Phonological Processing in Children with Dyslexia: Analyzing Nonword Repetition Error Types

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Brigham Young University

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Phonological Processing in Children with Dyslexia:

Analyzing Nonword Repetition Error Types

Camille Christine Stanley

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

Phonological Processing in Children with Dyslexia: Analyzing Nonword Repetition Error Types

Camille Christine Stanley
Department of Communication Disorders, BYU
Master of Science

This study analyzes quantitative and qualitative differences in errors made during a nonword repetition task between children with dyslexia (n = 75) and their typically developing (TD) peers (n = 75). Participants were auditorily presented with 16 nonwords based on a CVC (consonant-vowel-consonant) pattern; nonwords varied from two to five syllables in length. Verbal responses were recorded, transcribed, and consonant phonemes were analyzed according to the following error types: substitutions, omissions, insertions, and transpositions. Analyses found that children with dyslexia perform more poorly on nonword repetition as compared to their TD peers. Specifically, during this nonword repetition task children with dyslexia differed from their TD peers in overall accuracy and omission errors. Groups did not differ in the quantity and quality of substitution, insertion, or transposition errors. Findings from this study may provide insight into mechanisms underlying phonological processing in children with dyslexia. Implications for future research and clinical work are also discussed.

Keywords: dyslexia, nonword repetition, phonology
ACKNOWLEDGMENTS

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To my friends, thank you for your kind words and encouragement. Thank you especially to the members of my cohort, and now friends, for your insights, encouragement, and support in helping me become not only a better student and clinician, but also better individual. I am so grateful that I had the opportunity to share this experience with you.

Lastly, a special thank you to my family. Thank you for instilling the desire in me to seek learning opportunities and for your examples and encouragement throughout my formal education.
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DESCRIPTION OF THESIS STRUCTURE

This thesis, *Phonological Processing in Children with Dyslexia: Analyzing Nonword Repetition Error Types*, is part of a larger study originally created by Drs. Shelley Gray, Mary Alt, Nelson Cowan, Samuel Green, and Tiffany Hogan to investigate working memory and word learning in young children. Data were collected from second-grade children across multiple sites in Arizona, Nebraska, and Massachusetts. The analyses conducted in this study were based on a single task, nonword repetition, from that larger study. This thesis was written in a hybrid format with the beginning pages reflecting requirements from the university and the body written as a manuscript fitting for publication to a peer-reviewed journal. Excerpts of this thesis may be used for publication with the thesis author being listed as a contributing coauthor. An annotated bibliography is included in Appendix A, list of stimuli in Appendix B, parent consent form in Appendix C, and child assent form in Appendix D.
Introduction

It is estimated that approximately 9% of school-aged children have dyslexia (Pennington & Bishop, 2009). Currently amongst the general population there are many misconceptions regarding dyslexia. Some of these include that individuals with dyslexia have visual deficiencies, see letters and numbers backward, and/or are not as intelligent as compared to their typically developing (TD) peers (Shaywitz, 1996). According to Lyon, Shaywitz, and Shaywitz (2003), …dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge. (p. 2)

In addition, children with dyslexia are at significant risk for long term negative academic and social outcomes (Snowling, Muter, & Carroll, 2007).

The underlying cause of dyslexia has been debated extensively. At present, the leading consensus is that dyslexia is related to a fundamental deficit in phonology. This deficit has been described in multiple ways such as children with dyslexia reportedly have weak phonological representations (Elbro & Jensen, 2005), poor phonological awareness (Muter, Hulme, Snowling, & Stevenson, 2004), poor phonological memory (Kamhi & Catts, 1986), as well as general poor phonological processing (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Thus, although several leading researchers agree that at its core dyslexia is characterized as a phonological deficit, the exact nature of this deficit is complex and not well understood.
Nonword Repetition

Nonword repetition, a task which requires individuals to repeat nonsense novel words (e.g., cav, genfad) is commonly used in research to measure an individual’s ability to encode and retrieve novel phonological information. Several studies have shown that children with dyslexia show particular difficulty with this task, although the reason that children with dyslexia struggle with this task is not clear (Melby-Lervåg & Lervåg, 2012). Snowling (1981) was among the first to investigate nonword repetition in children with dyslexia. In this study, children with dyslexia, as well as TD children, repeated a list of 30 nonsense and real words that were two to four syllables in length. Analysis showed that as word length increased children with dyslexia made more errors than their TD peers, but this was only the case when repeating nonwords (Snowling, 1981). Snowling concluded that the discrepancy between real word and nonword repetition in children with dyslexia provides evidence that these children struggle to process novel phonological information, a deficit she attributed to weak sublexical phonological processing. Importantly, this task demonstrated that a phonological deficit manifests in individuals with dyslexia not only in decoding or reading tasks, but also in speech tasks absent of word reading (Snowling, 1981).

Although many children with dyslexia have difficulty with nonword repetition, the reason for the deficit is still unclear and that is likely because it is difficult to define exactly what mechanisms are at play during nonword repetition. Children are required to listen to, encode, temporarily store, retrieve, and reproduce the nonword heard all in the same task. Coady and Evans (2008) suggest that the use of nonword repetition tasks “closely matches the phonological component of word learning, and correlates with measures of phonological working memory” (p.1). But what is it about this task that is particularly difficult for children with dyslexia? Some
have hypothesized that nonword repetition deficits in individuals with dyslexia is evidence of a
generalized deficit in verbal short-term memory (Gathercole, 2006). By contrast, others have
suggested that nonword repetition deficits occur as a result of deficits in the encoding or
accessing of phonological representations (Ramus & Szenkovits, 2008). To address these
competing hypotheses, Melby-Lervåg and Lervåg (2012) conducted a comprehensive meta-
analysis of studies that used nonword repetition to evaluate children with dyslexia. As dyslexia
can be comorbid with an oral language deficit, they noted that the “nonphonological oral
language” skills between samples of individuals with dyslexia might have varied between studies
(Melby-Lervåg and Lervåg, 2012, p. 4). They analyzed two decades of research of children with
dyslexia and specifically included studies that included measures of verbal short-term memory
(e.g., digit span, word span) and measures of phonological awareness, which they used as a
proxy for the quality of phonological representations. This meta-analysis concluded that children
with dyslexia have difficulty with nonword repetition because of weak phonological
representations (a small but significant effect), but also that the biggest indicator of poor
performance in nonword repetition tasks was the presence of an oral language deficit.

It is possible that phonological awareness skill may not adequately capture the nature of
phonological representations in children with dyslexia. Moreover, previous studies analyzing
performance of dyslexia in nonword repetition tasks have primarily reported overall accuracy
data (at the word and syllable level). To further test the phonological representations hypothesis,
and to better describe the nature of nonword repetition deficits in children, we hypothesize that
analyzing specific error types made by children during a novel nonword repetition task will
provide more direct insight into the quality of underlying phonological mechanisms driving
performance during nonword repetition. Moreover, due to known phonological differences
between children with dyslexia and their TD peers (e.g., phonological awareness), we predict error types are likely to be variable between groups.

In this study, we analyze what types of errors children with and without dyslexia exhibit during auditory nonword repetition tasks including errors of substitution, omission, insertion, and transposition. Below, based on the literature, we hypothesize what specific error types might indicate about underlying phonological skills.

**Substitution Errors**

First, we consider the number and type of substitution errors children make during nonword repetition. Brady (1997) states that “inferior pseudoword repetition by disabled readers results in part from difficulty establishing speech representations” as well as that “results of categorical perception studies reveal a persistent pattern of difficulty on identification and discrimination by poor readers, suggesting that they are less accurate in their ability to form phonological representations” (pp. 41-42). The decreased ability to phonologically encode as well as hold the information in working memory for immediate recall may result in difficulty recalling nonwords (Coady & Evans, 2008). Due to the fact that their phonological representations are reportedly weak, or fuzzy, it is possible that individuals with dyslexia will make increased substitution errors due to their decreased ability to form strong phonological representations (Elbro & Jensen, 2005; Snowling, 2000). That is, we hypothesize that if children with dyslexia make more (or different kinds) of substitution errors than their peers, this may indicate that although these children are able to repeat novel nonwords, the phonological information in their production may be incomplete or only partially accurate. Toward that end, we will analyze both the amount of substitution errors as well as types of substitution errors including whether substituted phonemes constitute errors of place, manner, and voicing.
Omission Errors

