the various scores derived from the Rey AVLT represent different components of the memory process (Lezak, 1983). However, it has yet to be proven empirically that the different scores are, in fact, not merely different expressions of a single factor, but, rather, measures of different memory domains.

The question whether organization of memory should be subsumed in one general factor or in multiple factors remains unresolved. For instance, with regard to the distinction between verbal and nonverbal memory, some reports support the claim that at least in normal subjects there is only one major factor (e.g., Smith, Malec, & Ivnik, 1992). Other studies, however, do support such a distinction (i.e., Bornstein & Chelune, 1988; Wechsler, 1987).

This issue was examined by Delis, Freeland, Kramer, and Kaplan (1988) with regard to a very similar memory test, the California Verbal-Learning (CVLT). The results lent

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clear empirical support to the assumption that scores derived from the CVLT represented different factors. Similarly, the purpose of the present study was to submit the different memory scores derived from the Rey AVLT to factor analysis in order to learn how the different scores cluster together and which memory domains they represent.

Previous factor-analytic studies have included only a few scores from the Rey AVLT together with scores derived from other memory tests. Ryan et al. (1984) found that three of the Rey AVLT scores, together with the scores of the Paired Associates and Logical Memory subtests of the Wechsler Memory Scale (WMS), reflect a "verbal learning and memory" factor. Moses (1989) grouped three of the Rey AVLT scores along with Benton's Visual Retention Test (BVRT) scores in an "immediate memory" factor. However, in terms of the present goals, the two last-mentioned studies suffer from two shortcomings. First, the fact that they used only a few Rey AVLT scores, combining them with other memory test scores, precludes full understanding of the internal structure of the Rey AVLT itself. Second, the inclusion of neurological and psychiatric patients in the studies' samples may have influenced the interrelationship between scores.

Thus, the major purpose of this study was to apply factor analysis to different scores of only normal control subjects, derived solely from the Rey AVLT, in order to understand better the structure and relationship among the test's different scores. However, while doing so we selected scores carefully to avoid inclusion of linear composites of variables that also are included separately in the analysis.

It is expected that different Rey AVLT scores in the same modality (verbal) would reflect two factors that represent distinct processes, in terms of acquisition vs. retention (Ericson & Scott, 1977). In terms of information processing, three factors are expected to represent acquisition, storage, and retrieval (Huppert & Piercy, 1978; Squire, 1982).

METHOD

Subjects

The subject group consisted of 146 volunteers, who were recruited from the general population and had no history of neurological or psychiatric disease. There were 77 males and 69 females, whose ages ranged for 19 to 46 years (M age = 31). Subjects' educational level ranged from 8 to 20 years of schooling (M = 13.36).

Test and Procedure

A Hebrew version of the Rey AVLT was used. Administration was standard, as described in Lezak (1983). The test consisted of 15 common nouns, which first were read to the subject in five consecutive trials (Trials 1 through 5); each reading was followed by free recall. 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, subjects again were asked to recall the first list. Twenty minutes later, and again without an additional reading, subjects were asked once more 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, and 20 "new" common nouns) and asked to identify the 15 first-list words.

To measure the ability to remember temporal order, an extra trial (Trial 10) was added to the standard administration (Vakil et al., 1991). In Trial 10, which followed the recognition task, subjects were presented with the 15 first-list words written in an order different from that in which the subjects had heard them originally. Subjects were asked to rewrite the words in their original order.

RESULTS

In order to accomplish the structure analysis of the Rey AVLT, different sets of scores were submitted to factor analysis procedure.

Measures

Nine different scores were derived from the Rey AVLT used in the analyses:

Immediate memory (Trial 1 score)
Best learning (Trial 5 score)
Proactive interference (Trial 6 score)
Retroactive interference (Trial 7 score)
Delayed recall (Trial 8 score)
Recognition (Trial 9 score)
Temporal order (Trial 10 score). This represents contextual information, by evaluating correspondence of the subjects' judgment of serial position of words with the original word order of the list presentation (Vakil et al., 1991). This score was generated by using Pearson product-moment correlation calculated for each subject, between the judged order and the original order of presentation (Tzeng, Lee, & Wetzel, 1979).

