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Research Article

List Memory in Young Adults with Language Learning Disability

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Abstract

Purpose: To characterize the verbal memory limitations of young adults with language learning disability (LLD).

Method: Sixteen young adults with LLD and 34 age- and education-matched controls with typical language participated in a DRM (Deese-Roediger-McDermott, Deese, 1959; Roediger & McDermott, 1995) list recall experiment. Participants listened to 12-item word lists that converged on a non-presented critical item (e.g., rain) semantically (umbrella, drench, weather, hail), phonologically (train, main, ran, wren), or dually in a hybrid list (umbrella, train, drench, main) and recalled words in no particular order. Group comparisons were made on veridical recall (i.e., words that were presented) and false recall of non-presented critical items. Recall performance was analyzed by list type and list position to examine potential differences in the quality of memorial processes.

Results: The LLD group produced fewer veridical recalls than the controls. Both groups demonstrated list type and list position effects in veridical recall. False recall of the critical items was comparable in the two groups and varied by list type in predictable ways.

Conclusion: Young adults with LLD have verbal memory limitations characterized by quantitatively low levels of accurate recall. Qualitative patterns of recall are similar to those of unaffected peers. Therefore, the memory problem is characterized by limited capacity; memorial processes appear to be intact.

Key words: adult, language learning disability, verbal memory, the DRM paradigm

People with language-based learning disability (LLD) experience difficulties with academic learning due to deficits in receptive or expressive language skills in the oral and/or written modality (Paul, 2007). In affected adults, documented residual deficits exist in speech integration (Norrix, Plante, & Vance, 2006), grammatical processing (Grunow, Spaulding, Gómez, & Plante, 2006; Plante, Gómez, & Gerken, 2002), narrative processing (Plante, Ramage, & Magloire, 2006), and comprehension of complex language (Rost & McGregor, 2012). One underlying mechanism common to each of these deficient domains is verbal memory and, indeed, weaknesses in verbal memory have also been documented (Carvajal, Altmann, & Lombardino, 2010; Isaki & Plante, 1997; Isaki, Spaulding, & Plante, 2008; Cohen-Mimran & Sapir, 2007). In this study, we aim to further our understanding of the characteristics of LLD in adulthood through the use of the false memory paradigm, a verbal list recall task that allows us to closely examine the integrity of verbal memory representations both qualitatively and quantitatively.

Verbal Memory in Adults with LLD

Verbal memory refers to the ability to recall linguistic information that is visually or auditorily encoded (Isaki et al., 2008). Verbal memory can be further differentiated into short-term memory, working memory, and long-term memory (Bjorklund, 2005). Short-term memory is defined as the temporary storage of information, whereas long-term memory is a more durable and permanent storage of information. Working memory involves both the storage and processing of information held in short-term memory. Working memory is necessary for long-term learning and ongoing higher-order cognitive functions such as comprehension and reasoning (Baddeley, 2003). Baddeley’s theory of phonological working memory is by far the most prominent theory of verbal memory. According to Baddeley (2003), the phonological loop consists of a phonological store and a subvocal rehearsal system. The phonological store is responsible for temporarily holding materials in a phonological code. This phonological code is available for only a brief period of time (approximately 2 sec), unless refreshed by the subvocal rehearsal system, which allows silent verbal rehearsal to refresh the phonologically encoded materials and keep them preserved in memory for a longer period of time.

Studies of verbal memory in young adults with LLD have almost always included college students as participants. Even among this relatively high-functioning population, individuals with LLD often perform more poorly than unaffected controls on verbal memory tasks (Cohen-Mimran & Sapir, 2007; Isaki & Plante, 1997; Isaki et al., 2008). For instance, Cohen-Mimran and Sapir (2007) found significantly poorer performance than controls in the reading-disabled group on a range of memory tasks including Digit Span Forward, Digit Span Backward, and four versions of the Working Memory Token Test which required participants to attend to two or three different dimensions (size, color, and shape) with or without temporal conjunctions (before, after) (e.g., “Press the big yellow square after you press the small black circle”, Cohen-Mimran & Sapir, 2007, p.179). On the other hand, Isaki and colleagues (2008) found that the LLD group did not differ from controls on short-term memory and working-memory tasks of low or moderate demand. Their deficits became significant only in the most demanding working memory sentences task. This task posed the greatest processing demands because participants had to repeat a sentence after answering two true or false questions.

