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The Effect of Semantic Features on Gist and Verbatim Memory in Young Adults with Language-Learning Disabilities

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The Effect of Semantic Features on Gist and Verbatim Memory in Young Adults with Language-Learning Disabilities

by

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Dedication

This thesis is dedicated first and foremost to my family, for supporting me in innumerable ways and loving me equally at my best and my worst; the friends I've made in the grad program over the last two years for being the most driven, dedicated, kindest, and understanding group of women I've ever had the pleasure to meet; my professors for giving me a thorough education in the theory and practice of this field (it all sunk in eventually!); my supervisors both on- and off-campus for letting me benefit from their knowledge and experience; Carmen and Kim for keeping the UT clinic running smoothly and always making time for me when I needed help; and most of all to the wonderful clients who make it all worthwhile.

Acknowledgements

Abstract

The Effect of Semantic Features on Gist and Verbatim Memory in Young Adults with Language-Learning Disabilities

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This thesis is an expansion of an ongoing examination of gist and verbatim memory in young adults with language-learning disabilities (LLD) using the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). This study uses lists based on situation semantic features in addition to DRM lists based on backwards associative strength (BAS), which were categorized as strong-, mid-, and low-BAS (Stadler, Roediger, & McDermott, 1999). Items in each list (e.g., bacon, toast, cereal, muffin) related to a non-presented word (e.g., breakfast): the critical lure (CL). BAS is a measure of the likelihood that a list item will elicit the CL. Thirty young adults participated in this study and were divided into three groups: true LLD, compensated LLD, and typically developing (TD). Participants listened to word lists and verbally recalled the words they remembered hearing. Accurate recall was an indicator of verbatim memory; CL recall was an indicator of gist memory. The true LLD group recalled CL at a significantly higher rate than the other groups in the case of the situation lists; additionally, the compensated LLD group recalled CL for the low-BAS lists at a significantly higher rate than the other groups. These findings suggest that the LLD participants may process semantic information differently or may rely on gist memory to a greater extent than the

TD controls. Results also indicated list type differences for both verbatim and gist recalls, supporting the effects of both semantic features and BAS together with other factors.

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INTRODUCTION

Language-Learning Disabilities, Language Impairment, and Attention Deficit/Hyperactivity Disorder

The term *language-learning disability* may refer to individuals with "broad-based language deficits," or more specifically individuals who have difficulties with "word recognition and listening comprehension" (Catts & Kamhi, 2005). The term *specific learning disability* refers to low academic performance in at least one of the "three manifestation areas" of reading, writing, and mathematics, "intellectual and neurocognitive disorders" excluded (Scanlon, 2013). A wide range of criteria have been used to diagnose learning disabilities, but generally a student is considered to have a learning disability if there is a discrepancy between IQ and academic achievement, or if the student demonstrates academic impairment in the absence of cognitive and sensory deficits (Sparks & Lovett, 2009a; 2009b). Common types of language-learning disability include dyslexia, which causes "problems in word recognition" in reading (Catts & Kamhi, 2005), dysgraphia, which causes "poor or illegible handwriting" (Simner & Eidlitz, 2000), and auditory processing disorder, which involves difficulties perceiving and interpreting speech stimuli at the neural level (Moore, 2006).

Also of interest is *specific language impairment*, which denotes "a limitation in language ability" in one or more of the following components: "lexical, syntactic, semantic, morphological, phonological, or pragmatic" (Levy & Schaeffer, 2003). Although not typically classified as a learning disability, the deficits of specific language impairment overlap with those of the above types of LLD. Language-learning disabilities

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have varying levels of severity, with some affected individuals needing "very substantial support" during primary and secondary education and others having no noticeable effects of LLD until entering college (Scanlon, 2013; Sparks & Lovett, 2009b).

Attention Deficit/Hyperactivity Disorder is a condition beginning in childhood which has both cognitive and behavioral consequences (Goldstein, 2011). Affected individuals generally have problems with impulsivity, hyperactivity and/or attention; more specifically with executive functioning tasks such as concentration, self-control, planning, and working towards goals (Goldstein, 2011). ADHD is not generally considered to be a type of learning disability (Al-Yagon, 2013). However, ADHD has high co-morbidity with learning disabilities, suggesting a possible association between them or a common etiology for both in at least some cases (Venkatesh, et al., 2012; DuPaul, Gormley, & Laracy, 2013). Additionally, ADHD is associated with problems in linguistic comprehension and pragmatic aspects of communication (Bellani, et al., 2011; Bruce, 2006; Wassenberg, et al., 2010). Wassenberg, et al. (2010) found that individuals with ADHD were "significantly slower on language comprehension tasks" than controls. In a review of multiple studies of language development in children with ADHD, Bellani, et al. (2010) found deficits in "pragmatic aspects, verbal working memory and discourse analysis" and concluded this was likely due to problems both in "language abilities" and "general executive functions." Bruce's (2006) study examining the responses of parents of children with ADHD on a questionnaire of various neurodevelopmental issues found that these children had problems in communication, language comprehension, and social

pragmatics. For these reasons, individuals with ADHD were included with the LLD population in this study.

Several previous studies have examined memory abilities in young adults with LLD. Research by Cohen-Mimran and Sapir (2007) found evidence of working memory deficits in students with reading disabilities. Isaki, Spaulding, & Plante (2008) observed that individuals with language-based learning disabilities performed similarly to controls on measures of verbal short-term and working memory except under the condition requiring the highest amount of language processing and verbal memory, in which individuals with LLD showed a statistically significant verbal memory deficit.

