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Episodic Memory Retrieval in Adolescents with and without Developmental Language Disorder (DLD)

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Abstract

Background—Two reasons may explain the discrepant findings regarding declarative memory in DLD in the literature. First, standardized tests are one of the primary tools used to assess declarative memory in previous studies. It is possible that they are not sensitive enough to subtle memory impairment. Second, the system underlying declarative memory is complex, and thus results may vary depending on the types of encoding and retrieval processes measured (e.g., item-specific or relational), and/or task demands (e.g., recall or recognition during memory retrieval).

Aims—The aim of the current study was to adopt an experimental paradigm to examine episodic memory functioning in adolescents with and without DLD, with the focus on memory recognition of item-specific and relational information.

Methods & Procedures—Two groups of adolescents, one with DLD ($n=23$; mean age=16.73 years) and the other without ($n=23$; mean age=16.75 years), participated in the study. The Relational and Item-Specific Encoding (RISE) paradigm was used in order to assess the effect of different encoding processes on episodic memory retrieval in DLD. The advantage of using the RISE task is that both item-specific and relational encoding/retrieval can be examined within the same learning paradigm.

Outcomes & Results—Adolescents with DLD and those with typical language development showed comparable engagement during the encoding phase. The DLD group showed significantly poorer item recognition than the comparison group. Associative recognition was not significantly different between the two groups; however, there was a non-significant trend for to be poorer in the DLD group than in the comparison group, suggesting a possible impairment in associative recognition in individuals with DLD but to a lesser magnitude.

Conclusions & Implications—These results indicate that adolescents with DLD have difficulty with episodic memory retrieval when stimuli are encoded and retrieved without support from contextual information. Associative recognition is relatively less affected than item recognition in adolescents with DLD.

Keywords

Developmental language disorder; episodic memory; item recognition; associative recognition

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I have read and understood the journal's policy on declaration of interests and declare that I have no competing interests.

Introduction

Developmental Language Disorder (DLD) is a term used to describe a disorder, of which impairments in language, morphosyntax in particular, constitute a major feature despite grossly normal intellectual and sensory abilities (Bishop, Snowling, Thompson, Greenhalgh, & the CATALISE consortium, 2017). There is a debate in the field as to whether DLD represents the lower end of a continuous distribution with regard to language abilities, or is a qualitatively distinct clinical group (Dollaghan, 2011; Leonard, 2009).

One of the recent hypotheses accounting for DLD is the Procedural Deficit Hypothesis (PDH; Ullman & Pierpont, 2005), which states that the language profile of DLD is a consequence of the procedural memory system's impaired attempts to acquire rule- or pattern-based aspects of language (e.g., grammar), as well as of the declarative memory system's attempts to compensate for this shortcoming (see also Thomas, 2005). There has been substantial evidence showing impaired procedural learning in DLD (Lee & Tomblin, 2015; Lum, Conti-Ramsden, Morgan, & Ullman, 2014; Tomblin, Mainela-Arnold, & Zhang, 2007); however, results pertaining to the declarative memory system in DLD remain mixed (see Lum & Conti-Ramsden, 2013, for a review), which may be attributed to limited memory measures used in prior studies to examine the complex nature of the declarative memory system.

Declarative Memory and Language

Declarative memory is a form of long-term memory, which can be further divided into a semantic and an episodic component (Squire, 2004). Semantic memory, on the one hand, is a record of facts, concepts, and knowledge about the world, which is decontextualized and independent of personal experiences (e.g., memory of football as a type of sports). On the other hand, episodic memory represents the memory of experiences, from which we can reconstruct the incidences that occurred at any given point in our lives (e.g., memory of the last time we watched a football game together). These different components of declarative memory are supported by functionally distinct but overlapping neural networks (Wiggs, Weisberg, & Martin, 1998). The focus of the current study was the episodic component of declarative memory.

Information about episodic events can be encoded and retrieved by focusing on distinctive features of individual items (i.e., item-specific encoding and retrieval) or the relationship among multiple items (i.e., relational encoding and retrieval) (Hunt & Einstein, 1981). Previous studies showed that item-specific memory and relational memory depend upon distinct encoding operations within the medial temporal lobe (MTL), wherein the perirhinal cortex mainly processes and encodes information of individual elements within an episode, while the hippocampus subserves relational integration of those elements into a coherent representation (see Davachi, 2006, for a review). However, this distinction in the brain does not suggest independence of item-specific and relational memory, and it remains unclear in the literature whether relational learning can occur without item-specific encoding at the same time.