Others have examined verbal memory in more naturalistic tasks such as comprehension and recall of narrative passages (Carvajal et al., 2010; Plante et al., 2006). Carvajal et al. (2010) compared recall of narrative propositions by college students with developmental dyslexia and a control group. The narrative passage was presented twice auditorily and participants recalled it after each presentation. Group difference in the first recall task was not significant. The control group improved their recall after the second presentation but the dyslexic group did not and this lack of improvement resulted in a significant difference between the participants with dyslexia and the controls on the second recall task. The authors also found that recall was significantly correlated with measures of processing speed. Plante et al. (2006) presented short passages to college students with and without a history of learning disability under listening conditions that bias towards gist extraction (i.e., “Listen for general meaning”) versus verbatim encoding (i.e., “Listen for exact wording”). In the test phase, participants listened to sentences and provided “yes” or “no” responses following a gist cue (i.e., “Did the story mean…?”) or a verbatim cue (i.e., “Did the story state word-for-word…?”). The group with a history of learning disability gave fewer correct answers than the control group in both the gist (70% vs. 89%) and the verbatim (69% vs. 82%) conditions.

Together, these five studies (Carvajal, et al., 2010; Isaki & Plante, 1997; Isaki, et al., 2008; Cohen-Mimran & Sapir, 2007; Plante et al., 2006) indicate evidence for verbal memory deficits in young adults with LLD. Their deficits are more clearly manifested under conditions of relatively high memory and language processing demands.

Measurement of Verbal Memory

The list recall task can be used to investigate the underlying nature of memory representation from both a qualitative and a quantitative perspective. In a free list recall task, participants recall words presented without regard to the order of presentation. The number of words recalled provides a useful, quantitative index of verbal memory capacity. Moreover, patterns of recall provide a window into qualitative aspects of memory processes. Take, for example, the well-attested effect of list position on recall (e.g., Tan & Ward, 2000; Watson, Balota, & Sergent-Marshall, 2001). Participants usually begin recall with words at the end of the list and recall those words with the highest accuracy (the recency effect). In addition, words at the initial positions are recalled with higher accuracy (the primacy effect) than those in the middle of the list. List-final words are more easily recalled because these words are still accessible in working memory at the time of recall. The list-initial recall advantage is attributed to the increased opportunities to apply rehearsal strategies, which may result in the transfer of these words to long-term memory. Words in the middle of the list are more difficult to recall because neither benefit is available.

Variations in the type of stimuli to be recalled also provide qualitative insight with regard to memory processes. Some free recall paradigms involve lists comprised of words that are related to each other while others use lists of unrelated words. In one classic variation of the paradigm (i.e., the Deese-Roediger McDermott [DRM] paradigm, Deese, 1959; Roediger & McDermott, 1995), participants listen to lists of words that are related in meaning to a non-presented critical item (CI). For instance, hound, puppy, bite, pet, beware, bone, tail, cat are all related to the CI dog. Sommers and Lewis (1999) extended this paradigm to words that are related phonologically (e.g. log, hog, cog, doll, dig, dug, dock, dawn) to a non-presented CI (e.g., dog). Watson et al. (2001) made a further extension and presented semantic lists, phonological lists, and hybrid (mixed semantic and phonological) lists (e.g., with dog being the CI, the list is comprised of hound, log, puppy, doll, bite, dig, pet, dawn) to young adults, older adults and adults with Alzheimer's disease. All participants were more likely to accurately recall words on the semantic lists ($M = .55$) than words on either phonological ($M = .38$) or hybrid ($M = .40$) lists. It is likely that both the sound and the meaning properties of the to-be-recalled words play intricate roles during the encoding and retrieval of the words (Baddely, 1966; 2003). The processing of semantic relationships facilitates both encoding (Carneiro, Fernandez, Diez, Garcia-Marques, Romos, & Ferreira; 2012; Hunt & Einstein, 1981) and/or retrieval of the words (Payne et al., 2009). Conversely, phonological similarities in the to-be-encoded materials cause interferences in storing and rehearsing the information (Baddeley, 1966).

Watson and colleagues (Watson et al., 2001; Watson, Balota, & Roediger, 2003) also compared false recall of the CI. False recalls are thought to be avoided via source monitoring. A foundational tenet of the source-monitoring framework is the diagnostic monitoring process, which focuses on the quality of the memory evidence for the item in question. If not vivid and distinctive, it is likely to be rejected at test (Gallo, 2010). But this diagnostic process is more difficult to apply under some conditions than others. In particular, compared to semantic and phonological lists combined, hybrid lists elicit more than double the rate of false CI recalls (a phenomenon termed the “super additive effect”). To take Watson et al, 2001 as an example, the hybrid lists induced CI recalls at a rate of 49% whereas the rate for semantic lists was 15% and the rate for phonological lists was 28% (values were estimates using data from young adults in Figure 2, p. 260, Watson et al., 2001). The super additive effect is thought to reflect the process of spreading activation (Roediger & McDermott, 1995; Roediger, Watson, McDermott, & Gallo, 2001). Because hybrid lists provide converging activation of the meaning and sound of the CIs, these lists are the most likely to create vivid memory of these items and therefore conducive to false recall of CIs.