Because many studies involving young adults with LLD recruit participants from the college student population, it is important to point out that these individuals are likely to be among the least severely affected by deficits in language ability and memory capacity. As Sparks and Lovett (2009b) note, college students with the LLD label tend to demonstrate average academic performance, only appearing to have a deficit when compared to their above-average typically developing (TD) peers.

False Memory

The Deese-Roediger-McDermott paradigm is a method of testing verbal memory. Like other verbal memory tests, subjects listen to a list of words and immediately attempt to recall as many of the items as possible (Deese, 1959; Roediger & McDermott, 1995). Unlike other verbal memory tests, the lists are constructed with the goal of creating false memories of stimuli that were never presented, known as "critical lures" (Roediger & McDermott, 1995). For example, a list consisting of the items "bed, rest, awake, tired,

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dream", among others, is intended to elicit the critical lure "sleep", which is never presented (Roediger & McDermott, 1995). Presented list items have various relationships to the critical lure, including situational features, antonyms, synonyms, and taxonomic relations (*x* is a type/example of *y*), among others (Cann, McRae, & Katz, 2011).

In Deese's (1959) original study, 50 undergraduate students were tested on 36 lists of 12 words each. After hearing each list, they verbally recalled all the items they could remember (Deese, 1959). The frequency with which lists elicited the critical lure (referred to in this study as the "stimulus word") ranged from 0% to 44%, with a mean of 24% (Deese, 1959).

Roediger and McDermott (1995) conducted two experiments to test false recall of nonpresented critical lures in word lists. The lists, with some modifications, were drawn from Deese's (1959) original study. In the first experiment, 36 undergraduate psychology students were tested on six word lists of 12 items each. After each list, the students wrote down all the words they could remember from the list, starting with the last few items they had heard and then recalling the stimuli in any order (Roediger & McDermott, 1995). The probability of false recall was 40%. In the second experiment, 30 undergraduate students were tested on 24 word lists of 15 items each. False recall increased to an average level of 55%. Roediger and McDermott (1995) explain the higher rate of false recall in Experiment 2 as a result of the greater number of lists and/or the greater number of items on each list, which may have provided more of a challenge to the participants' memory and made accurate recall more difficult.

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Stadler, Roediger, and McDermott (1999) conducted a false memory study using word lists generated by Deese (1959) and Roediger and McDermott (1995) for the purpose of obtaining "normative data on lists that can be used to produce false memories." For this study, 205 undergraduate psychology students were tested on 36 word lists of 15 items each. After each list was presented, the students wrote down as many of the items as they could remember. False recall varied from 10% to 65%, with a mean of 40%. Results of this study provided preliminary normative data as to which word lists are more likely to elicit false recall of the critical lure.

Theoretical Framework

Current research in the DRM paradigm is based on several different theories of memory. In the theory of spreading activation, hearing a word will create "implicit associative responses" such that memory for semantically and phonologically related words is activated along with the presented word (Roediger & McDermott, 1995; Collins & Loftus, 1975). A weaker "associative network" would result in lower likelihood of false memory creation (Roediger & McDermott, 1995).

The theory of activation monitoring is based on the "parallel distributed processing" model of "encoding and retrieval" (Roediger & McDermott, 1995). In this model, it is difficult for an individual to distinguish between a true memory and a false memory if both representations were activated at the same time by the same stimulus (e.g., if "nap" activates the representations for both "nap" and "sleep," the individual may not realize that "sleep" was not the stimulus word) (Roediger & McDermott, 1995).

Therefore, false memories are created through a failure to monitor the source of the activated memory.

Fuzzy trace theory explains the different "levels of specificity" at which memory traces are stored (Brainerd & Reyna, 2002). Verbatim traces are "representations of the surface forms" of experiences, while "fuzzy" or gist traces are "interpretations of concepts" resulting from those surface forms (Brainerd & Reyna, 2002). Both verbatim traces and gist traces are encoded and retrieved, and although gist traces are less specific and accurate, they are easier to access and more stable (Brainerd & Reyna, 2002). In the context of the DRM paradigm, verbatim memory is indicated by correct recalls while gist memory is indicated by critical lure recalls.

The "phonological loop" theory of working memory states that verbatim traces must be rehearsed or they will decay (Baddeley, 2003). The length of the DRM paradigm lists makes continuous rehearsal of all 12 items extremely unlikely, given that working memory can typically hold between five and nine pieces of unrelated or non-meaningful information at one time (Miller, 1956). Therefore, participants could be expected to form a maximum of nine verbatim traces for list items, and rely on gist traces for the rest.

Associative Strength

Associative strength is a measure of the probability that a stimulus will elicit a particular word on a test of free recall (Roediger, Watson, McDermott, & Gallo, 2001). Associative strength is indexed by the frequency at which people produce a response to a stimulus in a word association task. For example, if 80 out 100 people say "bed" in

response to "sleep", then the associative strength from sleep to bed is .80. On the false memory task, backward associative strength (BAS) is a measure of the likelihood that an item in a word list will elicit the critical lure. It has been shown that BAS plays a significant role in the probability of recalling the critical lure such that lists consisting of high BAS words are more likely to elicit false recall of the critical lure than lists consisting of low BAS words (Roediger et al., 2011)