On the other hand, if children with dyslexia are more prone to making errors of omission, this may lend support to a deficit that is more specific to phonological memory. That is, it is possible that children make errors that reflect a difficulty creating any kind of representation for some phoneme segments, not just fuzzy representations. In a study investigating nonword repetition error types in children with language impairment, Edward and Lahey (1998) hypothesized that “[omission] errors indicate a difficulty with holding detailed phonological representations in working memory or a difficulty with forming such detailed representations” (p. 293) (emphasis added). It is possible that omission errors are evidence that children are not able to encode whole portions of words, such as a phoneme or a syllable. Omission errors are notable in that such errors alter not only the phonemic makeup of syllables and words, but may impact the entire syllable structure itself. For example, a child may hear the nonword “gen_fad” but say the nonword “ge()_fa()”. In this case the child has altered the syllable structure of the nonword from CVC_CVC to CV_CV (C = consonant V = vowel), significantly reducing the nonword’s complexity. Thus, it is possible that an increased number of omissions is evidence of difficulty encoding phonological information related to syllable structure. According to Edward and Lahey, these children may be unable to “[form] a phonological representation with the correct number of segments or [hold] such detailed representation[s] in working memory” (p. 295). Thus, we hypothesize that if children with dyslexia produce an increased number of omission errors relative to their TD peers, this would suggest they have specific deficits encoding complete segments in phonological memory.
**Insertion Errors**

The question of whether nonword repetition is affected by phonological memory as well as long term memory must also be considered. It has been found “that nonword repetition for unwordlike stimuli is largely dependent on phonological memory, whereas repetition for wordlike items is also mediated by long-term lexical knowledge” (Gathercole, 1995, p. 83). If nonword stimuli are similar to real words, it is possible that some children may try to add phonemes to make the nonwords sound more like real words found in their mental lexicon. The nonwords used in this study are considered “unwordlike” (per measures of neighborhood density and phonotactic probability) and therefore will depend largely on phonological memory as opposed to long-term lexical knowledge and should not be influenced by previous lexical experience. Due to this fact, we do not expect a large number of insertions to be present in the data set as an error type.

**Transposition Errors**

Lastly, we examine transposition errors in nonword repetition tasks. Transposition errors involve changing the order of phonemes in a particular word. In addition to having phonological deficits individuals with dyslexia have also been found to have deficits in serial order memory, or the ability to sequentially encode information (Cowan et al., 2017). One study found that children with dyslexia have a “slightly greater loss of serial order information for digits than was seen in the TD group” (Cowan et al., 2017, p. 224). Serial order deficits occur in phonological as well as visuospatial tasks (Majerus & Cowan, 2016). Similar results were found during the serial order memory in running span tasks (Cowan et al., 2017). It was found that “serial order information was lost relative to item information more severely in children with dyslexia than in children with TD” (Cowan et al., 2017, p. 224). When children with dyslexia were compared to
TD children, significant group differences regarding short-term serial order memory were found. Cowan concluded that these “group deficits are partly a function of serial order memory issues, not solely phonological memory issues” (Cowan et al., 2017, p. 228). This theory has not been tested in regard to a nonword repetition task. In this study we examine whether children with dyslexia have serial order deficits in nonword repetition, which we predict will manifest in the form of transpositions, or the exchange of phonemes in a syllable or word, similar to the exchange of digits in a digit span task. If children do produce more transposition errors than their TD peers, this would lend further support that children with dyslexia manifest with serial ordering deficits.

**Purpose of the Study**

In summary, the purpose of this study is to further analyze the errors that children make during a novel nonword repetition task. More specifically, we aim to compare the nature of errors made by children with and without dyslexia through conducting an in-depth analysis of the quantity and quality of phoneme substitutions, omissions, insertions, and transpositions. Based on the literature, this study will provide insight into underlying phonological organization and retrieval in these children.

Thus, our research questions are

- Do children with dyslexia and TD children differ in the number and/or type (place, manner, voicing) of substitution errors across varying nonword lengths in a novel nonword repetition task?
- Do children with dyslexia differ from their TD peers in the number and/or type (whole syllable, initial vs. final phonemes) of omission errors across varying nonword lengths during a novel nonword repetition task?
• Do children with dyslexia differ from their TD peers in the number of *insertion* errors across varying nonword lengths during a novel nonword repetition task?

• Do children with dyslexia differ from their TD peers in the number and/or type of *transposition* errors (within and across syllables) across varying nonword lengths in a novel nonword repetition task?

**Method**

**Participants**

One hundred and fifty monolingual English speaking second-grade children (aged 7-9) participated in this study. All children who participated in this study were participants in a larger multi-site study analyzing working memory and word learning in young children (Alt et al., 2017; Gray et al., 2017). Participants were from Arizona, Nebraska, and Massachusetts. All procedures were approved by the Institutional Review Boards of Ethics at each respective data collection site. Parents provided informed consent and children provided consent to participate. Of the 150 participants 75 (28 boys, 47 girls) were classified as TD and 75 (35 boys, 40 girls) were classified as having dyslexia. To qualify for this study TD children had to (a) be between 7 and 9 years old; (b) be in or just completed second grade; (c) pass a hearing screening at 20 dB at 1,000, 2,000, and 4,000 Hz; (d) pass a vision screening with at least 20/40 using Lea symbols cards (corrected vision was accepted); (e) pass a color vision screening (Waggoner, 2002); (f) have no reported neuropsychiatric disorders including attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD); (g) have no history of special education services; (h) never have repeated a grade; (i) be a monolingual English speaker; (j) achieve a score at or above the 31st percentile on the Goldman Fristoe Test of Articulation-2 (GFTA-2; Goldman & Fristoe, 2000) (exceptions were made if the score was compromised due to error in a single
consonant sound); (k) receive a standard score of at least 75 on the Kaufman Assessment Battery for Children-2 (KABC-2; Kaufman & Kaufman, 2004); (l) receive a composite standard score of at least 96 for second grade on the Test of Word Reading Efficiency - Second Edition (TOWRE-2; Torgesen, Wagner, & Rashotte, 2012); and (m) and receive a minimum standard score of 88 on the Clinical Evaluation for Language Fundamentals, fourth edition (CELF-4; Semel, Wiig, & Secord, 2003). Children classified as having dyslexia met a comparable criterion, however, they were not excluded if they had repeated a grade or been in special education services. For the purposes of this study children were considered to have dyslexia (a) if they scored at or below the 20th percentile (SS of 88) on the TOWRE-2 and (b) had a standard score of at least 88 on the CELF-4. (Cowan et al., 2017)

Procedures

The task. Participants in this study participated in a larger study of working memory and word learning that included the completion of 13 distinct working memory tasks and six word learning tasks (Gray et al., 2017). The tasks were completed over a two-week time period in six to seven hour long sessions. All tasks were presented via a pirate themed computer based game. The presentation of these tasks were randomized by the computer throughout the sessions to avoid task-order effects. During the tasks children sat approximately 52 cm away from a computer screen. A highly qualified research assistant (RA) sat next to them. The RA was present to advance the tasks as well as encourage attention. Both the participant and RA wore headphones through which the stimulus was presented. The participant’s headphones also had an attached microphone to record verbal responses.

The current study focuses on the results of the nonword repetition task, one of the 13 tasks of working memory. For this task children were instructed to help their pirate avatar build a
candy bridge over a river. Participants were presented with 16 nonwords (four each at two-, three-, four- and five-syllable lengths), one at a time. Two of the nonwords at each syllable length were considered phonologically similar while two were dissimilar to another nonword in the nonword stimulus set for the target syllable length. Nonwords at each syllable length did not statistically differ in spoken duration, had low frequency biphones, as well as no phonological neighbors, improving the probability of novel nonword learning (Storkel & Hoover, 2010).

After hearing the auditory stimuli through their headphones children verbally repeated the nonword back through the microphone attached to their headset. Children heard each nonword once. Responses were audio recorded for the purpose of offline scoring. After each attempt the RA advanced the game and the child was rewarded with a virtual piece of candy for their candy bridge.

**Transcription analysis.** Responses were analyzed in a two-step process. First, trained research assistants transcribed all child responses offline using the International Phonetic Alphabet. Participant responses at the nonword level were aligned phoneme-by-phoneme maintaining sequence in the target nonword to maximize accuracy. Each syllable was then scored for overall accuracy. Phonemes were scored as correct if they matched and scored as an error if any other phoneme (or no phoneme) was produced for the target. All errors were further analyzed for specific error types. Errors were coded as substitutions, omissions, insertions, or transpositions (see Table 1 for examples). First, the presence of substitution errors, replacing one phoneme for another phoneme, were accounted for. Further, each substituted consonant was compared to the original target to classify if the substituted phoneme varied from the target phoneme by place of articulation, manner of production, or voicing. It was noted, if there was an error in place or manner, whether the substituted phoneme had the same or different
Table 1

*Error Classifications*

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Classification</th>
<th>Target Response</th>
<th>Errored Response</th>
</tr>
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<tbody>
<tr>
<td>Substitution</td>
<td>Place</td>
<td>yit_vcd_gum</td>
<td>yik_vcd_gum</td>
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<tr>
<td></td>
<td>Manner</td>
<td>yit_vcd_gum</td>
<td>yit_vcd_gub</td>
</tr>
<tr>
<td></td>
<td>Voicing</td>
<td>yit_vcd_gum</td>
<td>yit_vct_gum</td>
</tr>
<tr>
<td>Omission</td>
<td>Whole Syllable</td>
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<td></td>
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<td>--</td>
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<td>yit_vcd_glam</td>
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<tr>
<td>Transposition</td>
<td>Within Syllable</td>
<td>yit_vcd_gum</td>
<td>tit_vcd_gum</td>
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<td></td>
<td>Across Syllables</td>
<td>yit_vcd_gum</td>
<td>yit_vct_gum</td>
</tr>
</tbody>
</table>