The Present Study

The purpose of this study is to further our understanding of the verbal memory problems of young adults with LLD. Of interest was whether these individuals’ memory deficits were of a qualitative or quantitative nature. To examine quantity, we focused on the probability of veridical recall of DRM word lists; to examine quality, we looked at the probability of false recall and the variability in responding given three well attested phenomena: 1) primacy/recency effects and 2) semantic facilitation effects in veridical recall; and 3) super-additive effects in false recall. If the LLD individuals' memory deficit is quantitative, we would expect reduced veridical recall as compared to the control group but comparable false recall and intact list position and list type effects. If the deficit is qualitative, in addition to reduced accuracy, we would expect different levels of false recall and/or distinct profiles of list position or list type. To be specific, an interaction between group and list position in veridical recall characterized by a reduced primacy effect on the part of the LLD group would suggest inefficient rehearsal processes. An interaction between group and list type on veridical recall characterized by reduced semantic advantages on the part of the LLD group would suggest a deficit in semantic processing. If, instead, that interaction is characterized by heightened phonological disadvantage on the part of the LLD group, we would infer exacerbated interference during rehearsal in the phonological loop. An interaction between group and list type characterized by lower super-additive effects on the part of the LLD group would suggest deficient spreading activation of semantically and phonologically related words. Finally, an elevated level of false recall across all list types by the LLD group would suggest difficulties with source monitoring.

Method

Participants

Fifty young adults, 25 women and 25 men, ages 18 to 25 participated in this study. Individuals were recruited through email announcements by the Services for Students with Disabilities office at the University of Texas-Austin and the University of Iowa, flyers posted on campus, emails sent out via a university-wide mailing list, and word of mouth referrals. To be included in the study, participants had to meet the following criteria: 1) monolingual speakers of English; 2) no history of hearing, social-emotional, or frank neurological impairment; 3) normal or corrected-to-normal vision; 4) nonverbal IQ above a standard score of 80 as measured by the Matrices subtest of the *Kaufman Brief Intelligence Test- Second Edition* (*K-BIT-2*; Kaufman & Kaufman, 2003); and 5) passed a hearing screening according to American Speech-Language-Hearing Association standards (1990).

Among the 50 participants 16 had LLD and 34 had a negative history of LLD (i.e., hereafter referred to as the typical language group [TL]). There were an equal number of males and females in both groups. All but one participant in the LLD group qualified for academic accommodation due to their LLD at the time of testing. We did not ask about the specific nature of the accommodation. However, typical types of support would include waivers of foreign language requirements, tutoring, extended test time or alternative test format, and classroom note-takers, all of which implicate problems in the language domain. In addition, as in Rost and McGregor (2012), participants had to meet the following criteria to be included in the LLD group: score more than one standard deviation below the normative mean on at least two subtests of the Test of Adolescent and Adult Language- Fourth Edition (TOAL-4, Hammill, Brown, Larsen, & Wiederholt, 2007), or on one subtest of the TOAL-4 and the Nonword Repetition subtest of the Comprehensive Test of Phonological Processing- Second Edition (CTOPP-2; Wagner, Torgesen & Rashotte, 1999). According to self-report, four of the 16 participants had a diagnosis of ADHD, four had ADHD and dyslexia, one had an auditory processing disorder, three had language and reading impairment, two had dyslexia only, and one had mild dyslexia and a spelling disorder. The diagnoses represented in this sample reflected the high comorbidity between language disorders, reading disorders, and ADHD (Catts & Kamhi, 2005; Tomblin, Zhang, Buckwalter, & Catts, 2000). One participant in the LLD group did not have a prior diagnosis; however, this person had two subtest scores that were more than one standard deviation below average and one subtest score that was two standard deviations below average. Twelve participants reported their race as white, two as Hispanic, one as African American, and one person reported mixed racial background.

Participants in the TL group reported no previous or current diagnosis of LLD. In addition, they had to score no lower than one standard deviation below the mean on all six subtests of the TOAL-4 and on the Nonword Repetition subtest of the CTOPP-2. The self-reported racial distribution of the TL participants was the following: 26 white, four Asian, one Hispanic, one African-American, and two mixed racial background.