Compared to other forms of memory (e.g., working memory), there is a paucity of research on the association between declarative memory, episodic memory in particular, and individual differences in language. Ullman is one of the first researchers proposing the role of multiple memory systems in language learning (Ullman, 2004). In his Declarative/Procedural model, the division between grammar and lexicon in language is closely tied to the division between procedural and declarative memory. Procedural memory plays an important role in syntactic acquisition, whereas declarative memory supports language by storing arbitrary word-specific knowledge in the brain, such as sound-meaning correspondences of words.

While declarative memory receives growing attention for its role in word learning, Duff and her colleagues extends the contribution of declarative memory to language even further, showing that the hippocampal declarative memory system supports a wide variety of language processing and use beyond the lexical domain, including reported speech, verbal play in social interactions, and use of definite references during online processing (see Duff & Brown-Schmidt, 2012, for a review). Based on the evidence derived from studies on hippocampal amnesia, Duff and Brown-Schmidt (2012) proposed that the same processes underlying the hippocampal declarative memory system, such as relational binding of items into integrated representations as well as flexible use and online maintenance of those representations, are indeed similar processes necessary for various aspects of language processing and use.

Declarative Memory in DLD

Several researchers showed impaired declarative memory for verbal information in DLD (Bishop & Hsu, 2015; Dewey & Wall, 1997; Lum, Conti-Ramsden, Page, & Ullman, 2012), but others showed no evidence of such mnemonic difficulty (Records, Tomblin, & Buckwalter, 1995; Shear, Tallal, & Delis, 1992). Lum, Ullman, and Conti-Ramsden (2015) found that after controlling for working memory, the discrepancy in verbal declarative memory between the DLD group and the comparison group became non-significant. Thus, they suggested that impaired verbal declarative memory in children with DLD should be accounted for by their poor working memory capacity.

Given that poor language abilities could be a confounding factor for interpreting poor verbal declarative learning in DLD, using nonverbal stimuli to test declarative memory in DLD will avoid this problem. With regard to nonverbal declarative memory in DLD, results are also mixed. Some work reported spared nonverbal declarative memory in children with DLD (Baird, Dworzynski, Slonims, & Simonoff, 2010; Bishop & Hsu, 2015; Lum et al., 2012), whereas others found poor performance on nonverbal declarative memory tasks in DLD (Bavin, Wilson, Maruff, & Sleeman, 2005; Kuppuraj, Rao, & Bishop, 2016; Poll, Miller, & van Hell, 2015). Two possible reasons may explain these inconsistent findings. First, standardized tests are one of the primary tools used to assess declarative memory in the DLD literature (e.g., Baird et al., 2010; Lum et al., 2012). Standardized tests are an excellent measure of general memory function; however, they may not be sensitive enough to subtle memory impairment. Thus, using experimental tasks to measure different encoding and retrieval processes underlying episodic memory is an alternative option to supplement

standardized tests. Second, the system underlying declarative memory is complex, and thus results may vary depending on the types of encoding and retrieval processes measured (e.g., item-specific or relational), and/or task demands (e.g., recall or recognition during memory retrieval).

To the author's knowledge, none of the published work includes tasks to assess contributions of different encoding and retrieval processes to episodic memory in the same sample of individuals with DLD. The paired associates learning paradigm, which entails pairing of two unrelated items, is one of the most widely used experimental tasks to index episodic memory in the DLD literature. Several researchers showed impaired associative learning of nonverbal information in individuals with DLD (e.g., Bavin et al., 2005; Kuppuraj et al., 2016; Poll et al., 2015), whereas Bishop and Hsu (2015) found that children with DLD did not have difficulty associating two unrelated nonverbal items together. Kuppuraj et al. (2016) suggest that this discrepancy lies in the nature of memory retrieval demanded by different tasks. Memory recall involves more activated brain regions than memory recognition, and thus places higher demands on the brain (Cabeza et al., 1997). In Bavin et al. (2005), Kuppuraj et al. (2016), and Poll et al. (2015), memory retrieval was assessed via spontaneous recall; in contrast, in Bishop and Hsu (2015), memory retrieval was assessed via recognition, which may explain, at least partially, why children with DLD performed comparably to their age-matched peers.