In order to find out if factors other than BAS significantly impacted false memories, Cann, McRae, and Katz (2011) investigated "semantic relations between list items and critical nonpresented words" that were responsible for creating false memories. In particular, they were interested in "situation features," which are people, objects, and various relationships that are associated with the same location, action, or period of time (Cann et al., 2011). The authors came up with 12 lists of 12 words each, all of which were semantically related to the critical lure through situation features (Cann et al., 2011). Accurate recall was 67%; false recall of critical lures was 5%. In a second experiment, participants did math problems in between hearing the lists (which included both situation lists and lists with high, mid, and low BAS) and recalling them in order to prevent them from mentally rehearsing the lists (Cann et al., 2011). Accurate recall was 67% for situation lists, 62% for strong-BAS lists, 63% for mid-BAS lists, and 52% for low-BAS lists. False recall was 52% for strong-BAS lists and 15% for situation lists, indicating that high BAS is more effective than situation features at eliciting false memories. The situation and mid-BAS lists were matched on BAS, but the situation lists' false recall rate of 15% was higher than the mid-BAS (5%) and low-BAS (9%) lists,

indicating that situation features play a role in false memory formation that is separate from BAS (Cann et al., 2011).

Learning Disabilities and the DRM Paradigm

Branch, Hilgert, Browne, and Monetti (2007) conducted a study on 40 students approximately 13 years of age, half of whom were in general education classes and half of whom were receiving special education services for specific learning disabilities. The students were individually tested on ten lists of 15 words each using the DRM paradigm (Roediger & McDermott, 1995). In order to "minimize differences in reading skill between the two groups", the students were given the lists to read and study while the words were simultaneously read aloud by the examiner (Branch et al., 2007). After each list, the examiner took the lists from the students and asked them numerical distracter questions for 25 seconds to prevent the students from mentally rehearsing the words they had read. The students were then asked to say all the words they could remember from the list. False recall of nonpresented critical items was 36% for the general education students, 21% for students with learning disabilities (Branch et al., 2007; McKelvie, 2008). Correct recall of presented items was between 79 and 113 words (M=89.25, SD=11) for the general education students and between 11 and 80 words (M=55.65, SD=18.57) for students diagnosed with learning disabilities. McKelvie (2008) comments that adult levels of false recall are between 37.4%-40.6%, which is similar to the performance of the children without learning disabilities in this study. Branch et al. (2007) attributes both the higher levels of correct recall and the higher levels of false recall to the general education students' stronger "semantic network," which would use

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each list's semantic theme, or "gist," to aid memory of the words; however, it would also make students without learning disabilities more vulnerable to falsely remembering words which were semantically related to the rest of the list, but which were never presented. This study indicates that adolescents with LLD have deficit in both gist and verbatim memory.

Weekes, Oakhill, and Holliday (2008) performed a DRM paradigm experiment with 32 children between the ages of 9 and 11, half of whom were "poor comprehenders" (children with "impaired reading comprehension" but "normal word recognition and phonological decoding skills"), and half of whom were typically developing. The participants were given six verbally presented lists of ten words each which were related to the critical lure either by semantic or phonological features. After each list, they did a numerical distractor task for one minute, then wrote down all the words they could remember hearing. The children who were poor comprehenders did not differ from controls on the phonological feature condition, but had significantly lower rates of false recall than the TD group for the semantic feature condition (Weekes et al., 2008). This indicates that poor comprehenders are able to process sound features, but demonstrate weaker gist memory and are less able to "infer themes" than TD children due to difficulties processing the meaning of words (Weekes et al., 2008).

Watson, Bunting, Poole, and Conway (2005) investigated the effects of working memory capacity on verbatim and gist recall in the DRM paradigm. College students were classified as high or low operation span based on their performance in a combined mathematical and verbal memory task (Watson et al., 2005). Participants studied 36 lists

of 16 words each, presented visually. Individuals with higher memory spans recalled more list items than those with lower memory spans, and false recall of critical lures was 15% for high span and 20% for low span participants (although the authors did not report this as a significant difference (Watson et al., 2005). The results of this study suggest that individuals with lower working memory capacity have poorer verbatim memory and greater tendency to falsely recall the unpresented critical lure.

In the above three studies on individuals with learning disabilities or low working memory capacity, these individuals generally displayed lower accurate recall of presented items than controls. This indicates the presence of a deficit in verbatim memory. Rates of false recall of nonpresented critical lures were inconsistent across these studies. Children and adolescents with learning disabilities displayed lower false recall than controls (Branch et al., 2007; Weekes et al., 2008), suggesting poorer gist memory, whereas the young adults with low working memory capacity recalled the critical lure at rates comparable to or higher than young adults with high working memory capacity (Watson et al., 2005), indicating average or above-average tendency to form gist memory traces.

Present Study

This thesis is part of an expansion of an ongoing study on false recall of verbally presented items in young adults diagnosed with LLD. College students with LLD vary in their degree of impairment, with some performing significantly below their TD peers and others demonstrating average or near-average academic ability, indicating that they have compensated for the LLD (Birch & Chase, 2004). This may be due to the availability of

support services and technologies increasingly offered by universities for students with LLD (Sparks & Lovett, 2009b) and to individual differences in using learning strategies and willingness to seek assistance (Trainin & Swanson, 2005). In order to acknowledge the diversity of this population, we differentiate between compensated LLD and uncompensated LLD (referred to in this study as true LLD). This study is intended to examine the effects of LLD on verbatim and gist memory. There have recently been a number of studies researching the effects of manipulating backward associative strength and other factors of inter-item and critical lure-item associative strength in typical populations, but so far no studies have looked at the effects of list types that differ on semantic relationships in the LLD population. We aim to remedy this gap by investigating recall of lists (taken from Cann et al., 2011) that vary in semantic relations and associative strength among individuals with LLD.

