Journal of Clinical and Experimental Neuropsychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ncen20

Aging and temporal order memory: A comparison of direct and indirect measures

Haya Blachstein [a], Yoram Greenstein [b] & Eli Vakil [a]

[a] Department of Psychology and Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel

[b] Kinneret Academic College, Zefat Academic College, Kibbutzim College of Education, Tel Aviv, Israel

Version of record first published: 21 Nov 2011

To cite this article: Haya Blachstein, Yoram Greenstein & Eli Vakil (2012): Aging and temporal order memory: A comparison of direct and indirect measures, Journal of Clinical and Experimental Neuropsychology, 34:1, 107-112

To link to this article: http://dx.doi.org/10.1080/13803395.2011.625352

JOURNAL OF CLINICAL AND EXPERIMENTAL NEUROPSYCHOLOGY
2012, 34 (1), 107–112

Psychology Press
Taylor & Francis Group

Aging and temporal order memory: A comparison of direct and indirect measures

Haya Blachstein[1], Yoram Greenstein[2], and Eli Vakil[1]

[1]Department of Psychology and Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel
[2] Kinneret Academic College, Zefat Academic College, Kibbutzim College of Education, Tel Aviv, Israel

The purpose of the present study is to compare the effect of aging on direct and indirect measures of temporal order memory, derived from the Rey Auditory Verbal Learning Test (AVLT). The spontaneous order in which the list was recalled in Trial 5 served as the indirect measure, and the explicit reordering of the words into their original order of presentation (i.e., Trial 10) served as the direct measure. Based on previously reported norms ($n = 528$) on the Rey AVLT, the effects of age (20–91 years) on the two measures of temporal order were analyzed. The results demonstrated that the direct measure was much more sensitive to the effect of age than the indirect measure. Furthermore, the direct measure was more significantly correlated with other verbal memory measures derived from the Rey AVLT. These results are consistent with studies that have documented that the frontal lobes, implicated in temporal memory, show the most significant degenerative changes over the years. As a result, the effortful and direct cognitive tasks in general and particularly in memory are more vulnerable to the effects of aging. These results lend further support to the dissociation between direct and indirect measures of memory in older adults. These temporal order measures, which are not usually assessed in standard batteries, could now be derived from a standard, frequently used test (i.e., Rey AVLT) and increase its diagnostic value.

Keywords: Aging; Temporal order; Rey Auditory Verbal Learning Test; Memory development.

The memory of an episode is complex. It contains the memory of an event, as well as the temporal, perceptual, and spatial context in which the event took place; we remember not only what happened, but also when and where it happened, and what preceded and followed this event (Cabeza, Anderson, Houle, Mangels, & Nyberg, 2000; Czernochowski, Fabiani, & Friedman, 2008; Fouquet, Tobin, & Rondi-Reig, 2010; Vakil & Blachstein, 1994). The memory of these spatial, temporal, and perceptual features is referred to as source or context memory (the "when, where, how" memory) as opposed to the item or content memory (the "what" memory, Cabeza et al., 2000; Gagnon, Soulard, Brasgold, & Kreller, 2007). This contextual memory has been repeatedly dissociated, both experimentally and clinically, from the memory of the event itself (Czernochowski et al., 2008; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991).

Regarding the neural substrate of contextual/source memory, patients with frontal lobe lesions made more errors in recalling the source of an item and did not differ from elderly persons (Janowsky, Shimamura, & Squire, 1989). Similar findings were found in temporal memory and recency judgment tasks (Cabeza et al., 2000; Craik, Morris, Morris, & Loewen, 1990). Imaging studies have found an increased activation of the prefrontal area (prefrontal cortex, PFC; especially the dorsolateral) during spatial and temporal contextual memory tasks (Cabeza et al., 2000; Czernochowski et al., 2008; Rajah, Crane, Maillet, & Floden, 2011; Rajah, Languay, & Valiquette, 2010; Rajaha &

This study was carried out as part of a PhD dissertation by Haya Blachstein at Bar Ilan University, Ramat Gan, Israel.

Address correspondence to Eli Vakil, Department of Psychology, Bar-Ilan University, Ramat-Gan, 52900 Israel (E-mail: vakile@mail.biu.ac.il).

http://www.psypress.com/jcen http://dx.doi.org/10.1080/13803395.2011.625352

McIntosh, 2008; St. Jacques, Rubin, LaBar, & Cabeza, 2008).