In contrast with relational encoding/retrieval, there is a dearth of studies on item-specific encoding/retrieval in DLD. Kuppuraj et al. (2016) examined the effect of the type of item-specific encoding (i.e., incidental versus intentional) on declarative memory performance in children with DLD. They showed that individuals with DLD did poorly on item-specific encoding in an incidental declarative memory task, but they were able to recognize items as well as the comparison participants during memory retrieval.

The Current Study

As can be seen from the review above, previous results are somewhat mixed. Two tentative hypotheses were made based on findings from prior research. First, adolescents with DLD would perform similarly on item recognition in comparison to their age-matched peers. This hypothesis was generated from the finding by Kuppuraj et al. (2016) showing normal item recognition after incidental encoding in DLD. To the author's knowledge, this is the only study available in the literature addressing item recognition after incidental encoding in DLD. Second, adolescents with DLD would show relatively poorer associative recognition in comparison to their age-matched peers. This hypothesis was generated from preliminary findings showing abnormal enlargement in the hippocampus (Lee, Nopoulos, & Tomblin, 2013) as well as poor performance on associative learning in DLD (Bavin et al., 2005; Kuppuraj et al., 2016; Lee, Brown-Schmidt, & Duff, 2015; Poll et al., 2015; but see Bishop and Hsu, 2015).

The aim of the current study, therefore, was to examine episodic memory functioning in adolescents with and without DLD using the Relational and Item-Specific Encoding (RISE) paradigm. The RISE task was chosen due to its good reliability and validity (Ragland et al., 2012), as well as its successful use with healthy individuals as well as people with

conditions associated with impaired episodic memory (Ragland et al., 2015; Solomon, McCauley, Losif, Carter, & Ragland, 2016). More specifically, the RISE task allows us to examine the effect of different encoding processes (i.e., item-specific and relational) on episodic memory retrieval in DLD within the same paradigm using non-verbal responses.

Methods

Participants

Two groups of adolescents, one with DLD ($n=23$) and the other without ($n=23$), participated in the current study. The mean age for the DLD group was 16.73 years with standard deviation (SD) equal to 1.50, and that for the comparison group was 16.75 years ($SD=1.55$). These participants were originally recruited for a brain imaging project concerning the neurobiological mechanisms of individual differences in language. Group assignment was made based on five language tests and two nonverbal IQ subtests of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The five language tests are: 1) Expressive Vocabulary Test, Second Edition (EVT-2; Williams, 1997) to assess expressive vocabulary, 2) Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4; Dunn & Dunn, 2007) to assess receptive vocabulary, 3) Word Derivations in the Test of Adolescent and Adult Language, Fourth Edition (TOAL-4; Hammill, Brown, Larsen, & Wiederholt, 2007) to assess knowledge of derivational morphology, 4) Recalling Sentences in Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel et al., 2003) to assess the ability to recall and reproduce sentences of syntactic complexity, and 5) Understanding Spoken Paragraphs in CELF-4 to assess passage comprehension. It should be noted that studies concerning DLD in the adolescent and adult years are relatively uncommon compared to their childhood counterparts, and thus there is no “gold standard” of tests for diagnosing DLD beyond childhood. The language tests used in the current study were carefully selected based on Tomblin, Freese, and Records (1992), and Fidler, Plante, and Vance (2011), with the aim to assess multiple domains of language.

Language composite scores were generated for each participant by averaging the five language test scores. Individuals with language composite scores at least one SD below the mean were assigned to the DLD group for the research purpose. In contrast, participants assigned to the comparison group needed to have each language test as well as the language composite scores above one SD below the mean. The demographic characteristics and test scores of the two groups were described in Table 1. All the participants in the DLD group had a nonverbal IQ within the normal range (i.e., nonverbal IQ equal or above 70), but were not required to have it above 85 (Bishop et al., 2017; Earle, Gallinat, Grela, Lehto, & Spaulding, 2017; Lee & Tomblin, 2012;).