Given the varied conditions and results of the published studies researching LLD and the DRM paradigm, it is difficult to make precise predictions regarding how college-aged individuals diagnosed with LLD will perform. The children and adolescents in Branch et al. (2007) and Weekes et al.'s (2008) studies had lower rates of accurate and false recall than controls, presumably due to overall poorer memory. Working on the assumption that true LLD individuals have more significant impairments and are more likely to have been identified in childhood, the true LLD participants could be expected to display both lower verbatim memory and lower gist memory. If the low memory operation span college-aged participants studied by Watson et al. (2005) can be assumed to have comparable performance to college students with compensated LLD, it is

possible that the children and adolescents with subtle deficits which are not identified until college (Sparks & Lovett, 2009b) develop stronger gist memory as a compensatory strategy. If this is the case, young adults with compensated LLD would display average levels of verbatim recall and higher levels of gist recall than controls.   With regard to list type, based on Cann et al. (2011), it is predicted that accurate recall will be highest for the situation lists, then the strong- and mid-BAS lists equally, with the lowest rate of accurate recall for the low-BAS lists. Additionally, false recall is predicted to be highest for the strong-BAS lists, then the situation lists, then the mid- and low-BAS lists equally.

METHODS

Participants

Thirty young adults ages 18; 0 to 23; 11 (months; years) participated in this experiment. All were native English speakers with no history of hearing impairment or neurological injury (per self-report and examiner observation). Participants were recruited via flyers posted around the University of Texas at Austin campus, advertisements in the newsletter of the Services for Students with Disabilities office, and advertisements in KnowEvents (a newsletter for UT-Austin students available via e-mail and website).

Twenty individuals with a current diagnosis of language-learning disabilities (LLD) and 10 age matched typically developing (TD) individuals participated in this study. The LLD group consisted of nine males and 11 females with a mean age of 20.5. Participants who took medication for ADHD were not asked to discontinue use of the medication during the study due to ethical concerns. The TD group consisted of five males and five females with a mean age of 20.98. According to test results, the LLD participants were further divided into two groups: true LLD (12 participants) and compensated LLD (eight participants). A participant was classified as true LLD according to a formula developed by Fidler, Plante, & Vance (2011) which identifies individuals with learning disability by weighing scores on a 15-word spelling list, the word definition subtest of the *Clinical Evaluation of Language Fundamentals—Fourth Edition* (CELF-4; Semel, Wiig, & Secord, 2003), and the *Modified Type Token Test* (Morice & McNicol, 1985). The formula has 78% sensitivity and 83% specificity in

identifying individuals with LLD (Fidler et al., 2011).   The following tests were also administered: the nonword repetition subtest of the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999), and the *Test of Adolescent and Adult Language-fourth edition* (TOAL-4; Hammill, et al., 2007). A participant who had received a diagnosis of LLD but performed on par with his or her TD peers was considered to be compensated LLD. Specifically, all individuals in the compensated LLD group had negative Fidler formula score and those with true LLD had positive scores. The true LLD group consisted of six males and six females with a mean age of 20.59, who reported their LD diagnoses as follows: auditory processing disorder only (2), dyslexia only (1), dysgraphia only (1), ADHD only (5), cognitive speech delay only (1), ADHD and dyslexia (1), ADHD and dysgraphia (1). The compensated LLD group consisted of three males and five females with a mean age of 20.42, who reported their LD diagnoses as follows: dyslexia only (1), ADHD only (6), auditory processing disorder and ADHD (1).

The following inclusion criteria were used for all participants: a) native English speaker, b) between the ages of 18 and 24, c) nonverbal IQ above a standard score of 80 on the *Kaufman Brief Test of Intelligence*—2nd Edition (Kaufman & Kaufman, 2004), d) no history of hearing impairment or brain injury. For the TD group, the additional criteria of scoring no lower than one standard deviation below the mean for any language or phonological test and a negative composite score for the Fidler et al. (2011) formula were used.

An analysis of variance (ANOVA) revealed no between-group difference on age (p=0.81), level of education (p=0.77), or KBIT scores (p=0.68), indicating that the three groups of participants were well-matched on these background characteristics. There was a significant between-group difference on CTOPP scores, F (2, 27)=4.82, p=0.016, η_p^2=0.26). Posthoc tests with Bonferroni corrections indicated that the true LLD group was significantly lower than the TD group; but the compensated LLD group did not differ from either. TD and compensated LLD did not differ significantly on the TOAL-Spoken test, but both scored significantly higher than the true LLD group F(2,27)=6.67, p=0.004, η_p^2=0.33). The TD group did not differ significantly from either LLD group on the TOAL-Written test, but the compensated LLD group performed significantly better than the true LLD group F(2,27)=3.88, p=0.033, η_p^2=0.22). See Table 1 for means and standard errors. To summarize, the three groups did not differ from each other on background characteristics or nonverbal IQ. As for standardized language and memory tests, the compensated LLD group was on par with the TD group on all measures, whereas the true LLD group had weaker scores than one or both of the peer groups.

Stimuli

Three situation feature word lists and nine DRM lists utilized by Cann, McRae, and Katz (2011) were used in this experiment (see Appendix A for the full list of stimuli and Table 2 for BAS values). All word lists were 12 items long. In the situation lists, each item related to the non-presented critical lure through one of the following features: function, action, participant, location, origin, time, manner, associated entity, spatial relationship, or state of the world (please see Cann et al. (2011) for a detailed discussion

of situation features). The nine remaining word lists were judged by Roediger et al.