*Note.* All nonwords presented are in Klattese. For reference see [http://www.people.ku.edu/~mvitevit/Klatt_IPA.pdf](http://www.people.ku.edu/~mvitevit/Klatt_IPA.pdf)

place/manner as compared to the target phoneme. (e.g., As seen in Table 1 if the child said “yik_vcd_gum” instead of “yit_vcd_gum” it would be noted that there was a substitution error in the final consonant of the first syllable and that the substitution error of “k” had a different place as compared to the target of “t” and that the manner of the substitution was the same; the absence of a voicing code would indicate that the voicing was the same). Next, if a phoneme was missing, it was counted as an omission. This error of omission was further classified indicating whether the initial consonant phoneme, final consonant phoneme, or both consonant phonemes
were omitted in each syllable. It was also accounted for if the child omitted the entire syllable. Insertions involved the addition of any extra phoneme into a syllable. Finally, a transposition error was noted if a consonant phoneme was replaced with a different consonant phoneme present in the target syllable or nonword. This analysis was done both within- and across-syllables. Cross-syllable transposition was also numerically accounted for by analyzing if transpositions within a syllable involved phonemes in the adjacent syllable, two syllables away, three syllables away, etc. (i.e., As seen in Table 1, the cross-syllable transposition was in the adjacent syllable). Although this study is not focused on types of vowel errors, the presence of vowel errors was acknowledged. A random 20% of participants were coded twice, each by different coders. Inter-rater reliability was 98.53%.

Results

In this study we compared nonword repetition accuracy and error types between two distinct groups of second-grade-aged children: dyslexic and TD. We conducted a series of multivariate analyses of variance (MANOVA) to determine group differences in error type between children with dyslexia and TD children. Due to hypothesized differences in theoretical underpinnings for each error type we conducted separate MANOVA analyses for each error type: substitutions, omissions, insertions, and transpositions.

This study had 150 participants \( (n = 75 \text{ DYS}; n = 75 \text{ TD}) \). Table 2 shows the descriptive characteristics of the sample, including age, parent rated ADHD, language, reading, and nonverbal IQ.
Table 2

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>TD (n=75) Mean (SD)</th>
<th>DYS (n=75) Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic Variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (in months)</td>
<td>93.16 (4.615)</td>
<td>94.43 (5.458)</td>
</tr>
<tr>
<td>ADHD (TD, n=55; DYS, n=54)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.16 (8.766)</td>
<td>13.04 (9.353)</td>
</tr>
<tr>
<td>Descriptive Variables</td>
<td></td>
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</tr>
<tr>
<td>CELFstd</td>
<td>109.05* (9.258)</td>
<td>100.53 (8.948)</td>
</tr>
<tr>
<td>KABCstd</td>
<td>118.36* (16.004)</td>
<td>108.17 (14.066)</td>
</tr>
<tr>
<td>TRstdg</td>
<td>108.47* (9.174)</td>
<td>81.33 (6.597)</td>
</tr>
</tbody>
</table>

Note. * indicates the groups significantly differed $p < .01$; TD = typically developing, DYS = dyslexic ADHD = ADHD parent rating scale, CELFstd = CELF-Core Language Scale, KABCstd = Kaufman Assessment Battery for Children standard score, TRstdg = Test of Word Reading Efficiency standard score, grade norms

Nonword Repetition Accuracy

A one-way multivariate analysis of variance (MANOVA) was conducted to determine whether children with dyslexia differed on overall accuracy on the nonword repetition task as compared to their TD peers. We first analyzed overall phoneme accuracy for all nonwords across two-, three-, four-, and five-syllable nonword lengths. There was homogeneity of variances, as assessed by Levene’s Test of Homogeneity of Variance (all $p$s > .05). There was a statistically significant difference on accuracy between groups across the combined syllable lengths, $F(4,145) = 3.987$, $p = .004$; Wilks’ $\Lambda = .901$; partial $\eta^2 = .099$, such that children with dyslexia had poorer overall accuracy than their peers (see Figure 1). Follow-up univariate analyses of variance (ANOVA) determined that there was a statistically significant group difference at the three-syllable nonword length $F(1, 148) = 14.771$, $p < .001$; partial $\eta^2 = .091$, using a Bonferroni adjusted $\alpha$ level of .0125. There were no differences between groups at the two-syllable ($p =$
Figure 1. Overall accuracy for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.

.412), four-syllable ($p = .103$), and five-syllable nonword lengths $F(1,148) = 6.075; p = .015$; partial $\eta^2 = .039$.

Substitution Errors

A separate MANOVA was conducted to determine whether the groups differed on the number of substitution errors between dyslexic and TD children. There was homogeneity of variances, as assessed by Levene’s Test of Homogeneity of Variance (all $ps > .05$). There were no significant differences between children with dyslexia and their TD peers in the quantity of substitution errors across all nonword lengths, $F(4,145) = .788, p < .535$; Wilks’ $\Lambda = .979$; partial $\eta^2 = .021$ (see Figure 2). To investigate the possibility that we were overlooking group differences in substitution patterns by collapsing substitution types we examined substitution errors at a finer grained level of analysis including place, manner, and voicing substitution errors.
Figure 2. Total substitution errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.

**Place substitution errors.** A separate MANOVA was run to determine whether the groups differed in the type, place, of substitution errors between dyslexic and TD children (e.g., same place substitution error: \( \text{yit}_\text{vcd}_\text{gum} \rightarrow \text{yid}_\text{vcd}_\text{gum} \); different place substitution error: \( \text{yit}_\text{vcd}_\text{gum} \rightarrow \text{ym}_\text{vcd}_\text{gum} \)). First, substitution errors with the same place were analyzed. There was a homogeneity of variances at the four- and five-syllable nonword lengths, however, not at the two- and three-syllable nonword lengths (\( ps < .05 \)). There were no significant differences in same place substitution errors at all nonword lengths \( F(4,145) = .889, p = .472; \) Wilks’ \( \Lambda = .976; \) partial \( \eta^2 = .024 \) (see Figure 3).

Next, substitution errors with a different place were analyzed. There was a homogeneity of variances for all nonword lengths (all \( ps > .05 \)). There were no significant differences in different place substitution errors at all nonword lengths \( F(4,145) = .699, p = .594; \) Wilks’ \( \Lambda = .981; \) partial \( \eta^2 = .019 \) (see Figure 4).
**Figure 3.** Same place substitution errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.

**Figure 4.** Different place substitution errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.
**Manner substitution errors.** A MANOVA was run to determine whether the groups differed in the manner of substitution errors between dyslexic and TD children (e.g., same manner substitution error: \( \text{yat}_\text{vcd}_\text{gum} \rightarrow \text{yip}_\text{vcd}_\text{gum} \); different manner substitution error: \( \text{yat}_\text{vcd}_\text{gum} \rightarrow \text{yn}_\text{vcd}_\text{gum} \)). First, substitution errors with the same manner were analyzed. There was a homogeneity of variances at all nonword lengths. There were no significant group differences in same manner substitution errors at all nonword lengths \( F(4,145) = .390, p = .816; \text{Wilks' } \Lambda = .989; \text{ partial } \eta^2 = .011 \) (see Figure 5).

Next, substitution errors with a different manner were analyzed. There was a homogeneity of variances for all syllable lengths. There were no significant group differences in different manner substitution errors at all nonword lengths \( F(4,145) = .581, p = .677; \text{Wilks' } \Lambda = .984; \text{ partial } \eta^2 = .016 \) (see Figure 6).

*Figure 5.* Same manner substitution errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.
Voicing substitution errors. A MANOVA was run to determine whether the groups differed in the voicing of substitution errors between dyslexic and TD children (e.g., same voicing substitution error: $\text{yit\_vcd\_gum} \rightarrow \text{yik\_vcd\_gum}$; different voicing substitution error: $\text{yit\_vcd\_gum} \rightarrow \text{yid\_vcd\_gum}$). First, substitution errors with the same voicing were analyzed.

There was a homogeneity of variance for all but the two-syllable nonword length ($p < .001$). There were no significant group differences in same voicing of substitution errors at all nonword lengths $F(4,145) = 2.043, p = .091$; Wilks’ $\Lambda = .947$; partial $\eta^2 = .053$ (see Figure 7).

Next, substitution errors with different voicing were analyzed. There was a homogeneity of variance for all but the two-syllable nonword length ($p < .001$). There were no significant differences in same voicing of substitution errors at all nonword lengths $F(4,145) = 2.043, p = .091$; Wilks’ $\Lambda = .947$; partial $\eta^2 = .053$ (see Figure 8).
Figure 7. Same voicing substitution errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.