Numerous studies have shown that elderly persons perform more poorly on contextual memory tasks than do younger persons and than on other memory tasks, indicating that old people have difficulty associating an event with a context and in retrieving contextual information (Craik et al., 1990; Dennis et al., 2008; Dumas & Hartman, 2003; Spencer & Raz, 1995). In a reality monitoring paradigm, aging participants made more false attributions of actions to incorrect sources and confused different sources of information (Cohen & Faulkner, 1989). Fabiani and Friedman (1997) have found that elderly participants performed at a chance level when required to cope with a recency judgment task, but had no difficulty in a recognition task. Similar findings were reported by Rajaha and McIntosh (2008) and Rajah et al. (2010). Golomb, Peelle, Add, Kahana, and Wingfield (2008) have found that older persons showed marked difficulty recalling the correct order of words presented to them; an analysis of serial position curves showed less use of temporal context by these individuals and that these temporal associations were less efficient. These older persons used more semantic associations, which are less helpful in a temporal order task, according to the authors. A recent meta-analysis carried out by Old and Naveh-Benjamin (2008) showed clear effects of age on memory of source, context, temporal order, and spatial location, in both verbal and nonverbal modalities. The frontal lobes show the most significant degenerative changes over the years (Fabiani & Friedman, 1997; Raz et al., 1997). Imaging studies of aging persons during contextual memory tasks have pointed to an abnormal pattern of activation of the frontal area (Cabeza et al., 2000). Czernochowski et al. (2008), using event-related recordings, also found that various brain regions, other than the PFC, were activated during recency judgments in older participants, perhaps as a compensatory effort for poorer functioning of the PFC area.

Measures of contextual memory may be direct (i.e., as in source memory tests) or indirect (i.e., context effect). Several studies conducted in our laboratory have demonstrated that direct, but not indirect, tests of context are age sensitive (Vakil, Golan, Grunbaum, Groswasser, & Aberbuch, 1996; Vakil & Tweedy, 1994; Vakil, Weise, & Enbar, 1997).

The purpose of the present study is to compare the effects of aging on direct and indirect measures of temporal order memory extracted from the Rey Auditory Verbal Learning Test (AVLT; Rey, 1964). The advantages in using the Rey AVLT for testing the effects of aging on direct and indirect measures of temporal order memory are twofold: First, this test is frequently used in neuropsychological batteries, and a variety of verbal memory measures may be derived from it. The addition of the direct and indirect temporal order measures would add to the test's diagnostic value by enabling the comparison of these measures to the other memory measures extracted from the test. The second advantage in using the Rey AVLT is that we benefit from our data bank of the normative sample. This sample consists of 528 of individuals ranging in age from 21 to 91 years (Vakil & Blachstein, 1997).

In Vakil and Blachstein (1994), we first reported on the supplementary measure of temporal order extracted from the Rey AVLT. Furthermore, in the normative studies for adults (Vakil & Blachstein, 1997) as well as for children (Vakil, Blachstein, & Sheinman, 1998), age norms for this measure were reported. One way to calculate the temporal order score is to compute the Pearson product–moment correlation between the original order and the order as reported by the participant. A comparison of several measures of temporal memory in the Rey AVLT has revealed that this Pearson correlation is more accurate and contributes a unique variance. This score was found to load on a retrieval factor, together with measures of recognition, best learning, delayed recall, retroactive interference, and total learning (Vakil & Blachstein, 1993). The correlation of this score with learning rate was low, indicating that it reflects long-term retention and retrieval, and not acquisition (Vakil & Blachstein, 1994).

In the present study, in addition to the direct measure, we generated an indirect measure of temporal order memory. It consists of the order in which the words were spontaneously recalled in the fifth trial, as compared to the order in which the words were read originally. The score is the Pearson product–moment correlation between the two. Preceding this trial, during learning and recall phases, participants were told that temporal order was not important in reporting the words recalled. The rationale for doing it this way is that previous studies have demonstrated that participants take advantage of the consistency of the repeated order in which the words are read. Learning rate across repeated learning trials was steeper when the words were read in a fixed than in a varied order (Vakil et al., 1997). The spontaneous recall in the fifth trial was chosen because it is the last trial in which the list was read to participants, thus providing maximum exposure to the temporal order of the list. Furthermore, in this way the comparison of the indirect and direct tests of temporal order was now

equated in terms of the number of repetitions of the list before test.

