A SUPPLEMENTARY MEASURE IN THE REY AVLT FOR ASSESSING INCIDENTAL LEARNING OF TEMPORAL ORDER

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Temporal order judgment is considered an important aspect of memory, both clinically and theoretically. Theories treat temporal order variously as an example of automatic process, contextual information, or source memory. However, despite its significance, temporal order is not well represented in standard memory tests or batteries. The well-known Rey AVLT (Auditory-Verbal Learning Test) was judged suitable for incorporation of a temporal order measure because it already includes several measures of learning and memory. The measure was administered to 190 healthy subjects divided into four age groups, who then were given list A in random order and asked to rewrite the words in their original order. Memory for temporal order was found to be sensitive to age and gender. Although temporal order judgment was part of incidental learning, scoring was significantly higher than could be attributed to chance. The correlation pattern between temporal order and other Rey AVLT scores suggests that temporal order is related to retention rather than to acquisition.

Temporal order of learned information is one of the more important aspects of memory. When recalling something, we usually recall not only what happened, but when it happened. Furthermore, we generally can distinguish whether a particular event occurred before or after another event. Memory for temporal order is of theoretical and clinical significance because it has been found to be sensitive to different pathological groups.

From a clinical perspective, impaired memory for temporal order is considered the source of amnesia—"temporal order hypothesis" (Hirst & Volpe, 1982, 1984; Huppert & Piercy, 1976; Williams & Zangwill, 1950). Referring to temporal order as contextual information, Hirst and Volpe (1982, 1984) have reaffirmed this unique impairment in amnesic patients. Evidence for impaired recall of temporal order also was found in patients with closed head injury and the elderly (Vakil, Blachstein, & Hoofien, 1991; Vakil & Tweedy, 1985). Various studies suggest that the recollection of temporal order of events may become more impaired than recall of the events themselves. For example, studies have found patients with frontal lobe lesions to be particularly impaired in encoding temporal order (Janowsky, Shimamura, & Squire, 1989; Shimamura, Janowsky, & Squire, 1990). Findings also were reported with regard to children diagnosed with ADHD, who showed a selective impairment in temporal order judgment (August & Garfinkel, 1990).

From a theoretical perspective, studies on laterality have attributed the processing of temporal order to the left hemisphere (Carmon & Nachshon, 1971); Hasher and Zacks

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(1979) argue that temporal order, frequency of occurrence, and spatial location are encoded automatically. In most of these studies temporal order was tested by presenting a list of words followed by a request to rearrange the words in the order of presentation, or by presenting pairs of words and asking subjects to judge which words appeared first, or by presenting single words and asking subjects to judge where they were presented in the list, i.e., in which quadrant.

Thus, a specific impairment of memory for temporal order may serve as a sensitive diagnostic tool to identify specific subgroups with memory impairment. Surprisingly, however, memory for temporal order rarely is included in standard memory batteries and seldom has been reported in a clinical description of patients. Lezak (1983) reports two tests developed by Milner (1971) and by Huppert and Piercy (1976) that measure the ability to estimate recency. These tests were used primarily in research rather than in a clinical setting.

The Rey AVLT (Auditory-Verbal Learning Test) (Rey, 1964) is a widely used memory test that has been found sensitive in differentiating among different clinical groups (Mungas, 1983; Query & Megran, 1984). One of the major advantages of the Rey AVLT is that it simultaneously provides several measures of learning and memory (Lezak, 1983; Ryan, Rosenberg, & Mittenberg, 1984; Wiens, McMinn, & Crossen, 1988). Among these measures are immediate and delayed recall, learning curve, recognition, proactive and retroactive interference, primacy, and recency. Thus, it was judged suitable for testing memory of temporal order. The test consists of repeating a word list that has been read five times consecutively in the same order to enable subsequent testing of presentation sequence. Because in real situations contextual information, such as temporal order, usually is encoded incidentally, we added the temporal order test following standard administration without any warning. Additional reasons for adding the test at the end were to avoid affecting the nature of the test and to preserve standard administration without any interference. In this way, the test's new version still can be related to the existing large body of literature on the Rey AVLT. Adding the new measure expands information provided by the test by enabling simultaneous comparison of different aspects of memory. This measure of temporal order memory, extracted from the Rey AVLT, already has been found to differentiate among closed-head-injured and control groups (Vakil et al., 1991).