(2001) to have strong BAS (doctor, smoke, sleep), moderate BAS (beautiful, bitter,

butterfly), and low BAS (long, trouble, whistle). However, as seen from Table 2, the

situation, mid-BAS, and low-BAS lists had comparable BAS values.

Table 1. Summary of participant information. Standard error is presented in parentheses.

	True LLD	Compensated LLD	Typically Developing
sample size	12	8	10
age	20.59 (0.54)	20.42 (0.67)	20.98 (0.6)
Education (years)	15.04 (0.55)	14.75 (0.67)	15.4 (0.6)
gender	50% M, 50% F	37.5% M, 62.5% F	50% M, 50% F
KBIT	108.25 (3.56)	112.5 (4.36)	112.1 (3.9)
CTOPP	7.83 (0.52)	9.38 (0.64)	10.2 (0.57)
TOAL-S	95.67 (3.06)	108.75 (3.75)	111.0 (3.36)
TOAL-W	103.17 (3.21)	116.38 (3.93)	112.7 (3.52)
composite	0.64 (0.13)	-0.42 (0.16)	-0.62 (0.14)

Note. The composite score was calculated by weighting scores on a 15-word spelling list, the word definition subtest of the *Clinical Evaluation of Language Fundamentals—Fourth Edition* (CELF-4; Semel, Wiig, & Secord, 2003), and the *Modified Type Token Test* (Morice & McNicol, 1985)using a formula provided by Fidler et al. (2011). We also administered the *Kaufman Brief Test of Intelligence*—2nd Edition (Kaufman & Kaufman, 2004), the nonword repetition subtest of the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999), and the *Test of Adolescent and Adult Language-fourth edition* (TOAL-4; Hammill, et al., 2007).

Table 2. Mean backward associative strength (BAS) of each list.

Situation (0.062)			Strong (0.342)			Mid (0.031)			Low (0.022)		
breakfast	casino	farm	doctor	smoke	sleep	beautiful	bitter	butterfly	long	trouble	whistle
0.035	0.09	0.06	0.303	0.209	0.513	0.046	0.013	0.034	0.046	0.013	0.0067

Procedures

All sessions took place at the University of Texas Speech and Hearing Center (UTSHC). Each individual participated in two sessions of no more than 90 minutes each on different days. The 12 lists were divided into three blocks, with each block containing one situation feature word list and one word list for each BAS level. Stimuli were recorded by a female speaker with a standard American accent and presented at a rate of approximately one word per second.

The lists were presented in blocks of four during the experiment, each separated by standardized tests of language skills and memory. Immediately following the presentation of each list, the participants verbally recited all items they could remember. Participants were given unlimited time to recall each list, and informed the examiner when they were finished. The participants' responses for each list were written down on-line by the examiner and audio recorded to ensure reliability.

Coding

Responses were coded by accuracy, presence of the critical lure, and error type. If participants recalled the non-presented critical lure, it was coded as "FM" (false memory). Errors other than the critical lure are referred to as intrusions. Intrusions based on semantic similarity to any items in the list (e.g. "orange" being recalled for a list that contained "fruit" and "juice") were coded as "SI" (semantic intrusion). Intrusions based

on phonological similarity to any items in the list (e.g. "lonely" in response to "lovely") were coded as "PI" (phonological intrusion). If an intrusion had characteristics of both semantic and phonological interference, the response was coded as "PSI" (phonological and semantic intrusion). If a participant repeated a response he or she had already given, the response was coded as "REP" (repetition). If a response was a different morphological form of a presented list item (e.g. "walked" for "walk" or "plates" for "plate") it was coded as "INF" (inflection). If an intrusion had no discernible relationship to any list item, the response was coded as "UNR" (unrelated). If a participant recalled an item that was unrelated to any item in the present list but had been presented in a previous list, the response was coded as "PL" (previous list). Due to very low incidence, the error types PSI, UNR, PL, INF were combined into error type "OTH" (other) for purposes of analysis. Responses were coded by the examiner who had carried out the testing and double-checked by a graduate student. Disagreements and uncertainties about coding were resolved through group discussion among examiners, graduate students, and the faculty supervisor.

RESULTS

Statistical analyses were performed using the computer software program Statistica version 7.1. Mixed-model group (true LLD, compensated LLD, TD) by list type (situation, strong BAS, mid BAS, low BAS) ANOVA was run to compare the accuracy of recall, critical lure recall, and frequency of error types. Recall that the fuzzy trace theory suggests that correct recall relies on verbatim memory whereas critical lure recall relies on gist memory. Below the two sets of terms are used interchangeably.

Table 3. Verbatim recall, gist recall, and error type by group. *Verbatim recall* refers to accurate recall of presented items; *gist recall* refers to false recall of non-presented critical lures. Standard errors are presented in parentheses. Maximum possible accurate recall per list type is 36; maximum possible critical lure recall per list type is 3.

	True LLD	Compensated LLD	Typically Developing
Accurate Recall	21.75 (0.77)	23.31 (0.94)	22.68 (0.84)
Critical Lure Recall	0.52 (0.10)	0.56 (0.13)	0.35 (0.11)
Semantic Intrusion	0.63 (0.18)	0.31 (0.22)	0.45 (0.19)
Phonological Intrusion	0.08 (0.04)	0.03 (0.05)	0.10 (0.04)
Repetition	1.44 (0.31)	0.50 (0.38)	0.63 (0.34)
Other	0.63 (0.16)	0.59 (0.19)	0.68 (0.17)

Note: LLD=Language-Learning Disability

Verbatim Recall

There were no significant between-group differences for accurate recall of presented list items $(F(2, 27)=0.87, p=0.43)$. As seen in Table 3, the three groups recalled the presented words at a comparable level that ranged from 60.4% to 64.8%. However, there was a significant list type difference $(F(3, 81)=10.69, p<0.001, \eta_p^2=0.28)$. As seen in Table 4, accurate recall for situation lists was significantly higher than for strong- and low-BAS lists, and accurate recall for mid-BAS lists was significantly higher than for low-BAS lists. The other pair-wise comparisons between list types were not significant.

