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DIRECT AND INDIRECT MEMORY MEASURES OF TEMPORAL ORDER: YOUNGER VERSUS OLDER ADULTS

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ABSTRACT

The memory changes associated with age are attributed to the deterioration of the frontal lobes, as well as to the middle temporal structures. Therefore, in addition to a decline in memory for facts and events, as found impaired in amnesics, a memory decline associated with age is predicted for tasks typically found impaired in frontal lobe patients (i.e., temporal order judgment). There are conflicting findings concerning whether indirect measures of memory for facts and events are associated with age. However, there are no studies that address this issue with regard to temporal order judgment. Thirty younger and thirty older adults were tested on a list of words which was repeated five times in fixed or varying order. The number of words recalled, as well as their temporal judgments, were the direct measure of memory. The effect of consistency of order of presentation on the number of words recalled was the indirect measure of memory for temporal order. Results suggest that direct, but not the indirect measures of memory were related to age.

Memory decline associated with age has been suggested to result from neural deterioration, not only of the middle temporal structures, but of the frontal lobes as well [1]. In accordance with this, source amnesia, that is, the memory for the source of the information (e.g., where or when it was learned), was found to be correlated with tests sensitive to frontal lobe dysfunction and to be associated

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with age [2-4]. Several studies have shown that temporal order judgment is spared in amnesic patients but impaired both in patients with localized frontal lobe damage [5-7] and in patients with diseases or injuries involving the frontal lobes, such as Korsakoff's syndrome [8] or closed-head injury [9-10]. Possible age effects concerning memory for temporal order has been a controversial issue. Some studies report that memory for temporal order is not associated with age [11-12], while more recent studies suggest that it is associated with age [13-17].

Graf and Schacter [18] and Schacter [19] have introduced a distinction between two types of memory processes—explicit (e.g., recall and recognition) and implicit (e.g., priming). Explicit memory requires effortful and intentional retrieval, whereas implicit memory, "is revealed when previous experiences facilitate performance on a task that does not require conscious or intentional recollection of these experiences" [19, p. 501]. Most studies have found that implicit memory is preserved in amnesic patients [20]. Similarly, several studies have reported minimal age related differences when implicit measures of memory were used [21-25]. However, some studies have reported reliable age differences under some conditions, even in implicit memory tasks [26-28].

In this study, the effect of age on temporal order judgment is measured directly and indirectly. Direct-indirect terminology refers to the nature of retrieval required in a given task. We chose to use the distinction made between direct and indirect measures of memory [29] instead of Schacter's terminology (i.e., implicit vs. explicit). When Schacter introduced his terminology, he noted that, "the concepts of implicit and explicit memory neither refer to, nor imply the existence of, two independent or separate memory systems" [19, p. 501]. Despite Schacter's comment, in the literature the explicit-implicit dichotomy is at times used to describe different tasks, but at other times it is used to reflect two different memory systems. Thus, in the present experiment we preferred the direct-indirect terminology in order to stress the characterization of the *tasks* [for further discussion see 29-30].

In a typical implicit paradigm, implicit memory is measured by presenting tasks to participants, other than memory tests per se (e.g., perceptual, problem solving). However, in the paradigm of the present study, the indirect measure is embedded within the direct *memory* task. The advantage of such a paradigm is that it allows for the study of the interaction between the two aspects of memory. For instance, one could investigate how indirect memory affects direct memory, if at all.

The rationale of the paradigm employed in the present study was based on findings that the learning rate of a list of words presented repeatedly is better when the list is presented in a fixed, rather than in a varying order [31-32]. A list of words was presented repeatedly five times in either fixed or varying order. The overall number of words recalled, as well as their temporal judgments (i.e., measured by correlating the original order of presentation in the fixed list to the order in which the subject rearranged the word list), were the *direct* measures of memory. The advantage of the number of words *recalled* when the list was presented in a fixed order versus a varying order, was the *indirect* measure of temporal order. It is assumed that the consistency of order of presentation contributed to this advantage, thus indirectly expressing the temporal order information. It was predicted that the performance of the older participants would be inferior to that of the younger participants in the number of words recalled, as well as in temporal memory when tested directly. However, both groups were predicted to benefit to the same extent from the consistency of order of presentation. Thus, although temporal order information is not accessible directly—intentionally, it is assumed to be expressed indirectly by facilitating the learning of the word list presented in a fixed order.

