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# Verbal learning and memory as measured by the Rey-Auditory Verbal Learning Test: ADHD with and without learning disabilities

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The primary purpose of the present study is to examine the effects of attention deficits, learning disability, and the combined effects of both on the learning and memory processes, as measured by the Rey Auditory Verbal Learning Test (AVLT). Thirty children (age range 12–17) diagnosed with attention deficit/hyperactivity disorder (ADHD), 18 children (age range 11–17) diagnosed with learning disabilities (LD), and 64 children (age range 12–17) diagnosed with ADHD as well as with LD, and 28, 18, and 62 matched controls, respectively, participated in this study. It was found that the children diagnosed with ADHD did not differ in any of the verbal learning and memory measures derived from the Rey AVLT. The group with LD was impaired in the overall number of words recalled across the learning phase. Performance of the children diagnosed with ADHD +LD showed a similar impairment as the group with LD (i.e., overall amount of words learned) and, in addition, their retrieval efficiency was also impaired. In conclusion, this study indicates that verbal memory is preserved in children with ADHD if they have no LD and their intelligence is in the normal range or above. LD by itself leads to difficulties in acquisition, but the combination of ADHD+LD leads to additional impairment in retrieval processes.

***Keywords:*** Verbal memory; Rey AVLT; ADHD; Learning disabilities; Attention.

Attention deficit/hyperactivity disorder (ADHD) and Learning Disabilities (LD) are the most frequent disorders diagnosed in children and adolescents. It is estimated that each disorder affects from 5% to 15% of school children, with a comorbidity rate between them ranging from 25% up to 80% (Ashkenazi, Rubinstein, & Henik, 2009; Bental & Tirosh, 2007; Jakobson & Kikas, 2007; Swanson, Mink, & Bocian, 1999). Both disorders increase the risk of lower IQ and poor academic functioning (Frazier, Youngstrom, Glutting, & Watkins, 2007). Genetics plays a major role in the etiology of both ADHD and LD (Ashkenazi et al., 2009; Geary, 2004; Kaufmann, 2008; Rosselli, Matute, Pinto, & Ardila, 2006; Shaywitz & Shaywitz, 2005).

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The most common explanations of ADHD involve deficits of executive functions, especially inhibition, working memory (WM), planning, and self-monitoring (see a review by Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Numerous studies have shown that WM is deficient in ADHD individuals, with verbal WM being better, worse, or equal to visual-spatial WM (e.g., Brocki, Randall, Bohlin, & Kerns, 2008). Working memory performance in ADHD individuals was characterized by intrusions, most probably reflecting an inhibition deficit (Cornoldi et al., 2001). Based on neuropsychological testing and brain-imaging data, several authors have suggested that ADHD results from a right hemisphere dysfunction, afflicting mainly the prefrontal cortex and striatum (Stefanatos & Wasserstein, 2001).

LD have been attributed to language deficits, specifically deficient phonological processing, phonological awareness, and slow naming (Bogliotti, Serniclaes, Messaoud-Galusi, & Sprenger-Charolles, 2008; Katzir, Kim, Wolf, Robin, & Lovett, 2008). LD, especially reading disorder (RD)[1], is considered by many investigators to be a left hemisphere syndrome, resulting from dysfunction of the angular and superior temporal gyri, among other areas (Shaywitz & Shaywitz, 2005). There is a high comorbidity rate among the different learning disabilities; Mayes and Calhoun (2007) have reported that 43% of their sample of children with Disorder of Written Expression had RD and/or Mathematics Disorder; while only 4% of the sample had RD alone or Mathematics Disorder alone.

Support for the distinction between executive function deficits in ADHD and language deficits in LD comes from numerous studies; for example, Pennington, Groisser, and Welsh (1993) have found that RD and RD+ADHD participants performed poorly on phonological processing tasks but performed normally on executive function tasks; the ADHD (without RD) participants showed the opposite trend, indicating a dissociation of RD and ADHD. ADHD individuals were found to suffer from executive function deficits, LD individuals showed difficulties on phonological tasks, and the combined group (ADHD+LD) showed more severe executive function deficits (Seidman, Biederman, Monuteaux, Doyle, & Faraone, 2001). Semrud-Clikeman, Guy, and Griffin (2000) also reported that LD individuals showed specific deficits in naming, while the ADHD group showed marked difficulty in sustained attention.

Not all studies support the dissociation of ADHD-LD in terms of deficient processes. It has been claimed by several researchers that both disorders also share some common deficits, such as poor WM and deficits of executive functions. Swanson et al. (1999) have found that individuals suffering from ADHD also showed some phonological deficits and LD individuals also showed several executive function deficits. Individuals with RD showed deficits in response inhibition and verbal WM; ADHD individuals had difficulties in some reading tasks and also on verbal WM tasks (Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Numerous studies have revealed that working memory and executive functions were related to planning, inhibition, attention switching, and self-monitoring and also to reading, arithmetic, writing, and academic performance in general (Alloway, Gathercole, Willis, & Adams, 2004; Altemeier, Abbott, & Berninger, 2008; Biederman et al., 2006; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Swanson & Alexander, 1997).