In a previous study when the direct (or intentional) and indirect (or incidental) measures of temporal order extracted from the Rey AVLT were compared, we found that the former but not the latter was sensitive to head trauma (Vakil, Blachstein, & Hoofien, 1991). Similarly, we hypothesize that the direct, but not the indirect, measure of temporal order would be found to be age sensitive.

METHOD

The temporal order measures analyzed in the present study are derived from the normative adults' Rey AVLT data published by Vakil and Blachstein (1997).

Participants

The 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 70–91 years. Mean education, as measured by years of schooling, was 13.65, 14.00, 13.42, 13.42, 12.59, and 12.47, respectively, for the six age cohorts. The educational difference between the groups reached significance, $F(5, 527) = 4.06$, $p < .001$. Follow-up analysis indicates that the difference between the youngest adult groups (mean years of education = 13.85) and the oldest groups (12.53) is the source of the significant difference. This is probably due to the fact that many of the elderly were immigrants and at the time did not have an opportunity to receive higher education. Thus, in this case it is reasonable to assume that the difference does not necessarily reflect lower cognitive abilities. As reported in our original adults' norms paper (Vakil et al., 1997): "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" (p. 358). The younger participants were volunteers who responded to advertisements placed at Bar-Ilan University (Israel) and in 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 citizen participants were referred by social workers, who judged them as nondemented 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). The majority of the participants cooperated fully, and the number of dropouts was negligible.

Tests and procedure

The Rey AVLT

The Hebrew version of the Rey AVLT was used (Vakil & Blachstein, 1997). Administration was standard, as described by Lezak, Howieson, and Loring (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.

In order to measure the ability to remember temporal order, an extra trial (Trial 10) was added to the standard administration (Vakil & Blachstein, 1994). Participants were presented with the 15 first-list words written (unlike the previous trials in which the words were read to them) in an order different from that originally presented. Participants were asked to copy the printed words in their original order, and the correlation was calculated between the subject's response order and the original presentation order of the words. The reason that the words were presented to them in writing was to extract a pure measure of memory for temporal order, which is independent of the memory of the words themselves. As mentioned above, Trial 5 data serve as the indirect measure, and Trial 10 data serve as the direct measure.

RESULTS

The temporal order scores were calculated for each participant, as Pearson product–moment correlation between the original order in which the words

were read and the order in which they were recalled in the 5th trial (i.e., indirect temporal measure) and the rearranged order on the 10th trial (i.e., direct temporal order; Vakil et al., 1991).

A mixed-design multivariate analysis of variance (MANOVA) was performed on the temporal order measures, with six age groups (20–29, 30–39, 40–49, 50–59, 60–69, 70+) and gender as between-subjects factors and the retrieval condition (indirect: Trial 5; direct: Trial 10) as a within-subjects factor. Age had a significant overall effect on performance, $F(5, 522) = 14.7$, $p < .0001$, $\eta = .12$. The two retrieval tasks were also significantly different from each other, $F(1, 522) = 88.5$, $p < .0001$, $\eta = .15$. These main effects were qualified by a two-way interaction of age by retrieval condition, $F(5, 522) = 4.3$, $p < .001$, $\eta = .04$. There were no gender differences, and no other interactions reached the significance level. The data are presented in Figure 1, separately for the different age groups, across gender. One-way analysis of variance (ANOVA) for each temporal order measure was conducted in order to detect the source of the interaction. Age group effect was found to be significant in both indirect and direct measures of temporal order, $F(5, 527) = 4.06$, $p < .001$, and $F(5, 527) = 21.01$, $p < .001$, respectively. Using the Duncan procedure, post hoc analyses of age effect on the two temporal order measures indicated that the indirect measure changed only at age 70 and above, but did not change from age 20 to age 69. On the other hand, the direct measure did not change between ages 20–39, but did change at ages 40–59, again at 60–69, and then again at age 70 and above.