Table 4. Verbatim and gist recall by list type. *Verbatim recall* refers to accurate recall of presented items; *gist recall* refers to false recall of non-presented critical lures. Standard error presented in parentheses. Maximum possible accurate recall is 36; maximum possible critical lure recall is 3.

	Accurate Recall	Critical Lure Recall
Situation	23.97 (0.56)	0.55 (0.13)
Strong BAS	21.75 (0.56)	1.01 (0.19)
Mid BAS	23.33 (0.70)	0.18 (0.07)
Low BAS	21.26 (0.55)	0.17 (0.07)

Note: BAS=Backward Associative Strength

Critical Lure Recall

There was no significant between-group difference on recall of the critical lure $(F(2, 27)=0.93, p=0.41)$. As seen in Table 3, the three groups recalled between 11.67% and 18.67% of the critical lures. There was a significant effect of list type $(F(3, 81)=11.35, p<0.001, \eta_p^2=0.30)$, with the situation and strong-BAS lists showing no significant difference, the mid-BAS and low-BAS lists showing no significant difference, and the former two eliciting significantly higher rates of critical lures than the latter two. There was also a significant interaction between group and list type $(F(6, 81)=2.73, p=0.02, \eta_p^2=0.17)$. This interaction was followed up with three one-way ANOVAs, one for each participant group. As seen in Figure 1, in the case of the true LLD group, situation lists were equivalent to strong-BAS lists, mid-BAS lists were equivalent to low-BAS lists (no true LLD participant recalled any critical lure for any low-BAS list), and the former two were recalled at higher rates that the latter two. For the compensated LLD group, no difference was found between list types. For the TD group, the critical lure from the situation lists was recalled at significantly lower rates than the strong-BAS lists (no TD participant recalled any critical lure for any mid- or low-BAS list).
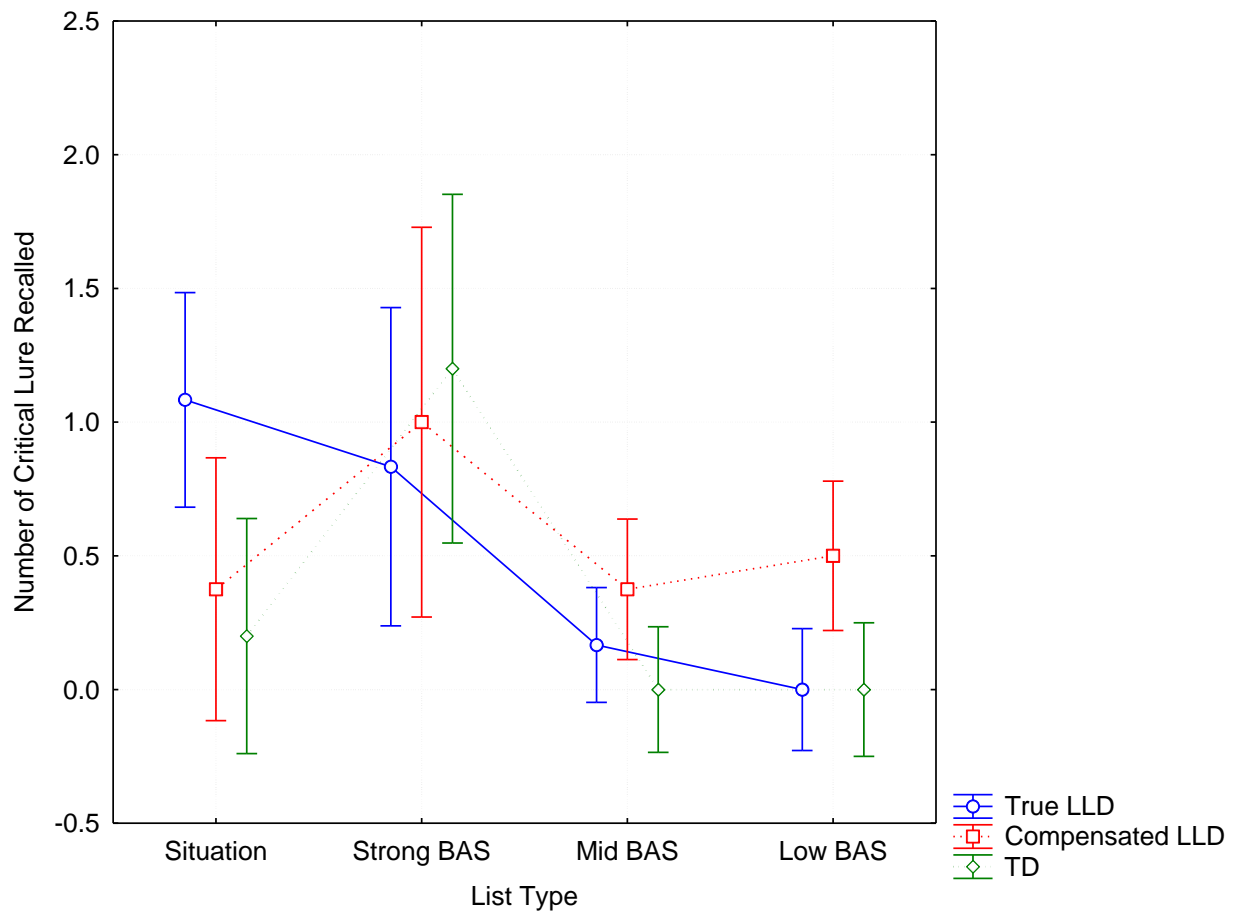
Figure 1. Recall of Critical lure as a function of group and list type. Error bars denote 95% confidence interval.