The two groups were matched on age and years of education (see Table 1 for details). Standardized test scores of the two groups are also shown in Table 1. The TL group scored significantly higher than the LLD group on nonverbal IQ, the CTOPP Nonword Repetition subtest, and the spoken, written, and general language composites of the TOAL (see Table 1 for means, t values, and p levels). For a subset of the participants (11 LLD and 23 TL), scores were available on the Peabody Picture Vocabulary Test – Fourth Edition (PPVT-4; Dunn & Dunn, 2007), a measure of receptive vocabulary. All participants in the LLD group had within average range PPVT scores (> 90). For 10 LLD and 19 TL participants, scores were available on the Competing Language Processing Task (CLPT; Gaulin & Campbell, 1994), a standardized task adapted from Daneman and Carpenter’s (1980) reading span task to estimate the simultaneous operations of the storage and processing functions of working memory. In the CLPT, participants must judge the truth value of 42 simple statements, divided into two groups at each of six difficulty levels, while remembering the last word of each sentence for recall at the end of a specific group of sentences. Recall accuracy was reported for this task. The PPVT and CLPT scores were not used for grouping purposes but as indicated in Table 1, the LLD group obtained significantly lower scores than the TL group on both tests.

Insert Table 1 about here

Stimuli

The stimuli consisted of 48 12-item word lists adapted from Watson, et al. (2003, Experiment 3) (see Appendix). Twelve non-presented CIs (i.e., <u>bad</u>, <u>ball</u>, <u>car</u>, <u>dog</u>, <u>face</u>, <u>mail</u>, <u>man</u>, <u>pen</u>, <u>rain</u>, <u>right</u>, <u>top</u>, <u>wet</u>) were selected from Watson et al.'s stimulus lists. For each CI, four types of lists were constructed: pure semantic, pure phonological, hybrid semantic-phonological (HSP), and hybrid phonological-semantic (HPS). The first 12 semantic or phonological associates in Watson et al.'s 16-word lists were selected for the current study. Each CI had a large number of semantic and phonological associates (Stadler, Roediger, & McDermott, 1999). A female native English speaker with a standard American accent recorded the stimuli at a speaking rate of two seconds per word using a Zoom H4 Handy Recorder. The recordings were segmented into individual sound files using the Praat program (Boersma, 2001), each containing one list of words. Intelligibility of the recordings was verified by having two listeners independently listen and write down the words presented in each of the 48 lists. Both listeners correctly identified all words.

Procedures

Participants were tested within a single 90-minute session and received monetary compensation for their participation. Participants were protected by the Institutional Review Board of their university and informed consent was obtained from each person before testing. All sessions took place in a small, sound-treated room at the university speech and hearing clinic.

Each individual was given four semantic, four phonological, and four hybrid lists associated with a total of 12 different non-presented CIs. The three list types were presented in blocks of four with the order of list type counterbalanced across participants. Standardized tests were administered in between blocks of DRM lists.

The lists were presented through two computer speakers (Altec Lansing Multimedia Computer Speaker System ACS95W) at a 60+dB level from a Dell computer. Individuals sat approximately two feet away from the speakers to ensure audibility of the signal. Each participant was administered two 12-word lists (different from the 48 lists used in the main experiment) for practice at the beginning of the session. One practice list contained semantically related words and the other contained phonologically related words. Participants were instructed to listen carefully to lists of words and recall as many words as possible in no particular order. Once the participant understood and completed the two practice lists, the first block of four experimental lists was administered. When a participant could no longer remember or recall stimuli, they typically provided a verbal response (e.g., “That’s all.” or “I don’t know.”). If only a pause was provided with no verbal termination stated, the examiner confirmed the participant’s completion of their attempt to recall stimuli. Each testing session was recorded on a Sony ICD-MX20 digital voice recorder. The participant’s responses were entered into an Excel spreadsheet by order of recall.

Coding

A graduate student in Speech-Language Pathology coded all responses into the following categories: 1) correct; 2) critical item (CI); 3) other intrusions. A second coder blind to the group assignment of the participants listened to the audio-recordings and independently coded the recalls of four participants in the LLD group and eight participants in the TL group. The two coders had 99% point-to-point agreement.

Results

Veridical Recall

Level of veridical recall was calculated for each participant and each type of list. To investigate list position effects, we obtained averages over three different list positions (first four, middle four, and last four) (see Table 2 for means). The HSP and HPS lists were combined to form a hybrid list category in all analyses because these two types of hybrid lists yielded a similar level of veridical recall in both groups [LLD: t (14) = -0.03, p = 0.98; TL: t (32) = -0.05, p = 0.96]. A mixed model ANOVA was conducted with group (LLD, TL) as the between-participant variable, and list type (semantic, phonological, hybrid) and list position (first, middle, last) as the within-participant repeated measures. We conducted tests on normality of distribution and homogeneity of variance and confirmed that both assumptions were met by all dependent measures. This ANOVA revealed a main effect of group, F (1, 48) = 16.28, p < 0.001, η_p^2=0.25, a main effect of list type, F (2, 96) = 99.86, p < 0.001, η_p^2= 0.68, a main effect of list position, F (2, 96) = 70.49, p < 0.001, η_p^2= 0.59, and an interaction between list type and list position, F (4, 192) = 2.62, p = 0.04, η_p^2= 0.05. The interactions between group and list type and between group and list position were not significant, Fs < 1, ps > 0.50.