Correlations

In order to analyze the relations between the two measures of temporal order and age (as a continuous measure) and with other memory measures extracted from the Rey AVLT, Pearson product–moment correlations were calculated. Consistent with the previous analyses, the correlation between age and the two retrieval measures was higher for the direct than for the indirect measure, $r(526) = -.42$, $p < .0001$, and $r(526) = -.16$, $p < .0001$, respectively. As can be seen in Table 1, the direct measure of temporal order, as compared to the indirect measure, was much more associated with other verbal memory measures.

DISCUSSION

Patient studies (Janowsky, Shimamura, & Squire, 1989) as well as imaging studies (Cabeza et al., 2000; Czernochowski et al., 2008; Rajah et al., 2011; Rajah et al., 2010; Rajaha & McIntosh, 2008; St. Jacques et al., 2008) have shown that the frontal lobes are involved in memory for temporal order. Several studies have documented that the frontal lobes show the most significant degenerative changes over the years (Fabiani & Friedman, 1997; Raz et al., 1997). Thus it is not surprising to

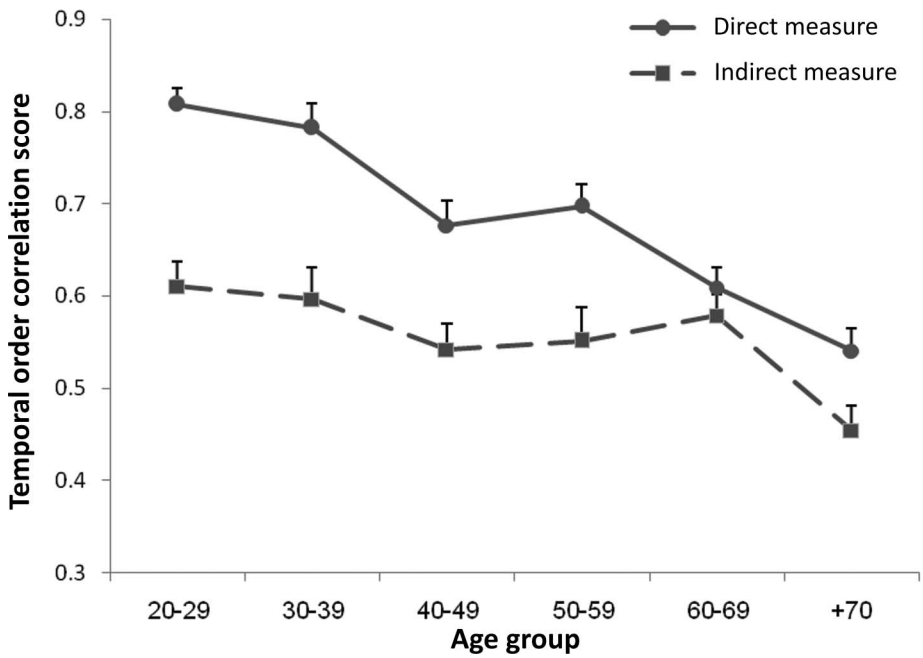

Figure 1. Direct and indirect temporal order correlation scores for the different age groups.

TABLE 1
Pearson correlations for the indirect and direct temporal order measures with other Rey AVLT scores

	Temporal order	
Rey AVLT scores	*Indirect measure*	*Direct measure*
Trial 1	.10*	.34*
Trial 5	.19*	.50**
Trial 6	.12*	.30**
Trial 7	.22**	.55**
Trial 8	.15**	.51**
Learning rate	.08	.14**
Total learning	.22**	.51**
Proactive interference	−.02	−.03
Retroactive interference	−.15**	−.31**
Retention	−.05	−.27**
Retrieval efficiency	−.14**	−.32**

Note. $N = 528$. Learning rate = Trial 5 minus Trial 1; Total learning = sum of Trials 1 through 5; Proactive interference = Trial 1 minus Trial 6; Retroactive interference = Trial 5 minus Trial 7; Retrieval efficiency = Trial 9 minus Trial 8; AVLT = Auditory Verbal Learning Test.
*$p < .05$. **$p < .01$.

find that compared to younger adults, older persons have difficulties in recalling temporal order (Craik et al., 1990; Dennis et al., 2008; Dumas & Hartman, 2003; Spencer & Raz, 1995).