WM and executive functions contribute to attention and academic performance in several ways. Executive functions (especially inhibition) determine the content of WM by affecting the selection of relevant information to be stored in WM; a lack of such inhibition

[1] The use of LD and RD in the text here follows the terms used by the authors in the research cited.

causes intrusions of irrelevant information and distractibility, which also affect the reading process (Brocki et al., 2008; Palladino, 2006). Limited WM capacity may also be related to distractibility, leading to loss of information, interfering with sustained attention, and creating irrelevant responses (Gathercole et al., 2008). WM capacity is also related to reading, because during reading several processes take place simultaneously, requiring storage, active manipulation, and comprehension of the text (Swanson & Alexander, 1997). It has also been argued that individuals with RD are deficient in the phonological loop component of WM, and individuals with ADHD are deficient on the Central Executive component (reviewed by Roodenrys, Koloski, & Grainger, 2001).

The Rey Auditory Verbal Learning Test (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 a distractor list (Trial 6) followed by recall of the first list (Trial 7). After a delay, participants are once more asked to recall the first list (Trial 8) followed by a recognition task (Trial 9). Unlike the California Verbal Learning Test (CVLT), a test similar to the Rey AVLT, in the latter, the word list consists of 15 unrelated words that make it difficult to cluster them together.

### Memory Studies of Verbal List Learning in ADHD

It has been claimed that memory performance in ADHD is intact when the task is simple (such as unordered recall), and no continuous effort or executive functions are required. In addition, it has been claimed that these individuals use "simpler" memory strategies such as rote rehearsal, and less organization or clustering. Also, performance is better on immediate recall but deteriorates when time delay is imposed. Intrusions may also be found, attributed to impulsivity or poor memory strategies (Cornoldi, Barbieri, Gaiani, & Zocchi, 1999; Douglas & Benezra, 1990; French, Zentall, & Bennett, 2003).

On the CVLT children with ADHD without RD differed from matched controls only in the delayed recall trials. Boys performed worse than girls, used less semantic clustering and recalled less from the middle of the list. Difficulties emerged also in recognition, because of a tendency to perseverate in saying a "no" response (Cutting, Koth, Mahone, & Denckla, 2003; Loge, Staton, & Beatty 1990). Intrusions and recognition difficulties on the CVLT were also found by Muir-Broaddus, Rosenstein, Medina, and Soderberg (2002). Performance on this test by individuals with ADHD was related to executive function deficits (Biederman et al., 2006).

### Memory Studies of Verbal List Learning in LD

Kramer, Knee, and Delis (2000) analyzed the performance of individuals with RD on the CVLT and found poor performance on Trials 2 and 5 and, during recognition, slower learning rate, more semantic false-positive errors, and fewer words recalled from the middle of the list. No indications of increased sensitivity to interference were found.

On an abbreviated version of the Rey AVLT, van Strien (1999) found in RD children that fewer words were recalled and recognized, as compared to controls, with no primacy effect.

### Memory Studies of Verbal List Learning in ADHD + LD

Most studies comparing ADHD, LD, and ADHD+LD have found that the combined group shows an additive difficulty leading to worse performance, as compared to the other two groups. For example, Purvis and Tannock (1997) have found on a test of story recall that individuals with ADHD had difficulties in organization and monitoring, attributed to executive function deficits, with no difference in recall. Individuals with RD showed language deficits, whereas the combined group showed all deficits combined. On the Wide Range Memory and Learning Test (WRAML), the combined groups (ADHD+ Mathematics Disorder and ADHD+RD) achieved a lower total score, as compared to the ADHD-alone group and healthy controls. However, no differences were found among ADHD+LD groups and controls on the CVLT (Seidman et al., 2001). Willcutt et al. (2001, 2005) have found that the combined group (ADHD+RD) had all the deficits of the individual groups (on measures of reading, WM, processing speed, language, response inhibition, set shifting, and phonological awareness).

The combined group performance was found to be affected by the number of presentations. Kaplan, Dewey, Crawford, and Fisher's (1998) study of the WRAML found that individuals with ADHD, RD, and ADHD+RD performed more poorly than controls on most measures after a delay; however, there were no differences among the groups on tests that were based on several presentation trials. On a test with a single trial (story recall), individuals with RD and RD+ADHD forgot more than controls and ADHD. The authors concluded that a single trial is not enough for individuals with RD to encode the material efficiently, because of an underlying verbal deficit.

Comparing ADHD and ADHD+LD on several memory tests has revealed that the combined group lost more information, had more intrusions and showed more sensitivity to verbal interference on tasks of visual unordered short-term memory and auditory unordered long-term memory. The ADHD-only group performed normally on the visual unordered task (Webster, Hall, Brown, & Bolen, 1996). Individuals with ADHD and ADHD+LD performed poorly on word, object, and spatial relation memory tests, while the ADHD group did not differ from the controls on sentence memory (Jakobson & Kikas, 2007). In groups of LD with and without ADHD, there were difficulties in ordered delayed recall, but performance on nonordered recall and ordered immediate recall was normal. The group of ADHD+LD was poor in visual memory (both ordered and nonordered) and worst in auditory-ordered memory (Kataria, Hall, Wong, & Keys, 1992).