Figure 8. Different voicing substitution errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.
**Omission Errors**

A separate MANOVA was conducted to determine whether there was a difference in the number and type of omission errors between dyslexic and TD children.

**Whole syllable omissions.** There was a homogeneity of variance for all but the three- and five-syllable nonword lengths ($p < .05$), in all other nonword lengths $p > .05$. There were no significant differences between those with dyslexia as compared to their TD peers for syllable omissions across all nonword lengths $F(3, 146) = 1.786, p = .152$; Wilks’ $\Lambda = .965$; partial $\eta^2 = .035$ (see Figure 9).

**Phoneme omissions.** There was homogeneity of variance for all but the five-syllable nonword length ($p = .003$), in all other nonword lengths $p > .05$. There was a statistically significant group difference for total omissions $F(4, 145) = 6.116, p < .001$; Wilks’ $\Lambda = .856$;

![Figure 9](image)

*Figure 9.* Whole syllable omissions for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.
partial $\eta^2 = .144$, such that children with dyslexia omitted more phonemes than children who are TD (see Figure 10).

Follow-up univariate ANOVAs showed there was a statistically significant group difference in omissions at the three-syllable nonword length $F(1,148) = 19.933, p < .001$; partial $\eta^2 = .119$, and the four-syllable nonword length $F(1,148) = 7.407, p = .007$; partial $\eta^2 = .048$, using a Bonferroni adjusted $\alpha$ level of .0125. The groups did not differ at the two-syllable length $p = .820$ or the five-syllable length $p = .030$.

*Figure 10.* Total phoneme omissions for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.

**Initial vs. final position of omissions.** To further quantify the types of omission errors made we investigated whether the groups differed in the position of the omission errors (initial vs. final). A MANOVA determined that children with dyslexia did differ as compared to their TD peers in position of omissions, $F(8,141) = 4.065, p < .001$; Wilks’ $\Lambda = .813$; partial $\eta^2 = .187$. Using a Bonferroni adjusted $\alpha$ level of .00625, children with dyslexia made statistically more
omissions in the initial position of syllables only at the three-syllable nonword length $F(1,148) = 13.982, p < .001; \text{ partial } \eta^2 = .086$. There were no differences in the number of initial position omissions at all other syllable lengths, all $p > .02$. In the final position of syllables children with dyslexia omitted more phonemes than their TD peers at the three-syllable nonword length $F(1,148) = 20.186, p < .001; \text{ partial } \eta^2 = .120$, and at the four-syllable nonword length $F(1,148) = 10.453, p = .002; \text{ partial } \eta^2 = .066$. The groups were equivalent at the two- ($p = .859$) and five- ($p = .015$) syllable nonword lengths (see Figure 11).

![Figure 11](image)

*Figure 11.* Differences in omissions between initial and final positions for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.

**Insertion Errors**

A separate MANOVA was conducted to determine whether there was a difference in the number of insertion errors between dyslexic and TD children. There was homogeneity of variance for all but the four-syllable nonword length ($p < .001$), in all other nonword lengths $p >
.05. There were no significant differences between children with dyslexia and their TD peers in the quantity of insertions across all nonword lengths, $F(4,145) = .982, p = .419; \text{Wilks’ } \Lambda = .974; \text{partial } \eta^2 = .026$ (see Figure 12). Notably, across all nonword lengths children inserted extra phonemes in less than 1% of opportunities.

![Figure 12](image)

*Figure 12. Insertion errors for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.*

**Transposition Errors**

A separate MANOVA was conducted to determine whether there was a difference in the number of transposition errors made within syllables and across syllables in two-, three-, four-, and five-syllable nonwords between dyslexic and TD children. There was homogeneity of variance for all nonword lengths $ps > .05$. There were no significant group differences in the quantity of transposition errors made within and across syllables (see Table 1 for description of these types of transpositions), $F(4,145) = .613, p = .654; \text{Wilks’ } \Lambda = .983; \text{partial } \eta^2 = .017$ across all syllable lengths (see Figure 13).
In sum, children with dyslexia differed from their TD peers only in overall accuracy, and omission errors. Groups did not differ in the quantity and quality of substitution, insertion, or transposition errors.

**Discussion**

The purpose of this study was to further analyze the errors that children with dyslexia and their TD peers make during a novel nonword repetition task. Due to the phonological nature of deficits in children with dyslexia we anticipated that the groups would differ in accuracy and error type on this task. Specifically, we analyzed the different error types of substitutions (place, manner, and voicing), omissions (whole syllable, initial, and final position of syllables), insertions, and transpositions (both within and across syllables). Despite the fact that the groups did not differ in many error subtypes, findings revealed that the groups did differ in overall accuracy as well as in omission error types.

*Figure 13.* Transpositions for nonword repetition across all nonword lengths for children with dyslexia and their TD peers.
Children with Dyslexia Perform More Poorly on Nonword Repetition as Compared to Their TD Peers

Consistent with previous research, children with dyslexia in our study performed more poorly on a nonword repetition task, based on overall accuracy, as compared to their TD peers (Catts, 1986; Kamhi & Catts, 1986; Melby-Lervåg & Lervåg, 2012; Snowling, 1981). At the two-syllable nonword length the groups of children performed almost identically, however, the groups diverged at the three-syllable nonword length at which point children with dyslexia performed significantly worse than their TD peers. Although the groups in our study did not statistically differ at the four- or five-syllable nonword lengths the overall pattern showed that children with dyslexia continued to perform numerically lower than their TD peers. Melby-Lervåg and Lervåg (2012) suggested that oral language deficits are what drive nonword repetition differences between children with dyslexia and TD children. In this study, we only included children with typical language skills. This suggests that children with dyslexia may have language within normal limits and still struggle with nonword repetition. Importantly, however, despite all participants being within normal limits, the groups still differed in language. Thus, we cannot rule out that group differences in nonword repetition are not related to group differences in language, even if language skills are within normal limits.

This nonword repetition task was created specifically for this project and has not been used previously. This task is unique in that the nonword lengths range in syllable length from two to five syllables. Other studies have limited their nonword stimuli to one to two syllables in length (Snowling, 1981) or two to four syllables in length (Kamhi & Catts, 1986). The nonwords in this task were also created to account for variables known to impact phonological memory including neighborhood density and phonotactic probability. Our findings show that even when
controlling for these variables, children with dyslexia continue to perform more poorly than their TD peers.

Our study included early readers with dyslexia that ranged in age from 7 to 9, which is traditionally on the earlier end of the spectrum of when children can be reliably diagnosed with dyslexia. Consistent with Kamhi and Catts (1986) whose participants were 6;2 to 9;2, children in our study with dyslexia performed more poorly than their TD peers. Future research should explore whether lower performance on a nonword repetition task is consistent in children who are at risk for dyslexia prior to a formal diagnosis, and before they are considered readers. For example, young children with poor phonological awareness (Hogan, Catts, & Little, 2005) or those who have a family history of dyslexia (Carroll, Mundy, & Cunningham, 2014) are at a significant risk for reading failure. These risk factors however do not guarantee that a child will have dyslexia. It would be important to investigate whether poor nonword repetition performance generalizes to prereading children at risk for dyslexia. If these findings are consistent this task may be used to help identify error patterns that may indicate a future dyslexia diagnosis.

**Children with Dyslexia Omit More Phonemes Than Their TD Peers**

Analyses revealed that overall, children with dyslexia omitted more consonant phonemes than their TD peers. These findings are consistent with Kamhi and Catts (1986) who found during their word repetition task that “deletion” was the most common error made amongst those with Reading Impairment. Our study was able to further analyze these errors and it was found that in this task children differed in where these omissions occurred in the nonword (initial vs. final positions of CVC syllables). Specifically, children with dyslexia omitted more phonemes in the initial position of syllables but only in three-syllable nonwords. Children with dyslexia
omitted more phonemes than their TD peers in the final positions of nonwords in three- and four-syllable nonwords, and neared significance at the five-syllable nonword length.

It is possible that children omitted phonemes more frequently in the final position of nonwords for various reasons. One reason may relate to the syllable structure patterns of English. Early in development children show a preference for open syllable shapes (CV) as compared to closed syllable shapes (CVC) due to their reduced complexity. When repeating nonwords it is possible that children with dyslexia are more likely than their peers to simplify syllable structure by omitting the final consonant in a CVC syllable structure because of limitations in phonological memory. It is also possible that consonants in final positions of nonwords are less salient and/or affected by decay in memory more quickly than consonants in the initial position of syllables. Further research is needed to further explore these possibilities and why it is particularly problematic for children with dyslexia relative to their TD peers.