Additional one-way ANOVAs revealed significant group effects on recall of

critical lures in the situation lists ($F(2, 27)=5.24$, $p=0.01$, $\eta_p^2=0.28$). Post-hoc tests with

Bonferroni correction showed that the true LLD group recalled these lures at significantly

higher rates than the TD group, but that there were no significant differences between the

true LLD and compensated LLD groups, or between the compensated LLD group and the

TD group. Critical lure recall in the low-BAS lists showed a significant group effect

($F(2, 27)=4.95$, $p=0.015$, $\eta_p^2=0.27$). As seen in Figure 1, the compensated LLD group

recalled an average .5 critical lures for these lists whereas the other two groups never

recalled the critical lure for the low-BAS lists. Critical lure recall for the strong and mid

BAS lists did not show any group differences.

To summarize, there were no significant group differences in correct recalls.

Subtle group differences were noted in the false recall of critical lures. Specifically, the

true LLD group produced more critical lures than the TD group for the situation lists and

the compensated LLD group produced more critical lures than the other groups for low

BAS lists.

Error Types

Frequency of semantic intrusions, phonological intrusions, and other kinds of

errors is presented in Table 3. No group or list type effects were found for any error type

($ps > 0.05$). Within this sample, LLD status did not influence the type of errors or the rate

at which participants recalled non-critical lure items which had not been presented.

Correlations between Language Test Scores and List Recall

Scores on the spoken subtest of the *Test of Adolescent and Adult Language-fourth*

edition (TOAL-4; Hammill et al., 2007) were positively correlated with correct recall on

all list types ($p < 0.05$ on situation, $p < 0.01$ all others). Scores on the nonword repetition

subtest of the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner,

Torgesen, & Rashotte, 1999) were positively correlated with correct recall on the strong-

BAS lists ($p < 0.01$) and negatively correlated with critical lure recall on the situation lists

($p < 0.05$).

DISCUSSION

This study examined verbatim and gist memory in young adults with compensated and true LLD using the DRM paradigm. Lists based on situation features and strong, mid, and low levels of BAS were presented to participants in an attempt to elicit the non-presented critical lure (CL) and assess accurate and false recall in relation to list type and LLD status. Based on previous studies by Branch et al. (2007), Weekes et al. (2008), and Watson et al. (2005), it was predicted that the true LLD group would demonstrate lower verbatim and gist memory than TD controls, and that the compensated LLD group would demonstrate average verbatim memory and higher gist memory than TD controls. Based on a study by Cann et al. (2011), it was predicted that verbatim recall would be highest for situation lists, next-highest for strong- and mid-BAS lists, and lowest for the low-BAS lists; additionally, it was predicted that gist recall would be highest for the strong-BAS lists, next-highest for situation lists, and lowest for mid- and low-BAS lists. In this section, the results are discussed in terms of similarities and differences among the true LLD, compensated LLD, and TD groups, and the four different list types' effects on verbatim and gist recall.

Group Similarities

Although there was a non-significant tendency for the true LLD group to show lower accurate recalls (please see Table 3 for details), there were no significant between-group differences on verbatim recall. This is surprising due to the fact that previous studies have consistently found group differences on accurate recall (Branch et al., 2007; Weekes et al., 2008; Watson et al., 2005). However, this finding may be the result of

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small sample size, and it is possible that the true LLD group's lower verbatim recall would become significant with a larger sample.

The three groups did not show significant between-group differences on recall of the critical lure for either the strong- or the mid-BAS lists. The groups' overall mean recall of critical lures was approximately 15%, identical to Cann et al.'s (2011) results for situation lists when including a distracter task before recall. This is much lower than previous studies' 40-55% rates of false recall in TD populations, possibly due in part to the lists in those studies being longer and greater in number as well as participants writing down their responses, which would take longer than verbal recall and potentially decrease the accuracy of their memories (Roediger & McDermott, 1995; Stadler, Roediger, & McDermott, 1999).   However, it is similar to the 20% false recall rate that Watson et al., (2005) found in college students with low memory capacity.

Correlations with test results indicate that strong verbal and phonological processing skills are associated with stronger verbatim memory, and in one instance, reduced CL intrusions. These findings support the interactive relationships among general verbal ability, phonological memory, and the memory processes utilized in the DRM paradigm.

Group Differences

Despite the many similarities across the groups, we also found subtle differences in CL intrusions. Specifically, the true LLD group recalled critical lures at a significantly higher rate than the other groups in the case of the situation lists. It is possible that true LLD individuals are more vulnerable to forming associations based on situation features

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than their compensated LLD and TD peers. This could point to true LLD individuals

having a different way of processing and/or storing verbal information. This fails to

support the hypothesis that the true LLD group would tend to have lower rates of CL

recall. Additionally, the compensated LLD group recalled critical lures for the low-BAS

lists at a significantly higher rate than either the true LLD or TD groups. This could

indicate that some compensated LLD individuals rely more heavily on gist associations in

order to compensate for overall poorer memory. This provides support for the prediction

that compensated LLD participants would demonstrate higher rates of false recall.