On the Rey AVLT, comparing individuals with RD with and without ADHD, only ADHD had an effect on Trials 1, 5, and 7. Individuals with RD were poor in naming and language tests only (Felton, Wood, Brown, & Campbell, 1987). Looking only at the total score of the Rey AVLT, Robins (1992) did not find any differences among the ADHD, RD, and the combined group. It has been claimed that the repetitions of the word lists have eliminated the difference; a single trial might have revealed a disadvantage of the clinical groups.

### The Present Study

The primary goal of the present study was to study the effects of attention deficits and learning disabilities, separately as well as combined, on verbal learning and memory processes as measured by the Rey AVLT. We decided to separate the groups with ADHD only, LD only, and ADHD+LD, so we could test separately the effect of attention deficits and the additive effect of LD on verbal list learning and memory. The Rey AVLT offers a unique opportunity to examine the processes of acquisition, interference, retention, and retrieval. Such an approach would enable us to assess the effects of ADHD and LD separately as well as when combined on verbal memory.

## METHODS

### Participants

The ADHD group consisted of 30 participants; the LD group consisted of 18 participants and the ADHD+LD group consisted of 64 participants. The ADHD, LD, and ADHD+LD participants consisted of children and adolescents, referred to a pediatric neurology clinic at a major teaching hospital, serving mainly the larger Jerusalem area of Israel. The clinic consists of a multidisciplinary team, including pediatric neurologists, a psychiatrist, developmental psychologists, a neuropsychologist, and an occupational therapist. A subgroup of the LD participants ($n = 11$) were referred to Haddad Center for Dyslexia and Learning Disabilities at Bar Ilan University, Israel. All children were referred by parents or school counselors due to learning and/or attention difficulties at school and/or at home. At the clinics, all the children undergo a comprehensive assessment. For some of the participants, school records and reports were available. About 34% of the participants were diagnosed in the past as suffering from ADHD, LD, or ADHD+LD by other centers. Since their present referral was intended mainly to decide about medication needs, therefore, some of the school data were not available to us. Participants were excluded from the study if there were indications of active psychiatric or physical illness, head trauma, epilepsy, tic disorders, cerebral palsy, mental retardation, or administration of medication. In addition, 11 participants diagnosed as having a Nonverbal Learning disability were also excluded.

The diagnosis of ADHD was based on a structured scale, corresponding to the *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (*DSM-IV*) criteria, that was constructed in the clinic. The scale was filled out by the participant, the parent, the pediatric neurologist, or the neuropsychologist. Only children satisfying the *DSM-IV* ADHD criteria were included in the present study, that is, at least six of the inattention and/or hyperactivity-impulsivity symptoms. Detailed demographic data of the ADHD group are displayed in Table 1.

**Table 1** Background Data of the ADHD and Control Groups.

| Group | ADHD ($n = 30$) | Controls ($n = 28$) | Comparison |
|---|---|---|---|
| Age (Mean ± *SD*) | 14.4 ± 1.5 | 14.2 ± 1.4 | $t(56) = 0.5$, *ns* |
| Age Range | 12–17 | 12–16 | |
| Boys | 14 (47%) | 14 (50%) | $\chi^2(1) = 0.1$, *ns* |
| Old Assessment | 4 (13.3%) | | |
| Full Scale IQ | 110.1±14.3 | | |
| Full Scale IQ Range | 74–128 | | |

The LD group consisted of children diagnosed as suffering from various verbal and or mathematical deficiencies for which an attentional deficit was excluded. The diagnosis of Reading Disability was based on a test of reading decoding used in Israel (Ben-Dror, Shani, & Deutsch, 1997). A score of at least one standard deviation below the mean was indicative of reading disability as commonly practiced in Israel (see, Amitay, Ben-Yehudah, Banai, & Ahissar, 2002; Katzir, Shaul, Breznitz, & Wolf, 2004).

The diagnosis of Mathematics Disorder was based on previous assessments or on performance of exercises and problems appropriate for the participant's age and class (the only mathematics normative test at the time of the assessment had norms up to age 12 years). The diagnosis of Disorder of Written Expression was based on a previous assessment or on a functional assessment of the participant's spelling, punctuation, and paragraph organization; significant difficulties in any of these domains indicated the existence of the disorder. The diagnosis of the 11 individuals from the Haddad Center was based on a different linguistic battery that included tests for visuographomotor abilities, phonological awareness, oral expression, picture and verbal naming, basic reading and basic writing, reading speed, reading comprehension, written expression, foreign language, and mathematics. The tests were administered in Hebrew with local norms. All the children in this group suffering from reading disorder showed deficient phonological processing, phonological awareness, and slow naming. The inclusion criteria for the LD group were that the individual had significant difficulties in at least four of these domains to indicate the existence of the disorder. The frequency of additional deficits of the participants in this group is presented in Table 2.

The ADHD+LD group consisted of children diagnosed as suffering from ADHD (fulfilling the criteria listed above with the ADHD group) and the criteria of LD described above. The frequency of additional linguistic deficits of the participants in this group is presented in Table 3.