Materials

The RISE paradigm comprised an encoding phase, followed by a retrieval phase. All the stimuli were visual familiar objects to minimize language demands on memory processing in individuals with DLD.

Encoding Phase—There were two types of stimuli in the encoding phase (see Figure 1). The difference between them lied in the type of encoding processes. The item-specific encoding stimuli, on the one hand, involved encoding of unique features of an individual item irrespective of contemporaneously presented context or elements. Participants made a two-button “yes/no” response to indicate whether the item-specific stimulus shown on the screen was “living”. Ragland et al. (2012) argued that this manipulation of semantic encoding was better than the commonly used decision question of “pleasant/unpleasant” because the latter revealed ceiling effects during their piloting. There were 36 item-specific encoding stimuli, and each stimulus was presented for two seconds, with a one-second inter-stimulus-interval (ISI).

On the other hand, the relational stimuli involved encoding of associations between the stimuli. Participants made a two-button “yes/no” response to indicate whether one item could fit inside of the other. They were instructed to focus on the size of the objects in the real world, not the size of them on the screen. There were 18 pairs of relational encoding stimuli, and each pair was presented for 4 seconds, with a one-second ISI.

Retrieval Phase—Participants proceeded to the retrieval phase after completion of the encoding phase. There were two conditions in the retrieval phase (see Figure 1). The first one was item recognition, wherein all 72 objects studied during the encoding phase (i.e., 36 item-specific encoding stimuli and 18 pairs of relational encoding stimuli) and 72 new unstudied foil object stimuli were randomly presented. Participants indicated whether the stimulus shown on the screen was old (i.e., they saw it during the encoding phase) or new (i.e., they did not see it during the encoding phase).

The second condition was associative recognition. In the task, all 18 pairs of the relational stimuli studied during the encoding phase were randomly presented, along with 18 rearranged pairs consisting of old items not originally shown together. Participants made a two-button “yes/no” response to indicate whether items in each pair were presented together in the retrieval phase.

Procedure

Participants were given the language and cognitive tests when they were originally recruited for a brain imaging project. The time gap between administration of the language/cognitive tests and of the RISE task ranges from two weeks to one month.

Regarding the procedure of the RISE task, in the encoding phase, three blocks of item-specific encoding stimuli (12 trials per block) and three blocks of relational encoding stimuli (6 trials per block) were alternated in a pseudo-random block design to reduce cognitive demands on participants. Participants were presented with an instruction screen to remind them of the encoding condition between blocks. In the retrieval phase, participants were instructed to “do it as quickly and accurately as you can”. To prevent additional encoding of the relational object pairs, item recognition always preceded associative recognition.

Participants had to successfully complete practice trials before beginning the encoding phase to ensure task understanding. After finishing the encoding phase, participants were required

to go through a test session before proceeding to the retrieval phase. During the test session, they responded on 10 trials of item recognition (i.e., whether the item shown on the screen was old or new), and 10 trials of associative recognition (i.e., whether items in each pair were presented together during the encoding phase). Participants whose scores did not reach a 60 percent accuracy level were disqualified from moving onto the retrieval phase due to their poor encoding processes or poor understanding of the task, which might confound interpretation of retrieval performance.

Data Analysis

Regarding the encoding phase, the response rate of each group was calculated to examine whether participants were engaged in the encoding processes. The scores of the test session (i.e., 10 trials of item recognition and 10 trials of associative recognition) were compared between the two groups to provide additional evidence for participants' understanding of and engagement in the encoding phase. It should be noted that the research interest was in engagement of encoding processes rather than the accuracy of equivocal responses (e.g., is an apple on the table living?), and therefore response accuracy was not taken into account (Ragland et al., 2012).

In terms of the retrieval phase, the dependent variable was the recognition memory discriminability index (d'), computed by subtracting the z -scored false alarm rate from the z -scored hit rate. For item recognition, a two-way analysis of variance (ANOVA) was performed to examine the effect of Group (i.e., the DLD group vs. the comparison group) on Encoding Condition (i.e., item-specific encoding vs. relational encoding). With regard to associative recognition, an independent samples t -test was conducted to compare the difference in the memory discriminability index (d') between the DLD and the comparison group.