The following two scores frequently are used in studies that employ the Rey AVLT. Both are combined scores derived from a combination of different raw scores. In order to test their position among the other scores, they also were computed.

Learning rate (Trial 5 score minus Trial 1 score). Used as a single score that reflects the learning ability of the subject (Mitrushina, Satz, Chervinsky, & D'elia, 1991; Query, Randy, & Berger, 1980).

Total learning (sum of the scores of Trials 1 to 5). This score represents the capacity to recall and accumulate words across learning trials (Crossen & Wiens, 1988; Moses, 1989; Ryan, Geisser, Randall, & Georgemiller, 1986; Ryan et al., 1984; Wolf, Ryan, & Mosnaim, 1983).

Sets. In order to avoid inclusion of linear composites of variables that also are included separately in the analysis, four different sets of scores were constructed from the above scores and were factor analyzed separately.

Set 1 included only the seven row measures: immediate memory, best learning, proactive interference, retroactive interference, delayed recall, recognition, and temporal order. The two combined scores (i.e., total learning and learning rate) were excluded from this set.

Set 2 included one of the combined scores (total learning) and the row scores except for immediate memory and best learning because they are included in total learning score.

Set 3 included the second combined score (learning rate) and the row scores except for immediate memory and best learning scores, for the same reason as in set 2.

Set 4 includes all nine measures.

Factor analysis was accomplished by SPSS-X (SPSS Inc., 1986). SPSS-X used principal component analysis procedure and determined the number of factors retained by the Kaiser's eigenvalue greater than 1.0 rule (K1). The K1 rule may underestimate the number of factors in analyses with a small number of variables (less than 40) (Franzen & Golden, 1984). Thus, the scree test (Cattell, 1966) also was applied. The scree test helps to distinguish between major and minor factors, and its use is advisable when the study's objective is structure, as in the present case (Franzen & Golden, 1984).

The emerged factors then were rotated orthogonally using Equamax procedure following Moses' (1989) study. This method is recommended to equalize variance among factors and to allow distribution of variance among factors (Sawicki & Golden, 1984). The subjects' ratio to variables in set 1 (seven variables) was 20 to 1, in sets 2 and 3 (six variables) the ratio was 24 to 1, and in set 4 (nine variables) was 16 to 1. Table 1 presents the means and standard deviations for the nine Rey AVLT scores used in the analyses.

Table 1
Means and Standard Deviations of the Nine Scores Used in the Analysis of the Rey AVLT

Score	*M*	*SD*
Immediate memory	7.73	2.11
Best learning	13.30	1.85
Total learning	56.90	9.03
Learning rate	5.58	2.07
Proactive interference	6.88	2.48
Retroactive interference	12.21	2.61
Delayed recall	12.23	2.77
Recognition	14.13	1.60
Temporal order	.76	.24

Factor Analyses

Principal-component analysis was performed for Set 1. According to the K1 rule, only one factor is produced; the associated eigenvalue was (4.26) and accounted for 60.9% of the variance. This result accords basically with other findings that at least for normal subjects, there is primarily one major memory factor. (See Bornstein & Celune, 1988; Roid, Prifitera, & Ledbetter, 1988). However, the scree plot indicates a break point after the first factor and a second break point after the third factor. This solution accounted for 82.8% of the variance. Franzen and Golden (1984) suggest that in cases in which primary factors account for most of the variance and are followed by a few minor ones, as in the present case, the scree test is more appropriate. Factor analysis proceeded with equamax rotation on three factors. Table 2 presents the structure of the three-factor solution.