**Table 2** Background Data of the LD and Control Groups.

| Group | LD ($n = 18$) | Controls ($n = 18$) | Comparison |
|---|---|---|---|
| Age (Mean ± *SD*) | 13.3 ± 1.8 | 12.9 ± 1.5 | $t\,(34) = 0.72$, *ns* |
| Age Range | 11–17 | 11–16 | |
| Boys | 11 (61%) | 13 (72%) | $\chi^2(1) = 0.5$, *ns* |
| Old Assessment | 4 (22%) | | |
| Single LD | 9 (50%) | | |
| RD | 7 | | |
| WED | 1 | | |
| AD | 1 | | |
| Multiple LDs | 9 (50%) | | |
| RD and Foreign language Deficiency | 1 | | |
| RD and WED | 6 | | |
| WED and AD | 1 | | |
| RD, WED and AD | 1 | | |
| Full Scale IQ* | 102.6 ± 5.3 | | |
| Raven ** | 75th percentile and superior | | |

*Note.* AD = Arithmetic Disorder; WED = Written Expression Disorder.
*The subgroup of Neuropediatric Unit, Shaare Zedek ($n = 7$). **The subgroup of Haddad Center ($n = 11$).

**Table 3** Background Data of the ADHD+LD and Control Groups.

| Group | ADHD+LD ($n = 64$) | Controls ($n = 62$) | Comparison |
|---|---|---|---|
| Age (Mean ± *SD*) | 13.5 ± 1.8 | 13.4 ± 1.7 | $t(124) = 0.4$, *ns* |
| Age Range | 11–17 | 11–16 | |
| Boys | 52 (81%) | 50 (81%) | $\chi^2(1) = 0.01$, *ns* |
| Previous Assessment | 31 (48%) | | |
| ADHD+ single LD | 18 (28%) | | |
| ADHD +RD | 6 | | |
| ADHD + WED | 8 | | |
| ADHD + AD | 4 | | |
| ADHD + multiple LDs | 46 (72%) | | |
| ADHD+RD and AD | 3 | | |
| ADHD+RD and WED | 8 | | |
| ADHD+AD and WED | 4 | | |
| ADHD + RD and AD and WED | 31 | | |
| Full Scale IQ | 105.1±12.3 | | |
| Full Scale IQ Range | 82–139 | | |

*Note.* AD = Arithmetic Disorder; WED = Written Expression Disorder.

The control participants (randomly chosen from the normative data base, matched for age and gender to each one of the clinical groups) were selected from a population of children in 14 public schools in central Israel, whose data was published in the past, as part of a normative study of the Rey AVLT (Vakil et al., 1998). 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 attention 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 control and clinical samples.

### 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, Howieson, and Loring (2004). The test consists of 15 unrelated 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

The ADHD, LD, and ADHD+LD groups were analyzed separately, because of different age and gender distribution. Therefore, a different control group was matched to each of the clinical groups. For the same reason, the clinical groups were not compared directly to each other but rather to their respective control groups. The verbal memory processes, as reflected in several Rey AVLT measures, were analyzed in each group.

### The ADHD Group

**Learning Rate: Trials 1–5.** A mixed-design analysis of variance (ANOVA) was performed on the Rey AVLT first five learning trials, with Group (ADHD and Controls) as a between-subjects factor and Learning Trial as a within-subjects factor. There was no significant group effect, $F(1, 56) = 0.14$, $p > .05$, $\eta^2 = .003$. There was a significant increase in the number of words recalled from trial to trial, $F(4, 224) = 169.4$, $p < .0001$, $\eta^2 = .75$. The interaction did not reach significance, $F(4, 224) = 1.2$, $p > .05$, $\eta^2 = .02$, suggesting that the learning rate of the groups was similar (see Figure 1).

**Proactive Interference: Trial 6 versus Trial 1.** No difference was found between the two groups in the number of words recalled in both Trials 1 and 6, $F(1, 56) = 0.03$, $p > .05$, $\eta^2 = .02$. The number of words recalled in Trial 6 was significantly lower than the number of words recalled in Trial 1, $F(l, 56) = 18.9$, $p < .0001$, $\eta^2 = .25$, indicating a proactive interference. The interference was equal for both groups, as indicated by the nonsignificant interaction, $F(l, 56) = 1.0$, $p > .05$, $\eta^2 = .02$.

**Retroactive Interference: Trial 5 versus Trial 7.** There was no difference between the groups in the number of words recalled in these two trials, $F(l, 56) = 0.87$, $p > .05$, $\eta^2 = .01$. The number of words recalled in Trial 7 was significantly lower than the number of words recalled in Trial 5, $F(l, 56) = 48.2$, $p < .0001$, $\eta^2 = .46$, indicating

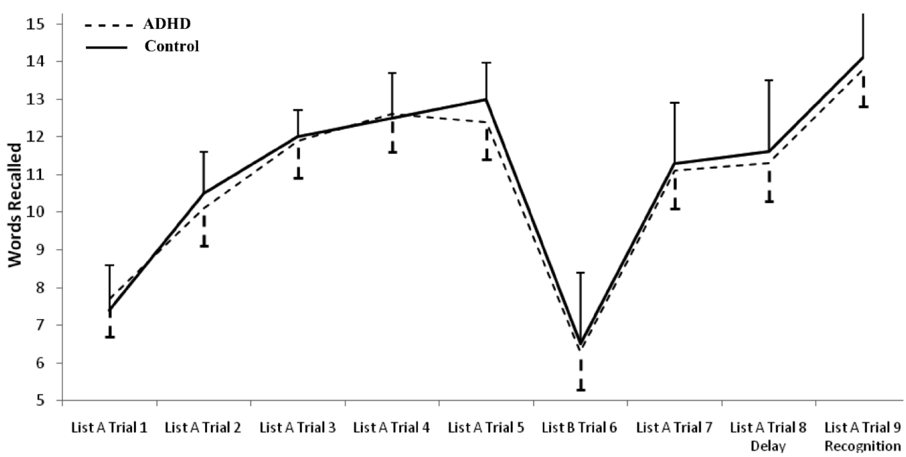


**Figure 1** Mean number of words recalled in the various trials of the Rey AVLT and standard deviation, by participants with ADHD and matched controls.