Last, the Sobel tests of mediation (Baron & Kenny, 1986; Sobel, 1982) were planned a priori to examine whether nonverbal IQ mediated the relationship between language composite scores and episodic memory measures. The rationale for using the mediation analysis instead of the analysis of covariance (ANCOVA) is based a theoretical assumption that language acquisition and learning are associated with general-purpose learning systems (e.g., Gomez & Gerken, 1999; Saffran et al., 1999 but see Chomsky, 2011, for a different perspective). Thus, instead of showing a specific and largely encapsulated association between memory and language after controlling for nonverbal IQ, mediation analysis provides a means to examine whether nonverbal IQ, which is closely related to cognitive function, mediates this association.

In order to perform the Sobel tests, two sets of data had to be obtained: 1) unstandardized regression coefficient B and its standard error (SE) for the association between language and memory measures, and 2) unstandardized regression coefficient B and its SE for the association between nonverbal IQ and memory measures when language was also a predictor of memory measures.

All statistical analyses were carried out using SPSS-24 software except for the Sobel tests, which were calculated via an online calculation tool (<http://quantpsy.org/sobel/sobel.htm>).

Results

Encoding Phase

The response rate was 97.67% (SD=2.63) for the DLD group and 99.03% (SD=2.43) for the comparison group. This difference was not statistically significant, $t(44)=1.83$, $p=.07$, indicating that all participants, regardless of their language abilities, were well engaged during the encoding phase.

With regard to the test session before the retrieval phase (i.e., 10 trials for item recognition and 10 trials for associative recognition), the independent samples t -tests showed no significant difference in item recognition, $t(44)=1.62$, $p=.11$, or associative recognition, $t(44)=.48$, $p=.64$, and none of the participants met the criteria of disqualification (i.e., 60 percent accuracy level). The results provide additional support for full engagement of both groups during the encoding phase.

Memory Retrieval: Item Recognition

A two-way ANOVA revealed a significant main effect of Group (DLD, Comparison), $F(1,44)=7.96$, $p=.007$, and of Encoding Condition (Item-specific encoding, relational encoding), $F(1,44)=95.67$, $p<.001$. The Group by Encoding Condition interaction effect was non-significant, $F(1,44)=.91$, $p=.35$. The finding suggested that the DLD group performed poorly on item recognition compared with the comparison group, and how the stimuli were initially encoded did not make a significant difference in the item recognition scores. The effect of Group on item recognition was larger following item-specific encoding (Cohen's $d=.85$) than relational encoding (Cohen's $d=.76$). Figure 2 illustrated item recognition discriminability (d') for the DLD group and the comparison group.

Memory Retrieval: Associative Recognition

The independent samples t -test showed that the DLD group was not significantly different from the comparison group with regard to the associative recognition discriminability, $t(44)=1.79$, $p=.08$, $d=.53$. Figure 3 illustrated performance of the two groups on associative recognition.

Is Nonverbal IQ a Mediator between Language and Episodic Memory?

Concerns may be raised with regard to the significant difference in nonverbal IQ between the two groups. It is hard to separate IQ from abnormal phenotypes in neurodevelopmental disorders, and therefore covarying IQ may partial out variance relevant to the phenotypes (Dennis et al., 2009). As a result, more and more researchers argued for the inappropriateness of IQ matching in studies on DLD (e.g., Botting, 2005; Earle et al., 2017). In the current study, nonverbal IQ not only correlated with language, but it also correlated with memory measures. Table 2 showed the correlation matrix among language composite scores, episodic memory measures, and nonverbal IQ. In the correlation analyses, language

was seen as a continuous variable, with language performance of DLD contributing to the lower end of the normal distribution with regard to language.