In terms of nonword length, the groups did not differ in the number of consonant omissions at the two-syllable nonword length. In fact, both groups made very few omission errors at this length. Although both groups made more omission errors at the five-syllable nonword length, they did not differ, suggesting that the task taxed phonological memory to an equal degree for both groups. That is, it appears that five-syllable length nonwords were equally complex for all children, regardless of dyslexia status. The groups appear to diverge, however, at the three- and four-syllable nonword lengths. The task used in this study was a novel task and had not been used previously. Previous nonword repetition tasks typically test up to four syllables in length. It is possible that this novel nonword repetition task was harder for all children because we included five-syllable length nonwords. Thus, nonword length may be an
important factor to consider when determining group differences in children with dyslexia and TD children.

The finding that children with dyslexia make more omissions than their TD peers suggest that, concerning phonological processing, children with dyslexia have specific deficits relative to phonological memory. Phonological memory involves the encoding of novel phonological information for later access and retrieval. Because children with dyslexia did not differ from their TD peers in other error types (substitutions, insertions, transpositions), we believe that omission errors indicate a unique difference these children have for encoding phoneme segments. It is possible that the omissions signify that those phonemes did not reach a stage of phonological memory where the representation could be substituted or transposed. Our analysis of quantity (overall accuracy) and quality (place, manner, voicing) of substitution errors did not note any significant differences between the groups. This suggests that when children with dyslexia do encode information in phonological memory it does not appear to be any more “fuzzy” than their TD peers. Relatedly, previous research using digit span tasks has shown that children with dyslexia have deficits in serial order memory, or the ability to sequentially encode information (Cowan et al., 2017; Majerus & Cowan, 2016). Our analyses of group differences in consonant phoneme transpositions both within and across syllables, however, were not significant. This suggests that the serial order deficits that are present in digit span tasks may not generalize to nonword repetition. Lastly, if children with dyslexia inserted phonemes more often this may have suggested that long term lexical knowledge/memory would have been interfering, however, as we hypothesized this was not significant.

Overall, analyses suggest that when children with dyslexia do encode phonemes in phonological memory, they are doing it with a similar rate of accuracy to those of their TD peers;
they are not substituting, inserting or transposing phonemes at a significantly higher rate as compared to their TD peers. The comparatively larger number of omission errors made by children with dyslexia shows these children have more difficulty encoding phonemes as compared to their TD peers.

**Limitations of the Study**

Participants in this study were second-grade children (aged 7-9), an age at which children can be more reliably diagnosed with dyslexia due to a failure to respond to reading instruction. Due to the limited age range this limits the conclusions that we can make about children with dyslexia and their nonword repetition error types. Future work is planned to include a wider age range of children to provide additional insights into how error types may differ across different ages. Another limitation concerns the demographics of the sample population included in this study. Although children were selected to have language and nonverbal IQ in a typical range, the groups in this study statistically differed on both language and nonverbal IQ. Previous studies have shown a relationship between oral language deficits and nonverbal IQ in relation to performance on nonword repetition tasks (Cowan et al., 2017; Melby-Lervåg & Lervåg, 2012). Future work is planned to match the samples on language and nonverbal IQ to determine whether this changes the results. Thus, having sample populations that do not differ in descriptive characteristics would strengthen any conclusions about group differences in error types.

**Future Directions**

Children with dyslexia are typically diagnosed based on their performance in word reading tasks that require them to either recognize sight words (e.g., said, yacht) or decode words or nonwords (e.g., fape, knap) using their knowledge of phonics skills. Unfortunately, this means
many children with dyslexia are not identified until the second or third year of schooling after they have failed to respond to reading instruction. Earlier diagnosis would allow children to receive early services to support phonological development that may prevent some of the negative outcomes associated with dyslexia (Snowling et al., 2007). The task presented in this paper is an auditory nonword repetition task which provides insight into underlying phonological knowledge and skill but does not depend on orthographic knowledge or word reading. The advantage of such a task is that it can be administered to any child, regardless of reading level. This study identified specific patterns of errors (overall nonword repetition accuracy, as well as omission errors) in diagnosed children with dyslexia and TD children. Future research, such as a longitudinal study with prereading children, is necessary to identify if these errors are consistent in young children, which could be beneficial in early identification of children with dyslexia. If findings are consistent this not only could have theoretical implications, but clinical implications as well, as it could suggest that therapy/remediation may benefit from interventions that target phonological memory and/or helping individuals with dyslexia more successfully encode phonemes.
References


APPENDIX A

Annotated Bibliography


**Objectives:** The purpose of this study was to “test the segmentation hypothesis of dyslexia by applying different methods, using a wide array of speech stimuli, to show that implicit phonological representations are deficient in dyslexia” (p.158).

**Methods:** The participants in this study ranged in age from 11-13. They were divided into four different groups of 20 participants each. The groups consisted of individuals with dyslexia, individuals with dyslexia and a speech sound disorder, individuals matched for reading age, and individuals matched for chronological age. The participants participated in three experimental tasks that included syllable similarity task, lexical gating task and priming tasks.

**Results:** The results support the idea that phonological representations in individuals with dyslexia are less mature as compared to peers matched from chronological as well as reading ability.

**Conclusions:** Individuals with dyslexia have poor phonological representations, as the segmentation hypothesis states, they are also believed to have “phonological representations that are less segmented than in children who read normally” (p. 182). Overall, in all the tasks in this study the conclusion supports the idea that individuals with dyslexia do not have as strong of phonological representations as compared to their peers matched for age and reading ability.

**Relevance to the current study:** One of the conclusions of this study is that individuals with dyslexia have poor phonological representations as compared to their peers matched for age and reading ability. The current study builds upon the conclusion that individuals with dyslexia have poor phonological representations as it classifies the types of errors that they may make due to poor phonological representations and their deficit of sequencing during a nonword repetition task.


**Summary:** This article discusses the relation between phonological representations and dyslexia. In relation to these two topics Brady explores various categories including (a) “research on speech perception and reading ability”, (b) “categorical perception”, (c) “speech repetition”, (d) whether “speech perception deficits stem from a more general auditory temporal problem”, as well as the (e) “consequences of speech perception on early reading: the mechanism of phoneme awareness” (pp. 22-41). Brady concludes stating that although the relation between speech
perception and reading is complex “results of categorical perception studies reveal a persistent pattern of difficulty on identification and discrimination by poor readers, suggesting that they are less accurate in their ability to form phonological representations” (p.41) she continues by proposing that “inferior pseudoword repetition by disabled readers results in part from difficulty establishing speech representations” (pp. 41-42). Finally, Brady concludes by stating further research should be done focusing “on the quality of phonological representations of disabled readers” (p. 42). The current study includes an in-depth analysis of substitution errors made during a novel nonword repetition task which may provide further insight into phonological representations of those with dyslexia.


**Objectives:** The objective of this article is to outline the Comprehensive Assessment Battery for Children-Working Memory (CABC-WM); a working memory test battery. The importance of assessing working memory in children is also discussed.

**Methods:** One hundred sixty-eight typically developing children with a mean age of 7 participated in this test battery. Tasks were administered on a computer in the form of a computer game. A research assistant was present to facilitate administration of the test and collect necessary data. Various tasks were used to assess “central executive, phonological working memory, visuospatial working memory, and binding functions” (p. 10). Notably the phonological working memory assessment included a nonword repetition task. Detailed description of how each task were administered are included in the article.

**Results:** Results for each task are outlined in detailed tables within the article. It is noted that 153 individuals participated in the nonword repetition task.

**Conclusions:** There are not many test batteries available to evaluate working memory. This test battery should be considered when evaluating working memory in children in second grade. The battery is currently undergoing reliability and validity evaluation.

**Relevance to the current study:** The Comprehensive Assessment Battery for Children-Working Memory was administered to all participants in the current study. Data from the nonword repetition task is specifically being analyzed for the current study.


**Objectives:** The purpose of this study is to explore the links/ differences “between children with family risk of dyslexia and children with speech difficulties in four different domains; literacy, phonological awareness, phonological processing and phonological learning” (p. 3).
**Methods:** Fifty-one children between the ages of 3;11 years and 6;06 years participated in this study. Seventeen of the children were considered high risk for dyslexia as they had either a parent or sibling who had been diagnosed with dyslexia. Another seventeen were considered speech-impaired and were currently receiving services from a Speech-Language Pathologist; these students were considered to have average language development and did not have a family history of dyslexia. The last seventeen children were used as the control group. These children did not have speech delays or a family history of individuals with reading difficulties. Each individual participated in various tasks. These tasks assessed language skills (receptive vocabulary), phonological processing (mispronunciation detection or input phonology, expressive phonology, and nonword repetition or output phonology), phonological learning, phonological awareness (syllable matching, rime matching, and phoneme matching) and emergent literacy (letter knowledge and reading).

**Results:** The participants at high risk for dyslexia and with speech impairments exhibited similarities in their patterns of impairment. These participants manifested an average vocabulary however they had “poor input and output speech processing, phonological learning, phonological awareness and reading development” (p. 1).