a retroactive interference. Both groups were similarly sensitive to the interference as indicated by the nonsignificant interaction, $F(1, 56) = 0.88$, $p > .05$, $\eta^2 = .01$.

**Retention: Trial 5 versus Trial 8.** The groups did not differ significantly on the number of words recalled in the fifth and the eighth (delayed recall) trials of the task, $F(1, 53) = 1.2$, $p > .05$, $\eta^2 = .021$. Fewer words were recalled in the delayed trial as compared to the fifth trial, $F(1, 53) = 28.4$, $p < .0001$, $\eta^2 = .35$. The forgetting rate of the two groups was similar, as the Group by Delay interaction did not reach significance, $F(1, 53) = 0.89$, $p > .05$, $\eta^2 = .02$.

**Retrieval Efficiency: Delayed Recall (Trial 8) versus Recognition (Trial 9).** Overall the groups did not significantly differ in the total number of words remembered in Trials 8 and 9, $F(1, 44) = 3.6$, $p > .05$, $\eta^2 = .07$. More words were recognized in Trial 9 than recalled in Trial 8, $F(1, 44) = 145.0$, $p < .0001$, $\eta^2 = .77$. The nonsignificant interaction indicates that this advantage was similar for both groups, $F(1, 44) = 3.3$, $p > .05$, $\eta^2 = .07$.

In summary, as reflected in Figure 1, the children with ADHD did not differ in any one of the verbal learning and memory measures derived from the Rey AVLT.

### The LD Group

**Learning Rate: Trials 1–5.** A mixed-design ANOVA was performed on the Rey AVLT first five learning trials, with Group (LD and Controls) as a between-subjects factor and Learning Trial as a within-subjects factor. There was a significant group effect, indicating that overall the LD group recalled less than the control group, $F(1, 34) = 6.72$, $p < .05$, $\eta^2 = .16$. There was a significant increase in the number of words recalled from trial to trial, $F(4, 136) = 111.9$, $p < .0001$, $\eta^2 = .77$. The interaction did not reach significance, $F(4, 136) = 2.31$, $p > .05$, $\eta^2 = .06$, suggesting that the learning rate of the groups was similar (see Figure 2).

**Proactive Interference: Trial 6 versus Trial 1.** No difference was found between the two groups in the number of words recalled in both Trials 1 and 6, $F(1, 34) = 2.29$, $p > .05$, $\eta^2 = .06$. The number of words recalled in Trial 6 was significantly lower than the number of words recalled in Trial 1, $F(1, 34) = 5.40$, $p < .05$, $\eta^2 = .14$, suggesting a proactive interference. The extent of interference was the same for both groups, as indicated by the nonsignificant interaction, $F(1, 34) = 0.08$, $p > .05$, $\eta^2 = .002$.

**Retroactive Interference: Trial 5 versus Trial 7.** There was no difference between the groups in the number of words recalled in these two trials, $F(1, 34) = 1.11$, $p > .05$, $\eta^2 = .03$. The number of words recalled in Trial 7 was significantly lower than the number of words recalled in Trial 5, $F(1, 34) = 19.71$, $p < .0001$, $\eta^2 = .37$, indicating a retroactive interference. Both groups were similarly sensitive to the interference as indicated by the nonsignificant interaction, $F(1, 34) = 0.61$, $p > .05$, $\eta^2 = .02$.

**Retention: Trial 5 versus Trial 8.** The groups did not differ significantly on the number of words recalled in the fifth and the eighth (delayed recall) trials of the task, $F(1, 34) = 1.0$, $p > .05$, $\eta^2 = .03$. Overall, fewer words were recalled in the delayed trial as compared to the fifth trial, $F(1, 34) = 24.6$, $p < .0001$, $\eta^2 = .42$. The forgetting rate of the two groups was similar, as the Group by Delay interaction did not reach significance, $F(1, 34) = 0.36$, $p > .05$, $\eta^2 = .01$.

**Retrieval Efficiency: Delayed Recall (Trial 8) versus Recognition (Trial 9).** Overall the groups did not significantly differ in the total number of words remembered in Trials 8 and 9, $F(1, 33) = 2.08$, $p > .05$, $\eta^2 = .06$. More words were recognized in Trial 9 than recalled in Trial 8, $F(1, 33) = 76.77$, $p < .0001$, $\eta^2 = .70$. This advantage was similar for both groups, as indicated by the nonsignificant interaction $F(1, 33) = 0.17$, $p > .05$, $\eta^2 = .01$.