METHOD

Participants

The sample consisted of two groups—thirty elderly and thirty young participants. All participants voluntarily participated in this experiment. The young group's age ranged from nineteen to thirty years (M = 25.53). Their education ranged from eleven to twenty years of schooling (M = 15.77). The elderly group's age ranged from sixty-five to eighty-nine years old (M = 73.93). Their education ranged from six to eighteen years of schooling (M = 11.23). In our opinion, although the number of years of schooling is significantly different between the two groups, it does not reflect a real difference in the level of intelligence between them. Many of the elderly participants, immigrating to Israel as youngsters, had to leave school and go to work, and therefore did not have the opportunity to fulfill their intellectual potential. The elderly participants were retired middle class individuals. All participants were reported to be in good health and had no uncorrected vision or hearing problems. None of the participants had a history of alcohol or drug abuse, or of psychiatric illness. All participants were proficient in Hebrew.

Stimuli

Forty-four high-frequency Hebrew words (more than 50 per 200,000 words) [33] were used to construct two twenty-two-item presentation lists. For half of the participants from each group, one list was applied for the "fixed order" condition and the other list for the "varying order" condition. For the other half of the participants, the assignment of the lists was inverted. *Fixed order*: each word from the list was typed on a 6.5 cm × 6.5 cm card, and the cards were arranged in random order. The list was presented five times with the same deck of cards in the same order. *Varying order*: the words of this list were typed five times on cards as above, to enable the presentation of the list five times in a different order each time. The five sets of cards of the list were then arranged each time in a different order, pseudorandomly, so that any sequence of three words was never repeated from trial to trial.

Testing Procedure

Each participant was tested individually. The order of testing was counter-balanced—half of the participants were first tested in the fixed order condition and half were first tested in the varying order condition. In the *fixed order* condition, the list was presented five consecutive times with the same deck of cards, in the same order. In the *varying order* condition, five differently ordered decks of cards were used. The cards were presented one at a time for three seconds each. In neither of the testing conditions was the participants' attention drawn to the order of presentation. Participants were told that they would be presented with a list of words a number of times, and that the words would be presented on cards. They were also informed that following each trial they would be asked to freely *recall* as many words as possible, in any order. The number of words recalled following each one of the five trials in the fixed and varying condition (i.e., total of 10 scores) were recorded by the experimenter. In addition, upon completion of the fixed order task, participants were presented with the words from the list, written in an order different from that in which they had been originally presented in the previous five trials. Participants were then asked to rewrite the words in their original order. Obviously, the memory for temporal order was tested only following the *fixed* order list, in which the words were presented consistently in the same order in all five trials. Notice that in order to avoid confounding with performance on the learning task, *all* the words were presented to participants regardless of which ones were recalled.

RESULTS

Three different memory measures were extracted from the data: the direct memory measure of words, measured by the overall number of words recalled across learning conditions; the indirect memory measure of temporal order, measured by the advantage of number of words recalled in the fixed over the varying list presentation order; and the direct memory of temporal order, measured by the comparison of the original order of presentation of the fixed order list to the order rearranged by the participants. Figure 1 presents the mean number of words recalled in five learning trials of fixed and varying order by the older and younger groups. The results were submitted to a mixed-design ANOVA to analyze the effect of group (young vs. old) by presentation order (fixed vs. varying) by learning trials (1 to 5). The three main effects reached significance. As predicted (i.e., the direct measure), the younger group recalled more words overall (M = 17.06, SD = 2.36) than the older group (M = 9.73, SD = 3.20),