Given the intertwined relationship among language, memory, and nonverbal IQ, it is inappropriate to run an ANCOVA. Thus, mediation analyses were used instead to examine if nonverbal IQ was a mediator in the relationship between language and episodic memory. In order to run the Sobel tests of mediation (Baron & Kenny, 1986; Sobel, 1982), regression analyses were first conducted to calculate unstandardized regression coefficients B s and SE s. Results showed that language ability was a significant predictor of nonverbal IQ (see path a in Figure 4), $B=.70$, $SE=.11$, $t=6.68$, $p<.001$. However, after controlling for language, nonverbal IQ was not a significant predictor of item recognition following item-specific encoding (see path b in Figure 4), $B=.008$, $SE=.01$, $t=.74$, $p=.46$, of item recognition following relational encoding, $B=.01$, $SE=.01$, $t=.93$, $p=.36$, or of relational recognition, $B=.02$, $SE=.01$, $t=1.37$, $p=.18$. The Sobel test, a Z-test to determine the extent to which a mediator (i.e., nonverbal IQ) contributes to the outcome variable (i.e., memory measures), showed that nonverbal IQ did not significantly mediate the relationship between language and item recognition following item-specific encoding, $z=.79$, $SE=.01$, $p=.43$, between language and item recognition following relational encoding, $z=.98$, $SE=.01$, $p=.32$, or between language and associative recognition, $z=1.91$, $SE=.01$, $p=.06$. Therefore, despite the close interrelationship among nonverbal IQ, language, and episodic memory, nonverbal IQ was not considered a strong mediator in the relationship between language and episodic memory in the current sample.

Discussion

Summary of Findings

The aim of the current study was to examine episodic memory functioning in adolescents with and without DLD, with the focus on the effect of item-specific and relational encoding on memory recognition. Language learning and acquisition involve both item-specific and relational processing, and therefore, teasing them apart will elucidate different components of episodic memory ability in DLD, which may shed light on new ideas for developing learning strategies for those with poor language ability.

The findings showed that despite comparable engagement during the encoding phase, the DLD group revealed poorer item recognition than the comparison group. This result indicates that adolescents with DLD have more difficulty with episodic memory retrieval when stimuli are encoded and retrieved without support from contextual information. This may lead to language learning problems when item-specific information is needed for processing and use. In terms of associative recognition, there was a non-significant trend to be poorer in the DLD group than in the comparison group, suggesting a possible impairment in associative recognition in individuals with DLD but to a lesser magnitude. A lack of statistical significance may be driven from small sample size or relatively low task demands on episodic memory for relational information.

According to the PDH, the declarative memory system is preserved in individuals with DLD, which takes over their incompetent procedural memory system. The current study

contributes to the declarative aspect of the PDH, showing that episodic memory for nonverbal stimuli in DLD is affected to a lesser magnitude when to-be-remembered items have contextual support (e.g., association with another object) and were retrieved via recognition, which places less demands on the completeness of memory representations. However, the current data do not support the notion that episodic memory is largely normal or even enhanced in individuals with DLD (Ullman & Pierpont, 2005).

Poor Item Recognition in DLD

Successful item recognition depends on retrieval of specific elements of an object in the memory, without reference to associative cues in the context. In the current study, the DLD group had inferior item recognition than the comparison group. The effect size of Group on item recognition was larger following item-specific encoding than relational encoding, suggesting that contextual information may facilitate item recognition to some extent.

This finding is in contrast with the hypothesis stating that adolescents with DLD would perform similarly on item recognition in comparison to their age-matched peers. Two possible reasons are proposed to account for poor item recognition in DLD. First, despite that all the stimuli used in the RISE task are familiar items, individuals with DLD may have incomplete representations of them, leading to insufficient/inadequate activations of item features, and thus causing poor item recognition at the retrieval phase. In contrast, contextual support exists in relational encoding and associative recognition, making up for incomplete activated features of an individual item. This possibility is consistent with findings of previous studies showing the contribution of limited semantic knowledge to vulnerable word retrieval in DLD (e.g., McGregor, Newman, Reilly, & Capone, 2002). In addition, the question used to elicit item-specific encoding (i.e., “*is ___ living?*”) involves a relatively abstract feature of an item, which may cause difficulty with item-specific processing in individuals with DLD. Second, it is also possible that individuals with DLD *do* have equivalent activations of item features compared to those without DLD; however, these activations decayed faster in the DLD group than in the comparison group, leading to less stable representations and poor item recognition later (e.g., McMurray, Samelson, Lee, & Tomblin, 2010). In contrast, during relational encoding and associative recognition, contextual information may compensate for the fast decay rate in the memory trace.