In summary, as reflected in Figure 2, the children with LD did not differ in any one of the verbal learning and memory measures derived from the Rey AVLT with the exception of a generally lower number of words recalled across the five learning trials.

### The ADHD + LD Group

**Learning Rate: Trials 1–5.** A mixed-design ANOVA was performed on the Rey AVLT first five trials, with Group (ADHD+LD, Controls) as a between-subjects factor and Learning trial as a within-subjects factor. There was a significant group effect, $F(1, 124) = 18.3$, $p < .0001$, $\eta^2 = .13$, indicating that that control group recalled overall more words than the ADHD+LD group. There was a significant increase in the number of words recalled from trial to trial, $F(4, 496) = 524.4$, $p < .0001$, $\eta^2 = .81$. The interaction did not reach significance, $F(4, 496) = 1.2$, $p > .05$, $\eta^2 = .01$, indicating that the learning rate of the groups was similar (see Figure 3).

**Proactive Interference: Trial 6 versus Trial 1.** A marginal difference was found between the two groups in the number of words recalled in both Trials 1 and 6, $F(1, 124) = 3.8$, $p < .053$, $\eta^2 = .03$. The number of words recalled in Trial 6 was significantly lower

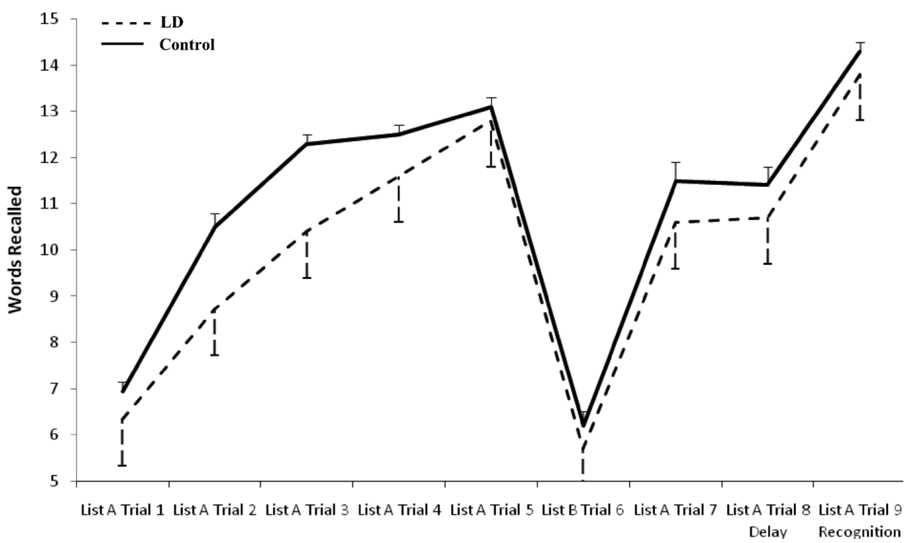


**Figure 2** Mean number of words recalled in the various trials of the Rey AVLT and standard deviation, by participants with LD and matched controls.

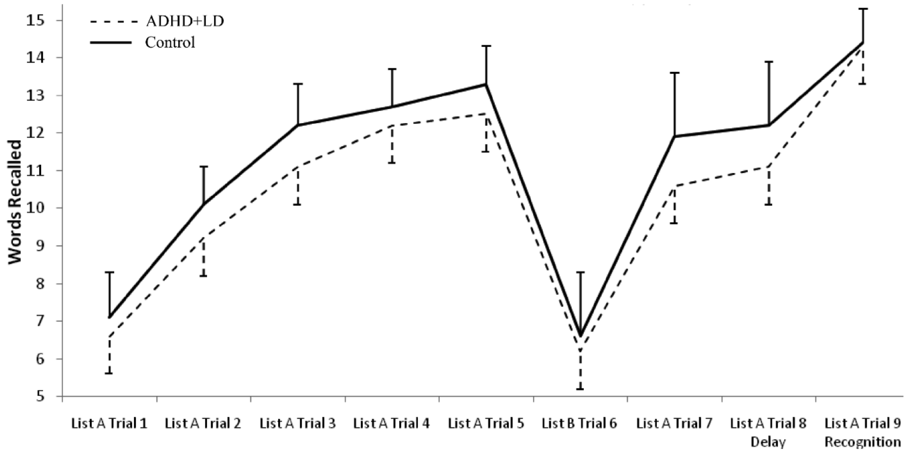


**Figure 3** Mean number of words recalled in the various trials of the Rey AVLT and standard deviation, by participants with ADHD+LD and matched controls.

than the number of words recalled in Trial 1, $F$(l, 124) = 5.5, $p < .02$, $\eta^2 = .04$, indicating a proactive interference. The extent of interference was similar for both groups, as indicated by the nonsignificant interaction, $F$(l, 124) = 0.10, $p > .05$, $\eta^2 = .001$.

**Retroactive Interference: Trial 5 versus Trial 7.** There was a significant difference between the groups in the number of words recalled in these two trials, $F$(l, 123) = 14.4, $p < .0001$, $\eta^2 = .11$. Also, the number of words recalled in Trial 7 was significantly lower than the number of words recalled in Trial 5, $F$(l, 123) = 93.7, $p < .0001$, $\eta^2 = .43$, indicating a retroactive interference. Both groups were similarly sensitive to the interference as indicated by the nonsignificant interaction, $F$(1, 123) = 2.4, $p > .05$, $\eta^2 = .02$.