**Conclusion:** Children at risk for dyslexia as well as those with speech impairments both have deficits in phonological representations, which can cause difficulty in reading. It is noted that during this study “nonword repetition confirmed that output phonological deficits are implicated in the family risk of dyslexia, though these are less severe than those observed among children with speech impairments” (p. 6).

**Relevance to the current study:** This study discusses characteristics that individuals at risk for dyslexia and with speech sound disorders manifest with at a fairly young age. This includes phonological difficulties. The current study is analyzing what types of phonological errors individuals with dyslexia make.


**Objectives:** The purpose of this study was to assess speech production/ phonological processing skills in children that have reading disorders.

**Methods:** Forty individuals 12 to 16 years of age participated in this study; 20 were diagnosed with a reading impairment, and 20 were typically developing individuals that attended the same schools and were matched for gender and age. The “children participated in naming, word repetition [of multisyllabic words], and phrase repetition tasks” (pp. 504-505). The two groups were compared for the amount of speech production errors made. The children with reading difficulties speech production as compared to their reading level was also analyzed.

**Results:** The results of the group comparisons proved that children with reading difficulties made more errors than the typical children in the naming, word repetition and phrase repetition tasks. It is also noted that overall children with reading difficulties “speech production scores were
significantly correlated with their reading ability. The strength of the relationship, however, varied across reading subtests and speech production tasks” (p. 505).

Conclusions: Children with reading difficulties may have phonological processing difficulties. These difficulties include “problems encoding or forming phonological memory codes, as well as the reactivation/execution of these codes/programs” (p. 507). It is suspected that difficulties in phonological processing may account for individual’s speech production deficits. Specifically, “in the naming and word repetition task, many of the speech errors produced by the RD subjects were indicative of difficulties inputting phonological information. These tasks the RD subjects often omitted or substituted sound segments in the production of the multisyllabic words…These errors generally did not involve a given subject misarticulating the same sound segment/s across words; rather errors seemed to be more word specific. This errors pattern suggests that the phonological analysis skills of RD subjects may not be as fine-tuned as those of normal children, and as a result, RD children many often be able to encode the phonological detail contained in multisyllabic words” (p. 506).

Relevance to the current study: This study discusses the relationship between reading difficulties and phonological processing difficulties. It also discusses how speech errors can be related to phonological encoding as well as that children with reading difficulties do not always make consistent errors. The current study is analyzing if there are any patterns of errors that children with dyslexia make when presented with novel nonwords.


Summary: This article is a review concerning the use of nonword repetition task for individuals that are typically developing as well as those with developmental language delay. The article states that “nonword repetition mimics the phonological component of the child’s task when learning a new word” (p. 12). This article discusses the relationship between vocabulary, lexical/sublexical influences, as well as “speech perception and discrimination, phonological encoding, phonological memory, phonological assembly, motor planning, and articulation” related to nonword repetition tasks as manifest in TD and individuals with DLD (p.1). The article discusses that when using nonwords that are unwordlike the nonword is evaluating working phonological representations/memory and the long term/ previous lexical knowledge is unrelated. It was also found that “generally speaking, children who successfully encode spoken words are less able to recall phonologically similar words...children with less efficient encoding strategies do not show these phonological similarity effects, making a similar number of errors on lists of phonologically similar and dissimilar words” (p.18). Overall, during nonword repetition task individuals with developmental language delay make more errors than those that are TD. This is relevant to the current study as the reasoning behind some of these errors can also provide insight into why individuals with dyslexia may make the same or similar errors.

Objectives: The purpose of this study is to evaluate whether individuals with dyslexia have deficits in serial order memory.

Methods: A large sample of second graders participated in this study. The second graders were divided into two main groups of typically developing and those with dyslexia. The participants with dyslexia were then further divided into those with and without language impairment. If children qualified for the study, they completed six word-learning games as well as “a comprehensive battery of working memory tasks, over the course of at least 6 days” (p 214).

Results: Non-verbal intelligence and oral language scores were used to match participants that were typically developing to those with dyslexia and an absence of language impairment. In regards to phonological memory, when matched there was no “difference between the groups in non-word repetition” (p. 222). The serial order memory in standard span tasks found that those with dyslexia without comorbid language impairment have a “slightly greater loss of serial order information for digits than was seen in the TD [typically developing] group” (p. 224). Similar results were found during the serial order memory in running span tasks. It was found that “serial order information was lost relative to item information more severely in children with DYS [dyslexia] than in children with TD. The differences were most prominent in the running span tasks” (p. 224). Using nonverbal intelligence scores, a correlation was also observed suggesting that since “cognitive skills are considered to be substantially related to dyslexia…the relation of serial order information to dyslexia is also substantial” (p. 226).

Conclusions: When children with dyslexia are compared to typically developing children there are significant group differences regarding short-term serial order memory. These “group deficits are partly a function of serial order memory issues, not solely phonological memory issues” (p. 228). Overall, a conclusion can be drawn that “serial order memory is impaired compared with typically developing individuals” (p. 229).

Relevance to the current study: This study evaluates short-term memory and deficits in serial ordering in those with dyslexia. The current study is a further analysis of the nonword repetition task presented in the study which is further analyzing and classifying what types phonological errors children with dyslexia produce.


Objectives: The objective of this study was to evaluate strength of predictors used to identify dyslexia. Specifically this study focused on how phonological representations can be used to identify individuals with dyslexia.

Methods: Forty-nine children with a minimum of one dyslexic parent and forty-two typically developing children participated in this study. This study was a longitudinal study conducted in Denmark that followed children from the beginning of kindergarten to second grade. At the beginning of Kindergarten children participated in various assessments that tested their prereading abilities, linguistic awareness, basic language abilities, phonological representations,
and basic cognitive abilities. Information regarding their family background was also collected. At the beginning of second grade various reading and language tests including tasks of nonword reading and identification of pseudohomophones were administered.

*Results:* Children at risk for dyslexia had significant differences as compared to the typically developing children in regard to their morpheme deletion, articulatory accuracy, and articulatory efficiency. Other statistically significant predictors of dyslexia were phoneme identification, initial phoneme deletion, short-term memory, and receptive vocabulary. Other family background indicators also are believed to be a positive indicator for dyslexia.

*Conclusions:* This study suggests quality of phonological representations in lexical items can help predict how phoneme awareness will develop as well as phonological recoding skills in reading. Results also suggest that “differences in phonological distinctness influence both the development of phoneme awareness and the acquisition of phonological recoding-in reading” (p. 53)

*Relevance to the Current Study:* One of the main goals of this study was to identify strong predictors that may be used in the early identification of dyslexia. The current study may provide another way that dyslexia may be identified in young children. This study also discusses the phonological weakness that children have as well as the difficulty that they have deleting phonemes. The current study is based on the knowledge that children with dyslexia have phonological weakness. This weakness is being analyzed through evaluating whether individuals make substitution, insertion, omission, or transposition errors during a nonword repetition task.


*Objectives:* The purpose of this study was to analyze whether individuals with dyslexia have poorer phonological representations, increased difficulty learning non-words, and increased difficulty with representations of familiar words when compared against a group matched for reading ability. It also analyzed whether quality of phonological representations and phonemic awareness were related in regard to word-specific gains.

*Methods:* Participants in this study were 38 Danish-speaking individuals. 19 of these participants (12 boys and 7 girls) with a mean age of 12;1 had been diagnosed with dyslexia while 19 other participants (10 boys and 9 girls) with a mean age of 8;6 participated in the study. Participants in the study completed tasks that evaluated their word decoding, non-word decoding, receptive vocabulary, phoneme awareness, quality of phonological representations, word and non-word learning, and ability to learn fully distinct phonological representations.

*Results:* Results of the study showed that individuals in the group with dyslexia had significant difficulty in their ability to decode non-words as compared to the reading matched group. The group with dyslexia also did not do as well on the phoneme awareness tasks. They made less correct substitutions and changed syllable structure (changing consonants instead of just vowels in the assigned task) more often than the control group. The dyslexic group also made twice as
many errors than the control group in a measure of the quality of phonological representations. Results also show that individuals with dyslexia were less able to learn new words and had difficulty learning new variants of known words.

Conclusions: Individuals with dyslexia’s phonological representations may be more fragile than typically developing individuals. It was shown in various tasks that individuals with dyslexia may have difficulty with phonology in general. This includes learning new phonological material as well as verbal productions of familiar words. Overall poor phonological representations are believed to be an underlying deficit in individuals with dyslexia.

Relevance to Current Study: Through various experiments this study concludes that individuals with dyslexia have poor phonological representations. The current study is built upon the hypothesis that individuals with dyslexia have poor phonological representations and is using an in-depth analysis to determine if there are consistent patterns that individuals with dyslexia make in non-word repetition tasks.


Objectives: The purpose of this study was “to examine the influence of word-level phonological and lexical characteristics on phonological awareness” (p. 1).