Kuppuraj et al. (2016) is the only study known to the author to examine item recognition after incidental encoding. They showed that children with DLD did poorly on item-specific encoding in an incidental declarative memory task, but they were able to recognize items as well as the comparison participants after 10- and 60-minute retrieval intervals. The current findings seem in contrast with those reported in Kuppuraj et al. (2016). However, the experimental design of the RISE task does not allow researchers to measure how accurate (i.e., percent accuracy) participants are on item-specific encoding; it simply informs us how well they are engaged during the encoding process. Therefore, it is hard to compare the two studies on incidental item-specific encoding in DLD, and further work is needed to address this issue. Regarding item recognition, the discrepancy between the two studies may be attributed to the existence of retrieval intervals. In Kuppuraj et al.’s study, participants waited for 10 and 60 minutes before moving onto the memory retrieval phase, whereas in the

current study, there was no time interval between encoding and retrieval. This difference implicates a possible role of memory consolidation in item recognition in DLD.

Associative Recognition in DLD

Some researchers showed poor performance of individuals with DLD on nonverbal paired-associative learning tasks (Bavin et al., 2005; Poll et al., 2015; Kuppuraj et al., 2016), whereas others found that children with DLD did not have difficulty associating two unrelated nonverbal items together (Bishop & Hsu, 2015). Kuppuraj et al. (2016) suggested that the discrepancy of findings lies in the nature of memory retrieval. Studies showing poor declarative learning in DLD used explicit recall retrieval, whereas Bishop and Hsu (2015) used recognition, which places less demands on the completeness of memory representations.

In the RISE task, the DLD group showed relatively better associative recognition than item recognition after relational encoding, which is consistent with Kuppuraj et al.'s suggestion that individuals with DLD could perform well on declarative learning when memory is measured via recognition instead of recall. However, the current findings of poor item recognition in DLD in contrast with non-significant difference in associative recognition suggest that there are factors beyond the different types of retrieval that influence declarative memory performance in DLD. As discussed above, it is possible that individuals with DLD are able to take advantage of simple contextual information (e.g., associative cues) to facilitate memory processing.

However, it would be inappropriate to conclude that associative learning is completely intact in DLD based on the current data, given the median effect size for the between-group difference in associative recognition. It is suspected that relational retrieval in DLD may be also abnormal, but to a lesser magnitude than item-specific retrieval. If that is the case, then we may expect to see significantly poor relational retrieval when demands on to-be-remembered pairs increase (e.g., increased number of pairs learned at the same time, or increased abstractness of the stimuli). Preliminary findings shown in Lee et al. (2015) seem to provide support for this hypothesis. In Lee et al. (2015), associative learning in young adults with and without DLD was tested using a spatial reconstruction task, wherein participants studied five pairs of item-location binding at the same time, and then reconstructed the array (i.e., putting the items back to their associated locations) after a short period of time. This task assesses relational memory and is considered hippocampal-dependent (Watson, Voss, Warren, Tranel, & Cohen, 2013). It is different from the RISE task in the way that associative learning in the RISE task involves one pair of two familiar items only. Lee et al.'s findings showed that although participants with DLD did not have difficulty identifying novel items of the five pairs, they made more errors than the comparison participants with regard to reversing the relative positions of item-location pairs. Thus, it is possible that associative recognition will be more affected when demands on learned stimuli increase.

Conclusion

The current study showed significantly poor item recognition as well as a non-significant trend for associative recognition to be poorer in adolescents with DLD.

Regarding study limitations, although the prevalence of DLD is relatively higher in males than in females (Tomblin et al., 1997), there were more females with DLD who were willing to volunteer for the current study than males with DLD. The unequal sex distribution may limit generalization of the findings. In addition, the stimuli used in the RISE task are visual pictured stimuli of real-world entities that are carefully selected reduce the demands on language. However, the questions asked to facilitate encoding and retrieval (e.g., “*is ____ living?*” or “*can ____ fit inside ____?*”) may still increase the language/cognitive load for participants, particularly for those with DLD, and thus raise an issue concerning the potentially confounding contribution of language ability to performance on the RISE task. Lastly, it should be noted there is a significant difference in nonverbal IQ between the two groups. The current study is in line with the recent consensus papers suggesting that children with low nonverbal ability who do not meet criteria for intellectual disability can be included as cases of DLD. It is because “pure” cases, such as *specific language impairment (SLI)* as used in traditional research settings with a discrepancy between language and nonverbal IQ, make it difficult to generalize research findings to many children seen in clinics, wherein co-occurring conditions are commonly observed (Bishop, Snowling, Thompson, Greenhalgh, & the CATALISE consortium, 2016, 2017). In addition, matching nonverbal IQ between the DLD group and the comparison group may create unrepresentative groups: either the DLD group will have higher nonverbal IQs than the DLD population, or the comparison group will have IQ scores below normative expectations (Dennis et al., 2009). However, given the inconsistent use of diagnostic criteria in the DLD/SLI literature, the current findings may be different from those yielded from participants with classic SLI.