As can be seen in Table 2, the first factor, which we refer to as *retrieval* from long-term storage, includes temporal order, delayed recall, retroactive interference, and best learning. The second factor, *storage*, includes only the recognition score. The third

Table 2
Equamax-rotated Factor Matrix for the Three Factors Analysis with the Basic Rey AVLT Scores

	Factor		
Variable	1	2	3
Temporal order	.88	.09	.20
Delayed recall	.70	.52	.34
Retroactive interference	.66	.52	.36
Best learning	.63	.51	.30
Recognition	.14	.92	.11
Immediate memory	.08	.37	.82
Proactive interference	.36	−.06	.82

factor, *acquisition* or short-term memory, includes immediate memory and proactive interference. (Each represents the first trials of lists A and B.)

When Set 2 was submitted to analysis, two factors emerged according to the K1 rule, whose eigenvalues were (3.20, 1.07) and which accounted for 71.2% of the variance. As can be seen in Table 3, the learning rate score created a separate factor after equamax rotation. We found the distinction between acquisition and retention a useful one in interpreting the two factors. The first factor represents *retention* over time (including recognition, delayed recall, retroactive interference, best learning, and temporal order scores). The second factor represents *acquisition* (including only the learning rate score). The scree plot identified three factors, which accounted for 83.9% of the variance. In this solution, the second factor was recognition, and the third factor was the learning rate score.

Table 3
Equamax-rotated Factor Matrix for the Two-factor Analysis with the Basic Scores and the Inclusion of the Learning Rate Score

	Factor	
Variable	1	2
Delayed recall	.93	.05
Retroactive interference	.92	.04
Temporal order	.77	.04
Recognition	.66	.12
Proactive interference	.65	−.42
Learning rate	.13	.93

Set 3 factor analysis results differed greatly from results with the learning rate score. According to the K1 rule, only one factor emerged, whose eigenvalue was 3.98 and which accounted for 66.4% of the variance. Two factors emerged according to the scree test and accounted for 89.9% of the variance. As can be seen in Table 4, the recognition score created a separate factor.

One finding emerged clearly from the analysis of Sets 2 and 3: The learning rate and total learning scores represent different aspects of memory. According to this distinction, the former may reflect the process of acquisition, and the second may represent

Table 4
Equamax-rotated Factor Matrix for the Two-factor Analysis with the Basic Scores and the Inclusion of the Total Learning Score

	Factor	
Variable	1	2
Proactive interference	.86	.00
Total learning	.74	.53
Temporal order	.72	.31
Delayed recall	.67	.65
Retroactive interference	.65	.64
Recognition	.08	.92

the retention process. This might be surprising because the two scores consist of the same basic scores. (Learning rate is the difference between the fifth and the first trial; total learning is the sum of trials one to five.) Further support for the lack of dependence between these scores is reflected in the very low correlation between them ($r = -.036$). This justifies inclusion of both scores in the following analysis (set 4). Two factors emerged according to K1 criteria whose eigenvalues were 3.99 for the first and 1.09 for the second factor; these accounted for 72.7% of the variance. These results basically replicate the previous results. As can be seen in Table 5, as expected the learning rate score created a separate factor (i.e., acquisition), while the total learning rate score combined with the rest of the scores to create the first factor (i.e., retention). According to the scree test three factors emerged, which accounted for 83.6% of the variance. In the three-factor rotated solution, recognition constituted the second factor and learning rate the third factor.

Table 5
Equamax-rotated Factor Matrix for the Two-factor Analysis with the Basic Scores and the Inclusion of the Total Learning and the Learning Rate Scores

	Factor	
Variable	1	2
Delayed recall	.93	.07
Retroactive interference	.92	.07
Total learning	.91	-.16
Temporal order	.76	.08
Proactive interference	.66	-.40
Recognition	.65	.15
Learning rate	.10	.93

In summary, factor analyses generated one, two, or three factors depending on the combination of scores included in the analysis and on the criteria used to determine the number of factors.