**Retention: Trial 5 versus Trial 8.** The groups differed significantly on the number of words recalled in the fifth and the eighth (delayed recall) trials of the task, $F$(l, 115) = 13.9, $p < .0001$, $\eta^2 = .11$. Overall, fewer words were recalled in the delayed trial as compared to the fifth trial, $F$(l, 115) = 46.9, $p < .0001$, $\eta^2 = .29$. The interaction of Group by Delay was not significant, $F$(l, 115) = 0.37, $p > .05$, $\eta^2 = .003$, indicating that the forgetting rate of the two groups was similar.

**Retrieval Efficiency: Delayed Recall (Trial 8) versus Recognition (Trial 9).** There was a significant difference between the groups in the total number of words remembered in Trials 8 and 9, $F$(1, 105) = 9.8, $p < .002$, $\eta^2 = .09$. More words were recognized in Trial 9 than were recalled in Trial 8, $F$(1, 105) = 264.1, $p < .0001$, $\eta^2 = .72$. The advantage of recognition over recall was larger in the ADHD+LD group than in the control group, as indicated by the significant interaction, $F$(1, 105) = 17.5, $p < .0001$, $\eta^2 = .14$. This suggests a retrieval difficulty in the ADHD+LD group.

In order to address further the question whether the severity of the LD is associated with the severity of the memory difficulties, we ran a secondary analysis in which the ADHD+LD group was divided into two subgroups: The first group had only one LD

($n = 18$), a second group had two or more LDs ($n = 46$), and a control group ($n = 62$). Overall the new results were similar to those above with two exceptions. The group with two or more LDs was significantly worse than the control group on delayed recall, $F(2, 114) = 7.51$, $p < .001$, $\eta^2 = .12$, and also showed a poorer delayed recall as compared to recognition (i.e., retrieval efficiency), as indicated by the significant Group by Retrieval interaction, $F(2, 104) = 10.39$, $p < .001$, $\eta^2 = .18$. The two ADHD+LD subgroups did not significantly differ from each other. These results suggest that poorer performance of the ADHD+LD group stems primarily from the subgroup (which is 71.88% of the group) with two or more LDs.

To summarize the ADHD+LD group data, significant differences exist between these participants and the control group, the latter recalling overall more words across trials. However, learning rate and interference show similar patterns in both groups. Regarding Retrieval Efficiency, the ADHD+LD show more retrieval deficits than the control participants.

In order to address the question whether differences in short-term memory have contributed to performance on the Rey AVLT, we reran the analyses for the ADHD and the ADHD+LD groups (Digit Span data were not available for the LD group) using the Digit Span score as covariate. These analyses yielded the same pattern of results as above.

## DISCUSSION

The primary goal of the present study was to study the effects of attention deficits and learning disabilities separately as well as combined, on verbal learning and memory processes, as measured by the Rey AVLT. Regarding the ADHD group (with no accompanying LD), we have found that these participants did not differ from matched controls on any of the measures, indicating similar encoding, storage, and retrieval processes. The group with LD was impaired compared to controls only in the overall amount of words learned in the first consecutive learning trials. The combined group, with ADHD+LD, showed an impairment similar to the group with LD (i.e., overall less words learned) and in addition their retrieval efficiency was also impaired.

The findings of the present study on children with ADHD are similar to previous findings of adults with ADHD; no differences were found in their performance on any of the Rey AVLT measures, except for double recall (repetitions, perseveration) and intrusions (new additions) (Pollak, Kahana-Vax, & Hoofien, 2008). However, our data are not fully consistent with the findings of Groom et al. (2008). In their study of Rey AVLT, adolescents with ADHD did not differ from controls on the delay and retrieval measures but recalled fewer words over the acquisition trials. One possible reason for the discrepancy is that Groom et al.'s sample had a mean IQ of 93.4, much lower than our sample (mean IQ = 110.1). Felton et al. (1987) have also reported difficulties of ADHD participants on the Rey AVLT, but their participants were younger than ours (range 8–12 years). Other studies as well found poorer performance in adult ADHD individuals. Dige and Wik (2005) and Dige, Maahr, and Backenroth-Ohsako (2008) found difficulties in their ADHD adult participants on several measures (Trial 1, total words learned, Trials 8 and 9). They also found that the combined ADHD group (hyperactivity-impulsivity with inattention) performed the worst, as compared to children with ADHD with hyperactivity-impulsivity only, and with the inattention-only group, which performed the best. It is important to note that in these studies, the participants were not screened for the possible existence of a learning disability, and that these adult participants reported significant difficulties in functioning in the present, possibly suggesting a more severe form of ADHD.