$F(1,58) = 101.86$, $p < .001$. More words were recalled overall in the fixed order ($M = 14.26$, $SD = 4.54$) than in the varying order presentation ($M = 12.53$, $SD = 4.92$), $F(1,58) = 44.18$, $p < .001$. The main effect for trial also reached significance, reflecting the overall increase in number of words recalled from trial to trial (see Figure 1), $F(4,232) = 231.64$, $p < .001$. The rate of learning, however, was steeper in the fixed than in the varied order of presentation, as indicated by the significant interaction between the two effects (i.e., the mean difference between the two lists is .18 and 2.68 words in the first and fifth trial, respectively), $F(4,232) = 11.93$, $p < .001$. As predicted (i.e., the indirect measure), the interaction between group and order of presentation did not reach significance, $F(1,58) = .05$, $p = .82$, indicating that both groups benefited from the consistency of presentation to the same extent. The interaction of group and learning trials did not reach significance either (although there is a tendency in this direction, $F(4,232) = 2.14$, $p < .08$), indicating that overall both groups benefited from the repeated presentations of the lists to the same extent. The triple interaction of group by presentation order by learning trials did reach significance, $F(4,232) = 11.93$, $p < .001$. In order to interpret this interaction, two simpler analyses were conducted, one for each learning list. The analysis of the fixed order list indicates that overall the younger group recalled more words than the older group, $F(1,58) = 107.99$, $p < .001$. The main effect for trial also reached significance, reflecting the overall increase in number of words recalled from trial to trial, $F(4,232) = 206.32$, $p < .001$. The group by learning interaction reached significance as well, $F(4,232) = 3.62$, $p < .01$. As can be seen in Figure 1, the younger group shows a steep increase in the number of words recalled from first to second trials, and the increase in the rest of the trials is more gradual. The older group, however, shows the steepest increase in number of words recalled in the first two trials, and then a more gradual increase. In the analysis of the varying order list, only the main effects reached significance, $F(1,58) = 77.95$, $p < .001$, and $F(4,232) = 114.41$, $p < .001$, for group and learning trials, respectively. The insignificant interaction between these two factors, $F(4,232) = .99$, $p > .05$, indicates a similar learning rate for the two age groups. Thus, the triple interaction observed in the initial analysis suggests that although both groups were affected similarly by the repeated trials and by the order of presentation, the effect of order of presentation on the rate of learning across the five presentations was different for each group.

For the analysis of temporal order judgment (i.e., the direct measure), a Pearson product-moment correlation was calculated for each participant, comparing the order judged and the order in which the words were originally presented in the fixed ordered list [34]. This correlation score reflects the accuracy of temporal order judgment. A preliminary analysis indicated that the counterbalance in the order in which the lists were presented (i.e., either the fixed or varying list first) had no effect on the overall accuracy in temporal order judgment $F(1,56) = .81$, $p = .37$, nor did it interact with the age group effect,

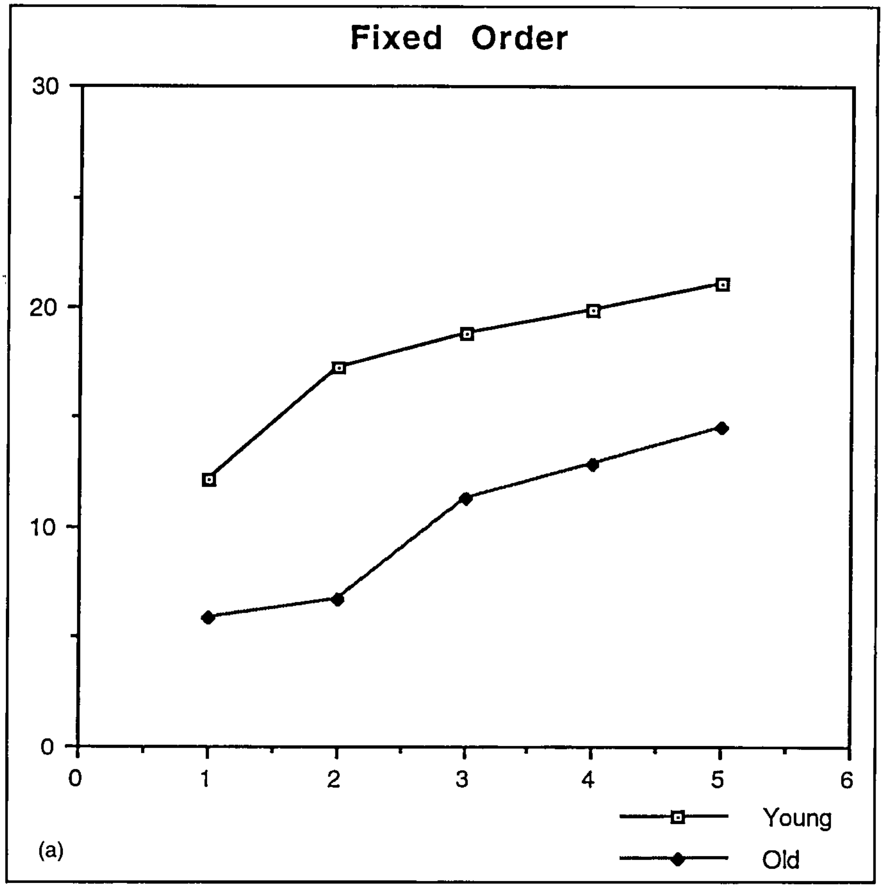

Figure 1. The mean number of words recalled in five learning trials of (a) fixed and (b) varying order by the older and younger groups.