Despite these limitations, the current study adds new information about the episodic memory retrieval processes of item-specific and relational information in individuals with DLD. Three lines of directions are proposed in future studies on the association between declarative memory and DLD: 1) neuroimaging work examining the structure and function of the MTL regions, which will shed light on the biological basis of declarative memory, 2) the extent to which associative learning is impaired in DLD, and 3) the role of memory stabilization and consolidation.

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What This Paper Adds

What is known on this subject

Evidence regarding the status of episodic memory in DLD remains mixed, which may be attributed to limited memory measures used in prior studies to examine the complex nature of the declarative memory system. In addition, there is a paucity of research on the episodic memory retrieval processes of item-specific and relational information in individuals with DLD.

What this study adds

The current study contributes to the declarative aspect of the procedural deficit hypothesis, showing that episodic memory for nonverbal stimuli in DLD is affected to a lesser magnitude when to-be-remembered items have contextual support (e.g., association with another object) and are retrieved via recognition. However, the current data do not support the notion that episodic memory is largely normal or even enhanced in individuals with DLD.

Clinical implications of this study

The better understanding of the degree of abnormality in the episodic memory system in DLD may shed light on new ideas for developing learning strategies for individuals with poor language ability.

Encoding Phase

Item-specific Encoding

Living?

Yes

No

Relational Encoding

Yes

Inside?

No

Retrieval Phase

Item Recognition

Old

New

Associative Recognition

Yes

Together?

No

Figure 1.

Illustration of the encoding and retrieval phase in the relation and item-specific encoding (RISE) task.

Figure 2.
Item recognition between the DLD and the comparison group.

Figure 3.
Associative recognition between the DLD and the comparison group.

Figure 4.
A conceptual diagram of the mediation analysis.

Table 1
Age, sex, language scores, and nonverbal IQ scores for the two groups of participants.

	DLG Group (n=23)		Comparison Group (n=23)		p
	M	(SD)	M	(SD)	
Age (year)	16.73	1.50	16.75	1.55	.96
Sex (Female:Male)	15:8		14:9		.76
Language Composite Scores	77.69	12.83	115.00	10.41	<.001
<i>EVT-2</i>	79.57	9.24	116.44	8.19	<.001
<i>PPVT-4</i>	79.96	11.26	116.39	9.01	<.001
<i>Word Derivations</i>	79.35	10.04	108.91	8.91	<.001
<i>Recalling Sentences</i>	76.74	16.28	105.23	6.07	<.001
<i>USP</i>	79.78	10.17	103.18	10.41	<.001
Nonverbal IQ	85.26	10.82	105.83	12.92	<.001

Note. Test scores were reported in standard scores with a mean of 100 and SD of 15. Language composite scores were calculated by averaging the five language scores. *EVT-2*: Expressive Vocabulary Test, Second Edition; *PPVT-4*: Peabody Picture Vocabulary Test, Fourth Edition; *USP*: Understanding Spoken Paragraphs.

Table 2
Correlation matrix among language composite scores, episodic memory measures, and nonverbal IQ.

<i>Measures</i>	1	2	3	4	5
1 Language composite scores	–	.46**	.41**	.30*	.71**
2 Item recognition following item-specific encoding	.46**	–	.89**	.43**	.39**
3 Item recognition following relational encoding	.41**	.89**	–	.43**	.38**
4 Associative recognition	.30*	.43**	.43**	–	.35*
5 Nonverbal IQ	.71**	.39**	.38**	.35*	–

** Correlation was significant at the .01 level;

* Correlation was significant at the .05 level.