Several reasons may account for the lack of differences, in the present study, between the ADHD participants and the control group: The Rey AVLT is composed of several identical presentation trials, allowing even for highly distractible/inattentive participants to accumulate and recall words throughout the learning trials and also to minimize possible interference effects that may be more evident in ADHD. It has also been argued in the introduction that ADHD is characterized mainly by EF and WM deficits, and difficulties may arise when ADHD individuals are required to use organization or other elaborate memory strategies. The Rey AVLT, being a free recall test with several repetitions, may be less dependent on advanced memory strategies, WM, or EF. It has been claimed that ADHD is a right-hemisphere syndrome (Stefanatos & Wasserstein, 2001); the Rey AVLT, being a verbal learning and memory task, may involve mainly left-hemisphere mechanisms. In addition, we have reported in a recent study (Greenstein, Blachstein, & Vakil, 2010) that the relationships between verbal memory measures, derived from the Rey AVLT, and several attention measures were highly correlated in younger age groups (8–12) but not in the older age groups (13–17), as were the majority of ADHD participants in the present study. At these ages, memory becomes less dependent or associated with attention, thereby enabling ADHD participants to function similarly to healthy controls. This could explain why in Felton et al.'s (1987) study, in which their participants were younger than ours (range 8–12), performance of the ADHD children was impaired on several memory measures.

Difficulties in the acquisition and storage of new information are the hallmark of learning disabilities. Consistent with previous studies, the LD group has shown impairment in verbal learning. O'Donnell, Radtke, Leicht, and Caesar (1988) analyzed the performance of adults with LD on the Rey AVLT and found poor performance relative to controls on Trials 1–6 (the only trials studied). Several studies have attempted to locate the main reason for the memory deficits of LD children. Maisto and Sipe (1980) claimed that encoding processes are at fault for LD individuals in memory. O'Donnell et al. (1988) have attributed the memory difficulties to faulty storage in the long-term memory (with an intact short-term memory), due specifically to the lack of organizational strategies; Swanson (2003) claimed that capacity limitations are the source of the deficits; Bauer (1977) suggested that rehearsal and retrieval are problematic in LD individuals. McNamara and Wong (2003) have argued for a retrieval deficit, because the presentation of cues greatly facilitated the LD participants' recall. Our findings support a capacity limitation and/or rehearsal deficit explanations in the LD group.

The presence of ADHD in addition to LD resulted in a broader impairment than that observed in the pure LD or ADHD groups. In addition to the initial learning difficulties, a retrieval deficit has been detected. The prefrontal areas have been implicated in retrieval strategies and control (Fletcher & Henson, 2001; Simons, Gilbert, Owen, Fletcher, & Burgess, 2005). As mentioned in the introduction, several studies based on neuroimaging data have demonstrated dysfunction of the prefrontal areas in ADHD children (Stefanatos & Wasserstein, 2001). The present results suggest that the prefrontal dysfunction of the ADHD group was not sufficiently severe to be expressed in retrieval difficulty. When combined, however, with learning disability, the retrieval impairment emerged (particularly in the subgroup with more than one LD).

Numerous studies, some cited in the introduction, indicate the existence of significant learning and memory difficulties for verbal and visual material in the combined ADHD+LD/RD group. Purvis and Tannock (1997) have found that the ADHD+RD group performed the worst on story recall, compared to ADHD, arithmetic disorder or

RD groups. Also, on the WRAML, the combined groups (ADHD+ Mathematics Disorder and ADHD+RD) achieved a lower total score, as compared to the ADHD alone group and healthy controls. Our data are also consistent with Kaplan et al.'s (1998) study that found (using the WRAML) that the performance of individuals with RD and ADHD+RD was poorer than the control group on the Verbal Learning subtest, consisting of a random list of words repeated four times. In all their analyses, they did not find a difference between RD and ADHD+RD on the WRAML subtests; both groups performed similarly and poorly, suggesting that the RD component is more important in affecting learning and memory processes than the attention deficit by itself.

We have shown in a previous study (Greenstein et al., 2010) that verbal memory measures derived from the Rey AVLT are highly correlated with several attention measures in younger age groups (8–12), but not in the older age groups (13–17). It seems that in more advanced age groups, memory is less dependent or associated with attention processes and is associated with more advanced and efficient memory strategies, such as better retrieval, which individuals with LD lack.

The present findings also shed some light on the etiology of the comorbidity of LD and ADHD. Various authors have tried to account for this high comorbidity by attributing it to several possible mechanisms (see review and theoretical discussion by de Jong, Oosterlaan, & Sergeant, 2006 and Willcutt et al., 2001). The dissociation of ADHD and LD and the more severe deficit shown by the combined group, as found in the present report, suggest that the latter may represent a different form or a more severe form of either ADHD or RD (the "Cognitive Subtype Hypothesis") as suggested by de Jong et al. (2006). It is possible that retrieval deficits of verbal memory may be an endophenotype of a comorbid ADHD+LD group; hence, assessment of this process should be included in any neuropsychological battery of LD/ADHD individuals.

We would like to point out two limitations of the present study that should be addressed in future studies. The first is the fact that the demographic characteristics of the three clinical groups were not similar, preventing us from comparing the groups directly to each other. The other limitation of the present study is that we were unable to examine the specific contribution of the various LDs (e.g., reading, writing, mathematics, etc.) to memory performance. In order to address this question, a larger sample consisting of subgroups with various LDs is required.

In conclusion, this study indicates that verbal memory is preserved in children with ADHD if they do not have LD and their intelligence is in the normal range or above. Children with LD have difficulties in acquiring verbal material. However, if children with ADHD also suffer from LD, even if their intelligence is in the normal range or above, they are prone to have difficulties in acquisition and retrieval of verbal material.

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