The group effect was due to better veridical recall for the TL (M = 0.48, SE = 0.010) than the LLD group (M = 0.41, SE = 0.014). The list type effect was due to a higher level of veridical recall for semantic (M =0.54, SE =0.011) than hybrid (M =0.42, SE =.011) and phonological lists (M =0.37, SE =0.011), p < 0.001 for both comparisons. Veridical recall was also higher for hybrid than phonological lists, p < 0.001. The list position effect was due to better recall of words in the list-final (M = .60, SE = .017) than list-initial positions (M= .42, SE = .019), and better recall of words in list-initial than list-middle positions (M = .31, SE = .013), ps < .001.

Insert Figure 1 and Table 2 about here

The interaction between list type and list position is depicted in Figure 1. According to posthoc one-way ANOVAs, recall of semantic lists was significantly higher than that of phonological and hybrid lists for all three list positions. Recall of phonological and hybrid lists were comparable for all but the list-initial position, where there was an advantage for hybrid lists. Moreover, the recency and primacy effects (last four > first four > middle four) were manifested for all list types.

To further examine if veridical recall for hybrid lists was driven by certain types of associations more than others, we compared the recall of semantic versus phonological associates on the hybrid lists. After confirming that normality and homogeneity of variance assumptions were met, a mixed-model ANOVA was conducted with group (LLD, TL) as the between-participant variable and word type (semantic, phonological) as the repeated measure. There was a significant group effect, F (1, 48) = 9.02, p = 0.004, η_p^2=0.16, and an effect of word type, F (1, 48) = 93.87, p < 0.001, η_p^2=0.66. The LLD group (M =0.39, SE =0.018) recalled fewer words on the hybrid lists than the TL group (M =0.45, SE =0.012). The semantic associates (M =0.53, SE =0.015) on the hybrid lists were recalled with higher accuracy than the phonological associates (M =0.31, SE =0.016). The interaction between group and word type was not significant, F < 1, p > 0.50.

To summarize, individuals with LLD were less accurate than their TL peers in veridical recall of DRM lists. Both groups showed recency and primacy effects when recalling words. Veridical recall was the highest for semantic lists, intermediate for hybrid lists, and the lowest for phonological lists. Veridical recall was also higher for semantic than phonological associates on hybrid lists.

False Recall

Mean number of CI intrusions per list is presented in Table 2. We conducted nonparametric Friedman one-way ANOVA to explore the effect of list type for each group. Significant ANOVAs were followed with Wilcoxon matched pairs tests. Between-group differences in CI intrusions were explored via Mann-Whitney U tests. For the LLD group, the list type effect was significant, Chi-square (N=16, df=2) = 10.30, p= .006. Wilcoxon matched pairs tests showed that CI intrusions were more common for hybrid than for both phonological and semantic lists, Zs $\geq$ 2.04, ps<.05. CIs were also more common for phonological than semantic lists, but this difference did not reach significance, Z=1.64, p=.10. For the TL group, the list type effect again was significant, Chi-square (N=34, df=2) = 30.23, p < .001, with hybrid lists eliciting more CIs than semantic and phonological lists, Zs $\geq$ 3.34, ps < .001, and phonological lists eliciting more CIs than semantic lists, Z=2.91, p = .003. There was no difference between LLD and TL groups on any single list type or on the list types combined, Zs $\leq$ 1.77, ps > .05.

To summarize, individuals with LLD demonstrated similar false recall profiles as their TL peers. Both groups were the most likely to falsely recall the CI for hybrid lists and the least likely to do so for semantic lists. Veridical and CI recall were unrelated with each other for semantic and hybrid lists; however, across LLD and TL groups, individuals who were more accurate in recalling phonological list words were also less likely to produce the phonologically similar CIs.

Insert Table 3 about here

Discussion

This study examined list recall performance in 16 individuals with LLD and 34 age- and education-matched controls. We selected the DRM false memory paradigm to help us determine whether the verbal memory deficits in individuals with LLD are qualitative or quantitative. Specifically, we investigated the effects of group, list type, and list position on the frequency of veridical recalls, and the effect of group and list type on the occurrence of false recalls.

Veridical Recall

Comparison of veridical recall revealed effects of group, list position, and list type but no interaction between group and the latter two. The finding of lower veridical recall among the LLD group was consistent with existing studies of verbal memory in this population (Carvajal, 2010; Cohen-Mimran & Sapir, 2007; Isaki & Plante, 1997; Isaki et al., 2008; Plante et al., 2006). We conclude that memory capacity for recently presented verbal material is limited for young adults with LLD.