$F(1,56) = .01$, $p = .94$. That is to say, whether the fixed list was presented first followed by the temporal order judgment, or the varying order was presented first followed by the fixed order list, and only then the temporal order, the performance on temporal order was not significantly different. Thus, the temporal order judgment in the two presentation orders were collapsed together. Participants of the younger group were found to be more accurate in their temporal order judgment, as compared to the older group, $t(58) = 6.99$, $p < .001$ (means were .822 and .441 for the younger and older groups respectively).

The above hypotheses were tested in yet another way; the correlation pattern between age and the different memory measures and among the memory

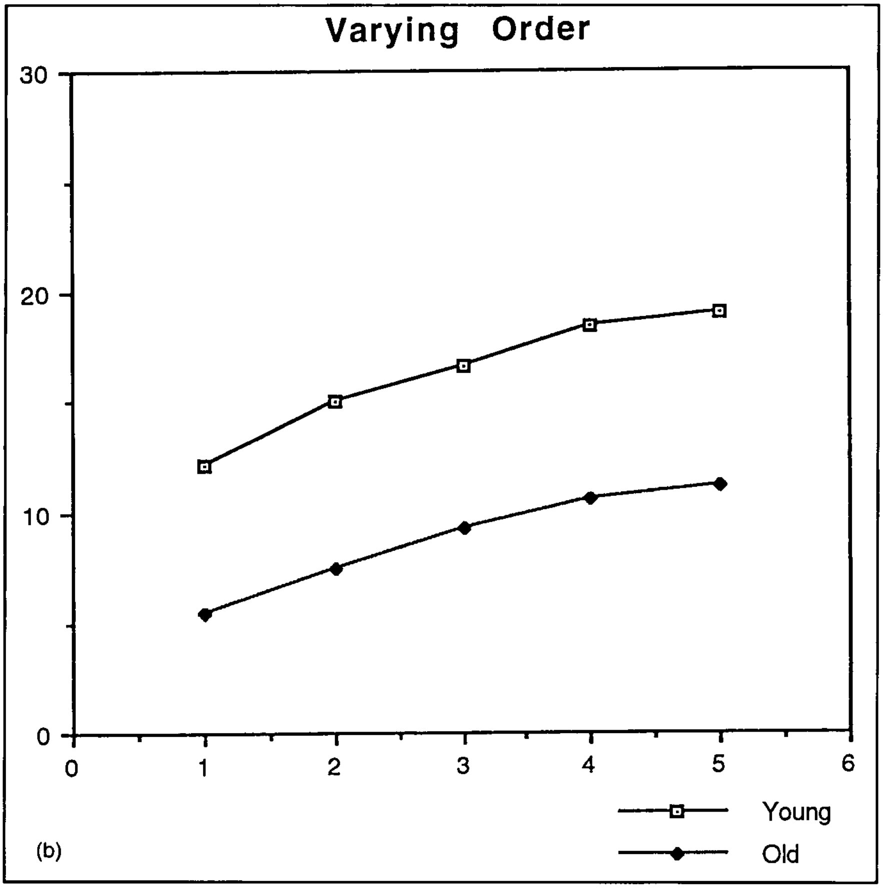

Figure 1. (Cont'd.)

measures themselves was investigated. Pearson product-moment correlations were calculated for age, total number of words learned in fixed order presentation, varying order presentation, the difference between these two scores (i.e., gain), and the temporal order judgment score. As predicted, the correlations presented in Table 1 clearly demonstrate that all the direct memory measures, including the recall in the two forms of presentation and the temporal order judgment, are closely related to each other and are significantly correlated with age. The indirect measure (i.e., gain), however, is not related to age and is correlated to only one of the other memory scores. These correlation patterns further confirm the results obtained above in which the direct, but not the

Table 1. Intercorrelations Between Age and Memory Measures for Both Age Groups

	($n = 60$)			
Measures	2	3	4	5
1. Age	−.83**	−.79**	−.69**	.05
2. Words recalled fixed order	—	.91**	.57**	.02
3. Words recalled varying order		—	.49**	−.38*
4. Temporal order judgment			—	.08
5. Words gained (fixed-varying)				—

*$p < .002$
**$p < .001$

indirect measures of memory are age related. They also confirm the existence of a dissociation between the direct and indirect measures of memory.

DISCUSSION

As expected, when memory was measured directly, either by word recall or by temporal order, the younger group's performance was found to be better than that of the older group. In accordance with other reports in the literature, the older group recalled fewer words than the younger group overall [35-37]. When measured directly, temporal order judgment was less accurate in the older group as compared to the younger group. This last finding is in accordance with some reports in the literature [13-17] but not with others [11, 12].