In these studies, temporal order was measured directly (i.e., explicitly). In the present study, we used an indirect measure in addition to a direct measure of temporal order. As predicted, the direct measure was more sensitive to aging than the indirect measure. This finding is consistent with our previous report with patients following traumatic brain injury (TBI), in which the same exact measures were used (Vakil et al., 1991). These results further support the dissociation between direct and indirect measures of memory in older adults. It is important to note that unlike the indirect measure of temporal order that was extracted from the fifth trial, the direct measure of temporal order was tested after the introduction of an interference list and after a 20-minute delay. Despite these disadvantages, overall performance was better under the direct than under the indirect condition for the younger age groups (i.e., 20–59) but not for the older age groups (i.e., 60 and above).

Memory for temporal order is considered as a kind of source or contextual memory. Previous studies have demonstrated an impaired source memory (i.e., direct measure) in elderly, as compared to younger, individuals. Older adults, nevertheless, benefit equally from context reinstatement (i.e., context effect: indirect measure; Naveh-Benjamin & Craik, 1995; Vakil, Melamed, & Even, 1996). Similarly, in the present study, the fact that with age it becomes increasingly difficult to directly or explicitly retrieve temporal order does not necessarily imply that the elderly could not utilize indirect or implicit temporal order as a retrieval strategy.

One of the strengths of the present study is the fact that the two temporal order measures were derived from a test frequently used in neuropsychological batteries (i.e., Rey AVLT). Thus, these measures, which are not usually assessed in standard batteries, could now be derived from a standard and frequently used test. Furthermore, it would enable the comparison of temporal order measures with various aspects of memory measures derived from the Rey AVLT. The other strength of the present study is that the two temporal order measures were analyzed on a very large sample ($n = 528$) derived from the normative adults' Rey AVLT data published by Vakil and Blachstein (1997).

The fact that the direct measure more than the indirect measure of temporal order was associated with other memory measures may possibly indicate that elderly persons have difficulty with effortful retrieval of the information. This conclusion is consistent with findings that the elderly have relatively preserved recognition as compared to recall (Fabiani & Friedman, 1997). Such a pattern is usually interpreted as reflecting a retrieval problem, (Cohn, Emrich, & Moscovitch, 2008; Vakil & Blachstein, 1997). Finally, the direct measure of temporal order has an important diagnostic value by being more sensitive to the aging effect than are other memory measures derived from the Rey AVLT (Vakil, Greenstein, & Blachstein, 2010; Vakil et al., 1997).

Original manuscript received 18 March 2011
Revised manuscript accepted 11 September 2011
First published online 21 November 2011

REFERENCES

Cabeza, R., Anderson, N. D., Houle, S., Mangels, J. A., & Nyberg, L. (2000). Age-related differences in neural activity during item and temporal-order memory retrieval: A positron emission tomography study. *Journal of Cognitive Neuroscience*, *12*, 197–206.

Cohen, G., & Faulkner, D. (1989). Age differences in source forgetting: Effects on reality monitoring and on eyewitness testimony. *Psychology and Aging*, *4*, 10–17.

Cohn, M., Emrich, S. M., & Moscovitch, M. (2008). Age-related deficits in associative memory: The influence of impaired strategic retrieval. *Psychology and Aging, 23*, 93–103.

Craik, F. I. M., Morris, L. W., Morris, R. G., & Loewen, E. R. (1990). Relations between source amnesia and

frontal lobe functioning in older adults. *Psychology and Aging*, *5*, 148–151.

Czernochowski, D., Fabiani, M., & Friedman, D. (2008). Use it or lose it? SES mitigates age-related decline in a recency/recognition task. *Neurobiology of Aging, 29*, 945–958.

Dennis, N. A., Hayes, S. M., Prince, S. E., Madden, D. J., Huettel, S. A., & Cabeza, R. (2008). Effects of aging on the neural correlates of successful item and source memory encoding. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *34*, 791–808.

Dumas, J. A., & Hartman, M. (2003). Adult age differences in temporal and item memory. *Psychology and Aging*, *18*, 573–586.

Fabiani, M., & Friedman, D. (1997). Dissociations between memory for temporal order and recognition memory in aging. *Neuropsychologia*, *35*, 129–141.