Both groups of participants demonstrated robust list type effects, showing the highest veridical recall for semantic lists and the lowest accuracy for phonological lists. Recall of hybrid lists fell between that of semantic and phonological lists. Our analyses revealed that the semantic associates on the hybrid lists were recalled with a comparable accuracy (0.53) as words on the pure semantic lists (0.54), and the phonological associates on the hybrid lists were recalled with similar accuracy (0.31) as those on the pure phonological lists (0.37). These results suggest that enhanced recall of the hybrid lists over the phonological lists was driven by the recall of the semantic associates on the hybrid lists.

These patterns are consistent with theories that link semantic gist extraction (Brainerd & Reyna, 2002) or spreading activation within the semantic lexicon (Roediger, Watson, McDermott, & Gallo, 2001) to success in veridical list recall as well as those that link failures in veridical list recall to limitations in phonological working memory (Baddeley, 2003). Of paramount importance here is the lack of interaction between diagnostic group and list type. The LLD group was similarly affected by semantic and phonological associations between to-be-remembered words as their unaffected peers.

The bow-shaped list position effect has been widely documented in the psycholinguistic literature (Tan & Ward, 2000; Watson et al., 2001; 2003) and was observed for both groups of participants. Words at list-final positions were recalled with the highest accuracy, words at the list-initial positions were recalled with an intermediate level of accuracy, and those in list-middle positions were recalled with the lowest level of accuracy. Our participants demonstrated the recency effect as memory traces for words at the list-final positions have not suffered the same degree of decay as those in the initial and medial positions. The participants also remembered words at the list-initial position better than words in list-medial positions. This advantage is typically attributed to the use of rehearsal and, consequently, the storage of those rehearsed words in the speaker’s long-term memory. Again, the lack of diagnostic group by list position interaction suggests intact rehearsal processes in these young adults with LLD.

False Recall

No significant group effect was observed for false recall in the current sample of participants. To our knowledge, this is the first study using the DRM paradigm with young adults with confirmed LLD diagnosis. Two previous studies (Brainerd, Forrest, Karibian, & Reyna, 2006; Branch, Hilgert, Browne, & Monetti, 2007) with adolescents have reported reduced levels of false recall in individuals with learning disability (LD) relative to typical peers. Brainerd et al. (2006) found that 11-year-old children with LD produced fewer veridical recalls and CI intrusions for semantic DRM lists than their age peers and that their levels of veridical and false recall were similar to a group of 7-year-olds who did not have LD. Similarly, Branch et al. (2007) found that 6^{th}-to-8^{th} graders with LD (mean age = 13 years 8 months) produced fewer veridical recalls and CI intrusions than age-matched peers for semantic DRM lists. The authors of these two studies interpreted the results as evidence for semantic processing deficits—specifically a problem extracting semantic gist—in school-age children with LD. However this pattern could reflect a deficit in spreading activation within the semantic lexicon as well.

The current result, although inconsistent with these previous studies, aligns well with findings from Watson and colleagues (2005), who administered semantic DRM lists to young adults with high versus low working memory capacity. Working memory capacity was measured by a word span task that required the participants to solve math problems followed by to-be-remembered words. The high- and low-working memory capacity participants were selected from the upper and lower quartiles of memory span score distribution. It is unclear whether the low-working memory capacity group in this study included young adults with LLD. The low-working memory capacity group produced fewer veridical recalls than the high-working memory capacity group; but the two groups produced a similar number of CI intrusions (0.20 for high- and 0.23 for low-working memory capacity groups). Watson et al. also utilized a warning condition wherein the participants were informed that each list was designed to elicit false memories of a non-presented critical word and they were encouraged to avoid recalling the non-presented word. Under this condition the low-working memory capacity group not only produced fewer veridical recalls but also <u>more</u> false recalls (0.18) than the high-working memory capacity group (0.10). Watson and colleagues interpreted these results as evidence for intact spreading activation but difficulties with cognitive control to suppress CI intrusions in the warning condition among the young adults with low working memory capacity.

Our results, together with Watson et al's, indicate that semantic processing in support of list memory is not an area of concern in young adults with LLD, at least for highly connected semantic word lists and under the standard (no warning) condition. In previous studies adults with LLD performed more poorly than controls in tasks of discourse comprehension and recall, which required extraction of semantic gist (Carvajal et al., 2000; Plante et al., 2006). Carvajal et al. also found that poorer recall was related to slower processing speed. Although gist extraction under optimal conditions (i.e., highly connected semantic word lists presented at a relaxed pace) is not an area of weakness in these young adults, results may change under task (e.g., passage recall) or presentation (e.g., faster speech rate, noisy background) conditions that require additional cognitive skills such as inferencing, efficient processing speed, sustained attention, and inhibition.