Methods: Sixty-four children between the ages of 6:9 and 9:0 (2nd graders) participated in this study. The children were divided into three groups of typically developing individuals, individuals with specific language impairment and individuals with dyslexia. Participants in the study participated in “a battery of language, word decoding, nonverbal intelligence, and phonological awareness assessments” (p. 3). The experimental measure that the children participated in was the Hogan deletion task in which children had to delete sounds in real and nonword stimuli.

Results: Typically developing children were more accurate at repeating words when the stimuli were from dense neighborhoods, they also did better during the deletion tasks on dissimilar words. Interestingly, the group with specific language impairment did better with similar/dense words as compared to the dissimilar words. The group with dyslexia performed worse than typically developing individuals on all four conditions of the deletion task. “These results suggest that children with DYS [dyslexia] have qualitatively different patterns of performance on repetition and deletion tasks compared to children with SLI [specific language impairment] and TD [typically developing] children” (p. 6). It is noted that 3/4 tasks were specifically difficult for individuals that only had dyslexia and did not have comorbid dyslexia and language impairment. Overall “results yielded three major findings: (a) typically developing children experienced and advantage for dense and dissimilar words, (b) children with SLI showed a similar pattern of performance to children who were typically developing, across the phonological and lexical conditions, and (c) children with dyslexia exhibited and aberrant, immature pattern of performance when compared to children with SLI and typically developing peers” (p.7).
“Children with dyslexia exhibit the opposite pattern of phonological and lexical influences on phonological processing compared to their peers with SLI and their typically developing peers” (p. 8).

**Conclusion:** This study supports the phonological deficit hypothesis in children with dyslexia which states that individuals with dyslexia have “underspecified phonological representations” (p. 8). Children with dyslexia in this study “appeared to have a more immature and aberrant pattern of phonological and lexical influence” (p. 9), as evidenced by them having difficulty with phoneme repetition and deletion when compared to individuals that were TD and those with SLI.

**Relevance to Current Study:** The current study builds upon the hypothesis discussed in this study that individuals with dyslexia have a phonological deficit. The current study is trying to identify in detail due to this hypothesis as well as the hypothesis that they have a sequencing deficit what errors children with dyslexia make during a nonword repetition task as compared to their typically developing peers.


**Objective:** Evidence has shown “that compared to good readers poor readers have difficulty (a) encoding phonological information in long-term memory (Byrne & Shea, 1979; Mark, Shankweiler, Liberman, & Fowler, 1977), (b) retrieving phonological information from long-term memory (Denckla & Rudel, 1976; Denckla, Rudel, & Broman, 1981), (c) using phonological codes in working memory (Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977; Shankweiler et al., 1979), and (d) segmenting speech into phonemic and syllabic units (Bryant & Bradley, 1981; Fox & Routh, 1975; Liberman, Shankweiler, Fischer, & Carter, 1974; Treiman & Baron, 1981)” (pp. 337-338). Individuals with language impairment have also been shown to have some difficulties with phonological processing. The purpose of this study is to compare children with language impairment and those with reading impairment (or dyslexia)’s phonological processing abilities.

**Methods:** Thirty-six children between the ages of 6;2 and 9;2 participated in this study. Twelve of the individuals were categorized as having language impairment, twelve with reading impairment (dyslexia), and twelve that were typically developing. Over two sessions each of the children participated in eight different tasks. Some of the tasks such as the word and sentence repetition tasks were administered to evaluate individuals speech production abilities while other tasks, such as the sentence and word division, elision, segmentation, and morpheme judgment tasks were administered to evaluate the participants knowledge of “phonological and language units” (p. 339).

**Results:** During the word and sentence repetition tasks participants with language impairment and reading impairment made significantly more errors than those that were typically developing. An in-depth group analysis showed that during the word repetition “the three most frequently used processes for the normal and LI [language impaired] groups were substitution, assimilation, and deletion. The order changed somewhat for the RI [dyslexic] children: deletion,
assimilation, and substitution” (p. 341). Overall, there were more phonological processes evident in the complex words as compared to the simple words. There was also no significant difference in the amount of phonological processing errors between those with language impairments and reading impairments while repeating complex words. While repeating simple words the typical children performed the best, then the reading impaired (dyslexic) children and then those with language impairment. The data was then analyzed using a distinctive feature analysis and it was found that “there was essentially no difference in the average number of feature shifts per substitution error for each group” even though those with language impairment, reading impairment and typical developing children make distinct varying levels of substitution errors (p. 342). Those with a reading impairment (dyslexia) also make fewer omissions during sentence repetitions as compared to those with language impairment. Individuals with reading impairment also did not perform as well as their typically developing peers on the elision and sentence division task. Individuals with language and reading impairment also performed significantly worse than typical peers on a morpheme judgment task.

Conclusions: Individuals with reading impairment (dyslexia) have poor phonological processing abilities. Although children with language impairment and reading impairment (dyslexia) may appear similar in various areas of phonological processing they should not be treated as a “homogenous group” as they do exhibit some differences in phonological processing (p. 344).

Relevance to the current study: This study analyzes the differences in phonological processing between those with language impairment, reading impairment, and typically developing children. This study also analyzes errors made using a distinctive feature analysis, omissions and substitutions. The current study is an in depth analysis of what types of errors children with dyslexia make as compared to their typically developing peers during a nonword repetitions task. This data is being analyzed for omissions, substitutions, insertions, and transpositions.


Working Definition of Dyslexia (1994): “Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterized by difficulties in single word decoding, usually reflecting insufficient phonological processing. These difficulties in single word decoding are often unexpected in relation to age and other cognitive and academic abilities; they are not the result of generalized academic disability or sensory impairment. Dyslexia is manifest by variable difficulty with different forms of language, often including, in addition to problems with reading, a conspicuous problem with acquiring proficiency in writing and spelling” (p. 2).

Working Definition of Dyslexia (2003): “Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/ or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge” (p.2).
Summary: This article, published in 2003, elaborates on the working definition of dyslexia that was published in 1995 in the *Annals of Dyslexia*. It discusses various topics including that dyslexia should be identified as a specific learning disability rather than being classified as a general learning disability as this term depreciates the specificity of the current working definition. It discusses how technology such as functional magnetic resonance imaging and magnetoencephalography have allowed researchers to further knowledge about how the brain functions differently in those with dyslexia as compared to typical individuals confirming that dyslexia is neurobiological in origin. The article discusses the science associated with Gordon Logan’s theory that there are two systems that are critical in automatic processing including word analysis and a whole word system. In addition the paper discusses how dyslexia manifests itself through poor spelling, decoding abilities, and especially through poor fluent word recognition (reading abilities). This article describes how these manifestations are due to fact that those with dyslexia have “a deficit in the phonological component of language” (p. 7). They have difficulty breaking words apart into distinct phonemes. This article discusses that the reading instructional history needs to be taken into account seriously if an individual is suspected of having dyslexia. It has been discussed that many individuals are poor readers because they have not had evidence-based instruction. When diagnosing dyslexia an individual’s response to adequate reading instruction should be documented. An individual’s poor reading abilities may results in poor reading experiences, comprehension and can negatively impact vocabulary acquisition and background knowledge. In conclusion the 2003 definition of dyslexia is the current working definition based upon the most current research. As time and research progresses however this definition is expected to evolve and change with the acquisition of new knowledge.


Objective: The objective of this study is to explore the theory that individuals with dyslexia have difficulties with rapid auditory processing which may alter speech perception causing phonological representations to be poorly formed.

Methods: Two different studies were conducted. In the first study 82 children with a mean age of 8;11 participated in various tasks over two data sessions that evaluated reading ability, nonverbal ability, phonology (including a nonword repetition task), and rapid auditory processing. In the second study 51 children were divided into three groups. The first group of 17 children (mean age 12;4) were identified with having dyslexia. The next two groups, each consisting of 17 individuals were comparison groups. One group were typical developing individuals matched for chronological age while the other group included individuals matched for reading age. Children participated in the same test battery as described in test one. Additional information through the use of a Strengths and Difficulties questionnaire was also acquired for the individuals with dyslexia.

Results: In the first study the data supports that auditory repetition task and phonological measures are correlated and show developmental effects. There was also a significant correlation between auditory repetition tasks and phonological scores and a moderate correlation between...
auditory repetition tasks and rhyme oddity, phoneme deletion and nonword repetition. However, when age and nonverbal IQ were controlled auditory repetition tasks did not predict nonword repetition. In the second study individuals with dyslexia performed worse than individuals matched for chronological age during a rhyme oddity task. The dyslexic group also performed worse than the other two groups on the phoneme deletion task. There was also a significant difference in the group with dyslexia as compared to the groups matched for reading and chronological age during the nonword repetition task.