Thus, the purpose of this study was to introduce a supplementary measure of temporal order into the Rey AVLT and to indicate how performance of normal subjects on this measure relates to their age and gender, as well as how it relates to other measures of memory reflected in the different Rey AVLT scores.

Method

Subjects

The sample consisted of 190 subjects (103 males and 87 females) with no psychiatric or neurological history, who volunteered to participate in this study. The average age was 35 (18-55); education ranged between 8-20 years of schooling, with an average of 13 years.

Measure and Procedure

A Hebrew version of the Rey-AVLT was used. A standard administration, as described in Lezak (1983), was utilized. List A: 15 common words were presented orally, at a rate of 1 word per second, in five consecutive presentations or trials (trials 1 through 5); each presentation was followed by asking the subjects to recall freely, and in any order, as many words as possible. List B, which consisted of 15 new words designed to interfere with the earlier list, was presented in trial 6, followed by free recall of the new words. Trial 7 consisted of a free recall of List A without an additional presentation.

Delayed recall, recognition, and temporal order judgment were assessed 20 minutes after the trial (Trials 8, 9, and 10). The recognition task included 50 words—15 from List A, 15 from List B, and 20 "new" common nouns.

Temporal order judgment assessment, Trial 10, followed the recognition trial. Subjects were presented with a written list of the 15 words in List A, in which the presentation order differed from the one used in the oral trials, and were asked to rewrite the word list to match the order of words in the original list as they had heard them. Words from List A were supplied to the subjects in order to avoid confusing the process utilized in temporal order judgment with that utilized in word retrieval.

Results

Different measures for estimating temporal order judgment are suggested in the literature (Zacks, Hasher, Alba, Sanft, & Rose, 1984). The data in this study were analyzed using three different measures of temporal order. The advantages and disadvantages of each will be discussed below. The measures are: (1) *Hits*: the number of words correctly placed at their original serial position; (2) *Correlation*: Pearson product-moment correlation calculated for each subject, between the listed order and the true order (Tzeng, Lee, & Wetzel, 1979); and (3) *Absolute Deviation*: This score was calculated by summing the absolute deviation of each word from its original position. The score for each deviation ranges from 0 to 14 (Vakil, 1985; Vakil & Tweedy, 1985). Table 1 presents the means and standard deviations for each temporal order measure for males and females in four age groups.

Table 1
Means and Standard Deviations for the Different Temporal Order Measures by Age Groups and Gender

	Age							
	18-25 (n = 57)		26-35 (n = 42)		36-45 (n = 48)		46-55 (n = 42)	
Measure	M	F	M	F	M	F	M	F
Hit								
M	6.42	7.90	6.18	8.28	5.33	4.83	3.54	4.94
SD	2.78	3.41	3.37	4.60	3.68	3.42	3.15	3.64
Absolute deviation								
M	26.38	18.00	27.57	18.86	33.25	34.42	41.67	31.89
SD	13.22	12.13	20.96	17.90	20.20	19.48	15.55	15.60
Correlation								
M	.79	.87	.75	.85	.69	.65	.57	.71
SD	.14	.13	.31	.21	.25	.27	.23	.22

Note.—M = males; F = females.

ANOVA was used to test the effect of age (four groups) and gender on the correlational measure of temporal order memory. The results suggest that both main effects, but not the interaction, reached significance; age (F[3,188] = 7.89, $p < .001$) and gender (F[1,188] = 4.05, $p < .05$); females scored better than males. In order to detect the source of significance of the age effect, the Duncan follow-up procedure was performed. This analysis indicated that each of the two younger groups differed significantly from each of the two older groups, although the two older and the two younger groups did not differ from each other. Two additional ANOVA conducted on the hit and absolute deviation measures revealed the same age and gender effects for the correlation scored.