The overall benefit of learning under fixed, over varying order of the word list was also found, as previously reported in the literature [31-32]. We view this order of presentation effect as an indirect measure of temporal order. The insignificant interaction between group and presentation order suggests that both groups equally benefited from the consistency of the order of presentation of the list, although the elderly group had more difficulty in intentionally retrieving the words. The significant triple interaction suggests that although both groups eventually benefit equally from the consistency of order of presentation, the rate of learning is affected differently by the two presentation orders for the two age groups.

The correlation pattern further supports the hypothesis that age is related to the direct, but not to the indirect measure of memory. Furthermore, the correlations indicate that the temporal order judgment, when tested directly, is much more related to the other direct memory measures (i.e., word recall) than to the indirect measure of temporal order (i.e., gain). It is important to notice that for the temporal order judgment task, *all* the words were presented to the participants regardless of which ones were recalled. This was done in order to avoid confounding temporal order judgment performance with performance on the learning task for which the older and younger participants were expected to differ. Thus, the high correlation with learning performance is even more telling considering the fact that participants were only asked to rearrange the words and no recall of the words was required. We interpret the high correlation to suggest that the distinction between direct and indirect tasks is more fundamental than the specific task requirement, whether it be word recall or temporal order judgment of given words. This finding indicates that the direct memory tasks have a common underlying memory mechanism which is different from that of the indirect tasks.

An alternative way to interpret the advantage of the fixed over varying order (i.e., gain) could be that it reflects an intentional associative link between words in the fixed ordered list, rather then an indirect effect of temporal order. If this were the case, one would expect that this strategy would be reflected to the same extent in the direct measure of temporal order as well. The insignificant correlation between the direct and the indirect measures of temporal order argue against such an interpretation.

This experiment reconfirms the importance of the distinction between direct and indirect measures of memory. That is, some aspects of the information presented, although not accessible via intentional retrieval mechanisms, were in fact encoded. Furthermore, this encoded information supported and contributed to the recall of the information that was directly accessible. This interaction between the two forms of memory can be evident only in the type of paradigm employed in the present study, in which both forms of memory are tested within the same memory task.

Several studies have shown a dissociation in the nature of the memory impairment associated with damage to middle temporal structures (i.e., amnesics) versus memory impairment associated with frontal lobe damage. Memory for events and facts is impaired in amnesics but source memory is intact (e.g., temporal order), while the reverse is observed in frontal lobe patients [5-7]. It is well established that information that is not available to amnesics when tested directly, is available to them when tested indirectly [for review, see 20]. The goal of the present study was to test whether the same would apply to memory impairment associated with frontal lobes. Specifically, we investigated whether we could demonstrate that memory for temporal order (which is associated with frontal lobe dysfunction) is preserved when measured indirectly, even when it is impaired when measured directly. As predicted, based on previous studies in the literature [1], older adults were inferior to younger adults in memory tasks associated with the function of middle temporal structures (i.e., words recalled), as well as in a memory task associated with the function of the frontal lobes (i.e., temporal order). The unique contribution of this study is that the second type of memory (i.e., temporal order) was found preserved when measured indirectly.

Closed-head injured patients are similar to older adults in that their memory deficit is also attributed to impairment of the medial temporal lobes as well as the frontal lobes [38]. The results of the present experiment concur with previous findings concerning closed-head injured patients where different tests of source memory (i.e., temporal order and frequency of occurrence) were impaired when measured directly, but preserved when measured indirectly [9, 10].

One of the questions requiring further investigation is whether the differential effect of the direct-indirect tests of memory for amnesics as compared to closed-head injured patients and older adults operates via the same memory mechanisms. The role of the frontal lobes in memory is viewed as responsible for the intentional strategic search in memory [39]. It is conceivable that indirect memory tests reduce the need to rely on frontal lobe functioning, thus enabling normal performance in closed-head injured patients and in older adults. One might then ask what brain areas are possibly involved in the processing of the indirect memory tasks. There is converging evidence that the processing of priming tasks involves the neocortex, particularly the posterior regions which operate at a modality specific, presemantic level [40]. These areas are relatively spared not only in amnesic patients, but in closed-head injured patients [38] and older adults as well [1]. This might indicate that these areas mediate the processing of the indirect memory of source information, tasks found preserved in closed-head injured patients and older adults.

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