Fouquet, C., Tobin, C., & Rondi-Reig, L. (2010). A new approach for modeling episodic memory from rodents to humans: The temporal order memory. *Behavioural Brain Research*, *215*, 172–179.

Gagnon, S., Soulard, K., Brasgold, M., & Kreller, J. (2007). Effects of normal aging on memory for multiple contextual features. *Brain and Cognition*, *64*, 208–216.

Golomb, J. D., Peelle, J. E., Add, K. M., Kahana, M., & Wingfield, A. (2008). Effects of adult aging on utilization of temporal and semantic associations during free and serial recall. *Memory & Cognition*, *36*, 947–995.

Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia*, *27*, 1043–1056.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment* (4th ed.). New York, NY: Oxford University Press.

Naveh-Benjamin, M., & Craik, F. I. M. (1995). Memory for context and its use in item memory: Comparisons of younger and older persons. *Psychology and Aging*, *10*, 284–293.

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging*, *23*, 104–118.

Rajah, M. N., Crane, D., Maillet, D., & Floden, D. (2011). Similarities in the patterns of prefrontal cortex activity during spatial and temporal context memory retrieval after equating for task structure and performance. *NeuroImage*, *54*, 1549–1564.

Rajah, M. N., Languay, R., & Valiquette, L. (2010). Age-related changes in prefrontal cortex activity are associated with behavioural deficits in both temporal and spatial context memory retrieval in older adults. *Cortex*, *46*, 535–549.

Rajaha, M. N., & McIntosh, A. R. (2008). Age-related differences in brain activity during verbal recency memory. *Brain Research*, *1199*, 111–125.

Raz, N., Gunning, F. M., Head, D., Dupuis, J. H., McQuain, J., Briggs, S. D., et al. (1997). Selective aging of the human cerebral cortex observed *in vivo*: Differential vulnerability of the prefrontal gray matter. *Cerebral Cortex*, *7*, 268–282.

Rey, A. (1964). *L'examen clinique en psychologie* [Clinical examination in psychology]. Paris, France: Presses Universitaires de France.

Schacter, D. L., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1991). The relation between source memory and aging. *Psychology and Aging*, *6*, 559–568.

Spencer, W. D., & Raz, N. (1995). Differential effects of aging on memory for content and context: A meta-analysis. *Psychology and Aging*, *10*, 527–539.

St. Jacques, P., Rubin, D. C., LaBar, K. S., & Cabeza, R. (2008). The short and long of it: Neural correlates of temporal-order memory for autobiographical events. *Journal of Cognitive Neuroscience*, *20*, 1327–1341.

Vakil, E., & Blachstein, H. (1993). Rey Auditory-Verbal Learning Test: Structure analysis. *Journal of Clinical Psychology*, *49*, 883–890.

Vakil, E., & Blachstein, H. (1994). A supplementary measure in the Rey AVLT for assessing incidental learning of temporal order. *Journal of Clinical Psychology*, *50*, 240–245.

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

Vakil, E., Blachstein, H., & Hoofien, D. (1991). Automatic temporal order judgment: The effect of intentionality of retrieval on closed-head-injured patients. *Journal of Clinical and Experimental Neuropsychology*, *13*, 291–298.

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

Vakil, E., Golan, H., Grunbaum, E., Groswasser, Z., & Aberbuch, S. (1996). Direct and indirect measures of contextual information in brain-injured patients. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *9*, 176–181.

Vakil, E., Greenstein, Y., & Blachstein, H. (2010). Normative data for composite scores for children and adults derived from the Rey Auditory Verbal Learning Test. *The Clinical Neuropsychologist*, *24*, 662–677.

Vakil, E., Melamed, M., & Even, N. (1996). Direct and indirect measures of contextual information: Older versus young adult subjects. *Aging, Neuropsychology, and Cognition*, *3*, 30–36.

Vakil, E., & Tweedy, J. R. (1994). Memory for temporal order and spatial position information: Tests of the automatic–effortful distinction. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *7*, 281–288.

Vakil, E., Weise, M., & Enbar, S. (1997). Direct and indirect memory measures of temporal order: Younger versus older adults. *International Journal of Aging and Human Development*, *45*, 195–206.