The intercorrelations between the different temporal order measures are presented in Table 2.

Table 2
Intercorrelations among the Different Temporal Order Measures

Measure	2	3
1. Hit	−.860**	.732**
2. Absolute deviation	–	−.961**
3. Correlation		–

**$p < .001$.

The three scores used for evaluation of temporal order judgment reflect two different scoring methods. Hits dichotomizes performance: correct/incorrect. The other two measures (Correlation and Absolute Deviation) evaluate performance on a continuum that represents proximity to the correct position. Because the latter method is considered a more accurate approach, the correlation score was used from this stage of the study on to best reflect temporal order memory.

The Rey AVLT measures used in the analyses were:

Immediate Memory (Trial 1 score),
Total Learning (sum of scores of Trials 1 to 5),
Proactive Interference (Trial 1 score minus Trial 6 score)
Retroactive Interference (Trial 5 score minus Trial 7 score)
Learning Increment (Trial 5 score minus Trial 1 score),
Delayed Recall (Trial 8 score),
Recognition (Trial 9 score)
Temporal Order (Trial 10 score).

Primacy and recency scores also were computed: The primacy score consisted of the number of times subjects recalled the first three words throughout the five learning trials, while the recency score consisted of the number of times subjects recalled the last three words throughout the five learning trials.

Correlations of the different Rey AVLT measures with the correlation score of temporal order are presented in Table 3.

Table 3
Correlations of the Correlation Temporal Order Score with the Different Rey AVLT Scores

Score	Temporal order
Immediate learning	.302**
Learning increment	.121
Total words learned	.544**
Delayed recall	.635**
Proactive interference	−.100
Retroactive interference	−.358**
Correct recognition	.212*

*$p < .01$. **$p < .001$.

Discussion

Three different scores that reflect memory for temporal order were calculated initially. Hits is the easiest to score; Absolute Deviation and Correlation are the more accurate measures, though they require additional computations. Correlation is recommended for group evaluation, e.g., in research. A computer program can be used for groups, but is impractical for individual tests. Intercorrelations between these measures suggest that they are related very closely. Although different scores in normal subjects are related closely, this would not necessarily hold for pathological populations, such as amnesics, so further testing is required.

Correlations between temporal order and different Rey AVLT scores were weak to modest, which suggests that this measure may account for unique variance. The pattern of correlations indicates a significant relationship between temporal order judgment and Rey AVLT scores that represent long-term storage, as measured by the total amount of words learned, delayed recall, and retroactive interference. There is no correlation with learning rate. This observation may indicate that organizational processes as reflected in temporal order encoding are related to retention rather than to acquisition of information.

This new memory measure extracted from the Rey AVLT, in addition to the other memory measures, was found to be sensitive to age and gender. This precise measure was found in a previous study to differentiate between closed-head-injured patients and the control group (Vakil et al., 1991).

The California Verbal Learning Test (CVLT) is similar to, but different from, the Rey AVLT. With this test Delis, Freeland, Kramer, and Kaplan (1988) found that closed-head-injured patients tend to rely on the temporal order of presented words more than normals. In view of our findings, it may be suggested that when the list consists of easily categorized words (i.e., CVLT), semantic clustering rather than temporal order becomes the strategy of choice for normals. However, when the words do not show a clear semantic relationship (i.e., Rey AVLT), temporal order becomes the preferred strategy. By contrast, temporal order usually seems to be the preferred option for closed-head-injured patients. The cognitive deficit evidently makes it difficult to utilize semantic categorization. Furthermore, it is important to distinguish between temporal order as expressed in the order of spontaneous recall (a measure used by Delis, Freeland, Kramer, & Kaplan, 1988) vs. intentional recollection of temporal order (as recommended in our study); further discussion of this distinction can be found in Vakil et al. (1991).

In conclusion, the Rey AVLT with the new measure of incidental learning of temporal order can be a very useful clinical and research tool for simultaneous study of different aspects of memory. The present study should be replicated with an English version of the Rey AVLT. Further study of different populations with this new measure is also necessary.

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