However, due to this experiment's small sample size, these patterns need to be confirmed

with a larger sample before these generalizations can be made.

List Type Effects

Accurate recall for situation lists was significantly higher than accurate recall for

strong- and low-BAS lists, which largely agrees with the results of the Cann et al. (2011)

study. It is possible that situation features create a cohesive mental representation that

makes each list item more meaningful and, therefore, easier to remember. The situation

lists elicited the CL at significantly higher rates than the mid- and low-BAS lists despite

their comparable BAS, which is also consistent with Cann et al.'s (2011) findings. This

indicates that the effects of situation features on gist memory, while often similar to

higher BAS, are separate from BAS. The same cohesive mental representation that made

each list item easier to remember may also have made it more difficult to realize that the

CL was not originally present, since, for example, the CL "breakfast" is an integral part

of the situation that includes toast, cereal, coffee, and the rest of the breakfast-related list items.

Verbatim recall on the strong-BAS lists was significantly lower than that of the situation lists, which agrees with Cann et al.'s (2011) results, but recall was comparable to low-BAS lists and lower than mid-BAS lists, which differs from Cann et al.'s (2011) findings. The strong-BAS lists, while consisting of many situation features, also contain synonyms, antonyms, and taxonomic relations. These different relationships may strengthen the gist representation, but fail to make each list item meaningful in itself, which may contribute to lower levels of accurate recall. The strong-BAS lists were equivalent to situation lists in terms of eliciting the CL, unlike in the Cann et al. (2011) study, in which strong-BAS lists elicited the CL at a significantly higher rate.

The mid-BAS lists were accurately recalled at a significantly higher rate than the low-BAS lists, in agreement with Cann et al.'s (2011) results. The BAS of the mid and low lists was not significantly different, but we considered them as separate categories in order to replicate the previous study. Higher verbatim recall for the mid- than low-BAS lists may have been due to non-semantic features in the list items: the "beautiful" and "butterfly" lists included multiple adjectives whereas the low-BAS lists consisted of mostly nouns; therefore the adjectives could have stood out more and been easier to remember. Additionally, the mid-BAS list "bitter" contained mostly one-syllable words, which would have allowed more items to remain in working memory for longer according to the phonological loop theory (Baddeley, 2003). The low-BAS lists tended to lack an obvious uniting theme, which resulted in individual list items being less

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meaningful and more difficult to remember. As in Cann et al. (2011), the mid- and low-BAS lists elicited the CL at similar rates.

Our findings suggest that all individuals, both LLD and TD, are sensitive to semantic relations between list words. It is likely that participants' recall performance reflects the way semantic information is organized. Because word lists made up of different types of features or having different levels of associative strength can lead to different levels of CL recall, both researchers and clinicians should keep this in mind when assessing participants and patients to ensure that any observed differences are due to an individual's performance and not factors specific to the word lists themselves. Knowledge of BAS and gist is also important in semantic feature analysis therapy for individuals with aphasia, in which the client attempts to generate a list of features relating to a central concept (Boyle, 2010). The clinician's understanding of which semantic relationships are most likely to elicit the CL could help the client to construct the most salient representation of the target word.

Memory performance is complex and relies on multiple factors, including word length and class (noun, verb, adjective) in addition to the semantic features and BAS tested in this experiment. Some of our findings may be due to factors such as individual variability combined with the small sample size, and unintended differences between the study lists.

Future Research

A larger sample size is desirable for future studies in order to see if the results observed in this experiment are reliable. An expansion of the LLD and TD groups to

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include individuals who did not attend college would provide a better representation of the general population, as well as a broader picture of the spectrum of language and memory capacity in individuals with LLD. The addition of a mathematical distracter task after list presentation and before recall, and/or having participants write their answers rather than say them aloud, could allow more reliable comparisons with the results of previous studies.

APPENDIX A: STIMULI

Situation			Strong-BAS			Mid-BAS			Low-BAS		
Breakfast	bacon		**Doctor**	physician		**Beautiful**	gorgeous		**Long**	short	
	toast			nurse			lovely			distance	
	cereal			stethoscope			pretty			hair	
	muffin			surgeon			girls			line	
	food			patient			ugly			narrow	
	plate			clinic			scene			road	
	coffee			dentist			homely			John	
	pancakes			medicine			nice			time	
	eggs			lawyer			picture			island	
	milk			health			mountain			thin	
	fruit			sick			snow			underwear	
	juice			cure			music			low	
Casino	alcohol		**Sleep**	nap		**Bitter**	sour		**Trouble**	help	
	tables			doze			taste			danger	
	blackjack			bed			sweet			difficulty	
	slots			awake			chocolate			problem	
	cards			drowsy			cold			shooter	
	money			snooze			lemon			worry	
	chips			slumber			angry			sorrow	
	lights			rest			hard			fear	
	craps			tired			acid			school	
	Las Vegas			snore			almonds			police	
	dealer			wake			herbs			fight	
	gambler			dream			grape			sad	
Farm	barn		**Smoke**	cigar		**Butterfly**	cocoon		**Whistle**	train	
	tractor			cigarette			insect			blow	
	cow			pipe			wing			noise	
	stables			tobacco			bird			sing	
	fence			puff			fly			tune	
	rooster			chimney			yellow			sound	
	field			lungs			flower			song	
	pitchfork			pollution			bug			shrill	
	hay			billows			summer			boy	
	pig			ashes			color			lips	
	house			fire			bee			wolf	
	mud			blaze			stomach			loud	

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