Discussion

The purpose of this study was to clarify the structure of the Rey AVLT by submitting different test scores to factor analysis. Different combinations of scores produced different factorial structures. Whether it comprises one, two, or three factors, each configuration of results has theoretical and clinical implications.

In two cases that used more restrictive criteria for factor extraction, only one factor was produced (i.e., the row measures analysis and the row measures with the total learning measure analysis). This finding suggests that at least in normal subjects, even if memory consisted of different components, these components would be related strongly to each other. Other studies also have reported a single factor in memory even when scores of different memory tests were included (Bornstein & Celune, 1988; Roid et al., 1988; Smith et al., 1992). These findings may be understood in the framework of approaches that assume that in normals all cognitive abilities are closely related. Moreover, when a significant dissociation appears it usually serves as an indication of pathology, such as brain damage (Lezak, 1983).

In other analyses conducted according to restrictive criteria for factor extraction, two factors emerged (i.e., in the two analyses that included the learning rate score). We interpret this result according to the distinction made between memory acquisition and retention. The first factor represents *retention* over time, and the second factor represents *acquisition* of information. This distinction was supported in studies with amnesics (Ericson & Scott, 1977) and with closed head injured patients (Vakil, Hoofien, & Blachstein, 1992). Squire (1981) has suggested a dissociation between two forms of amnesia. Amnesia due to bitemporal lesions is characterized by impaired ability to retain information over time. The other form of amnesia is due to diencephalic lesions and is characterized by an impairment in the acquisition process.

We interpreted the three factors that emerged in the row scores analysis (set 1) as reflecting the three stages of memory in terms of information processing: (a) *acquisition*; (b) *storage*; and (c) *retrieval* (Huppert & Piercy, 1978; Squire, 1982).

The recognition score represents the storage factor. Recognition reflects the amount of information stored in memory better than does recall because it bypasses retrieval. Retrieval is represented in the first factor. All scores in this factor are indices of processes that require retrieval. The best learning, delayed recall, retroactive interference, and total learning scores are all determined by retrieval ability. The temporal order measure introduced here also correlates with retrieval. This finding suggests that retrieval efficiency is very much related to internal organization of information, as reflected by the temporal order measure.

The major apparent difference that emerges from comparison of the two vs. three factors that result from factor analysis is that while the acquisition factor stands, the retention factor was broken down into two factors, storage and retrieval. This distinction within the retention process is important because according to some findings retention is impaired when recall is measured (requires retrieval), whereas recognition was found to be preserved. Thus, storage exists with impaired retrieval.

Delis et al.'s (1988) factor analysis study of the CVLT scores interpreted clustering in six factors as representing: general verbal learning factor, learning strategy, acquisition rate, serial position, discriminability, and learning interference. In spite of the similarity between the Rey AVLT and the CVLT, they differ in construction of the word list and in procedure (the addition of a cued recall). Moreover, the Delis et al. (1988) study differs from the present study in that they submitted combined scores composed of the same raw scores to factor analysis. Therefore, the results cannot be compared easily. However, it is important to point out that at least two factors are consistent. The general verbal learning factor in the Delis et al. (1988) study coincides with what has here been termed retrieval, and the learning slope factor accords with the acquisition factor in the present study. It is noteworthy that in both studies these two factors accounted for the most variance.

It is important to note that in such studies, aside from pure statistical considerations, it is important to judge the results according to the interpretability criterion (Franzen & Golden, 1984). According to our interpretation of the present findings, the Rey AVLT alone can provide the clinician or the researcher with measures that represent different indices of memory. It seems to us that the basic factors found are acquisition and retention; the latter can be broken down further into storage and retrieval, which forms three factors.

Replication of the structural analysis of Rey AVLT is recommended to reconfirm the emerged factors, particularly in different groups, such as elderly and head-injured patients.

Our findings reconfirm the importance of using multifactoral tests that provide a range of scores rather than a global score insufficient for characterizing patients, whether for clinical or theoretical purposes.

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