List type effects were evident for CI intrusions in both groups. Consistent with Watson et al. (2001), we found that hybrid lists led to a super-additive effect in false recall of the CI: As seen in Table 2, CI intrusions were more common in the hybrid condition than both semantic and phonological conditions combined. This finding is best explained by the activation-monitoring account of memory intrusions (Roediger & McDermott, 1995). Because half of the words on the hybrid lists are semantic associates and the other half are phonological associates to the CI, hearing these words activates both the semantic and phonological representations of the CI. Strong activation of the CI impedes source monitoring and renders the CI intrusion highly probable. We also found higher CI intrusions for phonological than semantic lists. Here, strong spreading activation at the phonemic level, coupled with phonological similarity between the CI and presented words, makes it difficult to differentiate the CI from presented words. Again, these processes characterized the LD group as well as their unaffected peers in the TL group.

Clinical Implications

Increasing numbers of students are entering postsecondary institutions with LD diagnoses (Joyce & Rosen, 2006). Despite access to accommodations, these students are less likely than unaffected peers to obtain a degree (Horn, Berktold, & Bobbit, 1999; Murray, Goldstein, Nourse, & Edgar, 2000). Our findings of reduced veridical recall suggest that study habits that support memory encoding could be especially useful for these at-risk students. One such habit is self-testing. Extensive empirical evidence demonstrates that testing enhances retention more than additional exposure to the material even when the tests do not include feedback (see review in Roediger & Karpicke, 2006). Studying notes is fairly passive. Testing requires more effort and an actual response thus introducing desirable difficulty into the task (Bjork, 1999). Difficulty improves encoding and retention of verbal information, presumably because the learners' active engagement and struggle with the material help to establish additional or more robust retrieval routes. College students who studied science facts by generating answers to test questions embedded in the material later recalled more correct information than those who studied the same material by reading alone (Richland, Bjork, Rinley, & Linn, 2005).

In addition to self-testing, findings also lend support to the need for guided note-taking for these LLD students (for review see Boyle & Rivera, 2012). Research has demonstrated that note-taking during lectures is critical to understanding and retention of information (Kobayashi, 2005). Instructors may consider providing these students with teacher-prepared outlines of the lecture to guide the students through the lecture. Guided notes utilize a cloze format and provide students with an outline of the content from the lecture and contain designated spaces for students to record more detailed information about specific lecture points (Hamilton, et al., 2000). This technique can alleviate the negative impact of limited verbal memory capacity and enable students to follow the lecture and pay particular attention to the missing keywords.

Conclusion

This study revealed many similarities in list recall performance among college students with and without LLD. Individuals with LLD and typical controls showed a similar level of CI intrusions for all three list types. Both groups demonstrated sensitivity to semantic and phonological relationships among presented words. Semantic relatedness facilitates recall whereas phonological similarity hampers recall. All participants were highly susceptible to critical item intrusions when recalling hybrid lists, suggesting spreading activation among phonologically-related and semantically-related words. Individuals with and without LLD also demonstrated robust recency and primacy effects in list recall. These findings suggest that basic memory processes, the processing of gist semantic information, and spreading activation of semantic and phonological information are largely intact in young adults with LLD. Nevertheless, deficits emerged in the veridical recall of words. These findings indicate qualitative similarities in memory processes but quantitative differences in verbal memory capacity.

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Table 1. Participant information and performance on standardized tests (including means, SDs, and ranges)

	LLD	TL	t value	p level
Age	20.81 (1.76)	20.79 (1.81)	0.03	0.97
	18-24	18-25		
Sex	8 M; 8 F	17 M; 17 F		
Education	14.88 (1.82)	15.19 (1.83)	-0.57	0.57
	12-17	12-21		
K-BIT	97.25 (8.41)	108.47 (14.99)	-3.01	0.004
	86-115	82-132		
NWR [a]	6.09 (1.81)	10.00 (1.96)	-5.66	<0.001
	4-10	7-13		
PPVT-4 [b]	99.18 (7.10)	116.70 (12.04)	-4.45	<0.001
	91-111	98-143		
CLPT recall [c]	77% (7.55%)	87% (8.12%)	-3.18	0.004
	65-92.5%	75-100%		
TOAL-Spoken	86.31 (6.68)	109.18 (7.15)	-10.77	<0.001
	74-97	93-124		
TOAL-Written [d]	89.93 (9.46)	112.76 (9.55)	-7.52	<0.001
	77-102	92-134		

Note. K-BIT = standardized score on the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 2003); NWR = standardized score on the nonword repetition subtest of the Comprehensive Test of Phonological Processing (Wagner et al., 1999); PPVT-4 = standardized score based on the Peabody Picture Vocabulary Test - Fourth Edition (Dunn &

Dunn, 2007); CLPT = Completing Language Processing Test (Gaulin & Campbell, 1994); TOAL-Spoken = the spoken language quotient on the Test of Adolescent and Adult Language (Hammill et al., 2007), which includes the word opposites, word deviations, and spoken analogies subtests; TOAL-Written = the written language quotient on the TOAL, which includes the word similarities, sentence combining, and orthographic usage subtests. There were 16 participants in the LLD group and 34 participants in the TL group unless otherwise denoted.

[a] Based on 11 LLD and 26 TL participants for whom standard NWR scores were available; [b] Based on 11 LLD and 23 TL participants to whom the PPVT scores was administered; [c] Based on 10 LLD and 19 TL participants to whom the CLPT was administered; [d] Based on 14 LLD and 33 TL participants.

Table 2. Mean proportion of veridical recall and mean number of false recall (expressed as mean number of CI intrusions per list). SDs are presented in parentheses and score ranges are on the next line.

	Semantic List		Phonological List		Hybrid List	
	Veridical	False	Veridical	False	Veridical	False
LLD	0.50 (0.08)	0.27 (0.28)	0.34 (0.07)	0.43 (0.25)	0.39 (0.07)	0.61 (0.20)
	0.40-0.69	0-0.75	0.23-0.48	0-0.75	0.25-0.48	0.25-1
TL	0.58 (0.07)	0.15 (0.22)	0.41 (0.08)	0.32 (0.24)	0.45 (0.07)	0.58 (0.26)
	0.42-0.73	0-0.75	0.29-0.54	0-1	0.33-0.60	0.25-1
All	0.56 (0.08)	0.19 (0.25)	0.39 (0.08)	0.36 (0.25)	0.43 (0.08)	0.59 (0.24)
	0.40-0.73	0-0.75	0.23-0.54	0-1	0.25-0.60	0.25-1

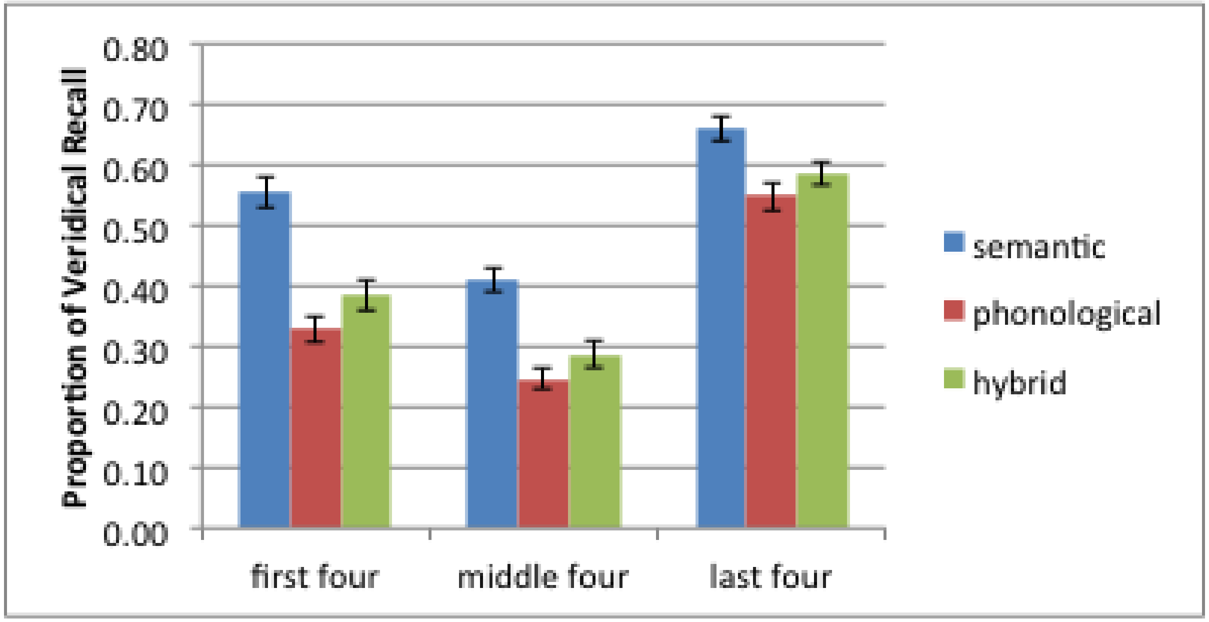

Figure 1. Proportion of Veridical Recall by List Type and List Position. Bars denote standard errors.