**Conclusion:** In conclusion the first study found a “moderate relationship between rapid auditory processing skill, phonological abilities, and single-word reading in a sample of normally developing children” while the second study found “age-related deficits among children with dyslexia on the [auditory repetition task]” (p. 936). However, these studies “found no evidence for a direct causal relationship between rapid auditory processing ability…and phonological skill” (p. 938).

**Relevance to the current study:** This study confirms that individuals with dyslexia do not have impaired rapid auditory processing ability. This is important as it confirms that the phonological deficit in individuals with dyslexia is not due to a general auditory processing problem. The current study builds upon this knowledge that dyslexia is an implicit phonological deficit and not a deficit of general auditory processing.


**Objective:** The objectives of this study were to analyze how visual and phonetic factors influenced grapheme phoneme correspondence as well as measure how processing of visual and phonetic factors influences novel grapheme phoneme learning.

**Method:** Forty children in kindergarten, first, and second grade participated in this study. Twenty of the children were classified as having dyslexia, 10 of the children were TD and matched for mental age, and 10 were TD and matched for reading age. The children were instructed in a grapheme-phoneme learning task where they were taught the following four corresponding pairs; phonetically similar visually similar, phonetically different visually different, phonetically different visually similar, phonetically similar visually different. They then participated in a sound deletion task, sound categorization task, short term memory task, and rapid naming task.

**Results:** When analyzing phonetic and visual similarities it was discovered that children with dyslexia “had the least difficulty learning the correspondence pair with different phonemes and graphemes, and the most difficulty learning the correspondence pair with the similar phonemes and graphemes” (p. 264). When analyzing the phonological processing tasks those with dyslexia did worse on all tasks as compared to those matched for mental age. They also did worse than the reading matched group on the visual processing task, short term memory task, as well as rapid naming of objects.
Conclusion: Overall this study concluded that children with dyslexia required more repetitions to learn “novel phoneme grapheme correspondence pairs” (p. 259). They also needed more repetitions to learn correspondence pairs that had similar phonemes and graphemes as compared to the pairs that had different phonemes and graphemes. They also concluded short term memory was the biggest predictor for results of the learning task.

Relevance to current study: This article relates to the current study as the current study is also interested in phonemic learning in children with dyslexia. The current study is an auditory nonword repetition task (eliminating visual cues) to more fully analyze phonological deficits in word learning in children with dyslexia.


Summary: This article is a meta-analysis of studies that have been done using nonwords to evaluate dyslexia as well as language impairment. The article suggests various hypotheses of why individuals with dyslexia may struggle with nonword repetition. One of these hypotheses is that individuals with dyslexia have deficits in verbal short-term memory. The second hypothesis is that they have poor phonological representations. Overall, children with dyslexia perform poorer on nonword repetition task as compared to TD peers. Results indicated that this may be due to a phonological deficit, it is also noted that as individuals get older their performance on nonword repetition tasks improves. The authors of this study indicate however, that they believe the biggest predictor for poor performance in nonword repetition is language based. This article relates to the current study as the current study is an in depth analysis that will provide further insight into the errors that individuals with dyslexia are committing during nonword repetition task.


Summary: This article discusses the similarities and differences between speech sound disorders, language impairment, and reading disorders (developmental dyslexia). In this paper Pennington and Bishop state that dyslexia is characterized as having “significant difficulty learning to read accurately and fluently despite intelligence within normal limits and adequate opportunity to learn” (p. 285). It estimates that the prevalence for dyslexia is “around 9%” (p. 285). This paper also defines language impairment and speech sound disorders. It discusses the comorbidity between speech sound disorders, language impairment, and dyslexia. Cognitive overlap, etiological overlap, and varying comorbidity models are also discussed. This paper is relevant to the current study as it defines dyslexia. This study also discusses the comorbidity between developmental language delay and dyslexia, which is a subgroup that is may be analyzed in the current study.

**Objectives:** The purpose of this study was to explore if individuals with dyslexia and those with childhood apraxia of speech have similar difficulties in processing sequential information.

**Methods:** Fifty-four adults participate in this study; 22 with dyslexia, 10 with suspected childhood apraxia of speech, and 22 typical adults that were used as controls. Participants in the study participated in nonword repetition tasks as well as multisyllabic real word repetition tasks, and nonword decoding tasks. (p. 10-11). Sequence and substitution errors were analyzed using a phonological process analysis.

**Results:** During the nonword repetition task, multisyllabic real word repetition task, and nonword decoding tasks those with dyslexia and childhood apraxia of speech committed more errors than the typical control group. During the nonword repetition task it was noted that more sequencing errors were committed as compared to substitution errors. Those with childhood apraxia of speech committed the majority of sequencing errors during the real word repetition task while those with dyslexia committed the majority of their sequencing errors during the nonword decoding task.

**Conclusions:** Individuals with dyslexia and childhood apraxia of speech both have difficulties sequencing in motor speech and linguistic tasks. There is evidence that these two groups also have impairments with encoding sensory information, short-term memory, and motor planning/programming.

**Relevance to the current study:** This study analyzed and confirmed that those with dyslexia and childhood apraxia of speech process sequential information differently than typical individuals. The current study is analyzing what types of phonological errors children with dyslexia make in nonword repetition tasks.


**Summary:** In this article Frank Ramus and Gayaneh Szenkovits discuss phonological representation in individuals with dyslexia as it relates to the phonological deficits of poor phonological awareness, verbal short-term memory, and delayed lexical retrieval. Various studies were conducted on French University students (whose first language was French) to gather information regarding phonological representation. Results found that individuals with dyslexia when compared to their typically developing counterparts had difficulty with input representation, which was evident by their increased difficulty in discrimination tasks as compared to repetition tasks. During a non-word discrimination task it was also found that individuals with dyslexia performed more poorly than their peers when words were phonologically similar however, as the words increased in similarity their accuracy improved at a similar rate to those that were typically developing. The hypothesis that individuals with dyslexia
never develop firm phonological categories, as in babies was also discussed however; it was found that this was not true. Individuals in this study were also proven to produce voicing assimilations at a similar rate to typically developing individuals. This study concluded that individuals with dyslexia have intact phonological representations, including the grammatical process that act on them. Ramus and Szenkovits claim that tasks that tax short-term memory are the most difficult phonological awareness tasks for individuals with dyslexia. They hypothesize that individuals with dyslexia have difficulties with phonological access, which they define as “all processes by which (lexical or sublexical) phonological representations are accessed for the purpose of external computations” (p. 137). The authors also suggest that memory deficits may also be more detrimental to an individual’s language abilities as compared to phonological representations. Overall, this study relates to the current study as it discusses how phonological representations differ in individuals with dyslexia as compared to their typically developing peers. The current study is an in-depth analysis analyzing various errors that native English-speaking children make including substitutions, insertions, omissions, and transpositions, as compared to their typically developing peers.


**Summary:** This paper is a glossary describing various “phon words” as they relate to speaking and listening, metalinguistic awareness and skills, phonological memory and naming, as well as reading and writing. Eighteen individuals involved in various disciplines including “linguistics, speech/language sciences, psychology, and education” participated in defining these terms (p. 301). It is noted that some terms, such as phonological processing, have differing meanings across different disciplines. This paper also discusses non-words as they relate to phonological representations, codes, and memory. This paper specifically has a section about phonological aspects of dyslexia where it is hypothesized that individuals with dyslexia have a deficits in phonemic awareness. It is also discussed that individuals with dyslexia “have difficulty only with speech input, not with other kinds of auditory perception, and that temporal processing speed is not responsible for their phonological and reading deficits” (p. 330). Overall, this article is relevant to the current study as the literature surrounding dyslexia discusses deficits in various areas of the “phon words”. It also specifically discusses deficits that have been observed in individuals with dyslexia as they relate to the “phon words”.


**Objective:** The purpose of this study was to learn more about phonological differences in individuals with dyslexia and those that are typically developing, matched for reading age. Specifically, this study was conducted to identify differences in ability to read real and nonsense words as well as repeat real and nonsense words provided an auditory stimuli.

**Methods:** Two experiments were conducted. In the first study 22 typical readers and 20 dyslexic children, who were then subdivided into strong and weak readers, read 36, one or two syllable nonsense words that included no, one, or two consonant clusters. In the second study participants
repeated 30 real and 30 nonsense words (that were either two, three, or four syllables in length) after an auditory stimulus. Data was analyzed quantitatively for amount of errors made in each task.

**Results:** In the first experiment it was found that increased word length (two syllables) along with increased consonant clusters impacted reading ability for those with dyslexia greater than those that were typically developing. In the second experiment it was found that there was no significant difference in typically developing individuals and dyslexic individuals ability to repeat real words however, individuals with dyslexia were significantly worse at repeating nonwords as compared to their typically developing peers as word length increased. It is noted that “normal readers made more misrepresentations of *real* words of four syllables than dyslexics did…while dyslexic readers made more misrepresentations of *nonsense* words with four syllables than normal…normal and dyslexic readers made a similar number of misrepresentations of all other word types” (p. 230).

**Conclusions:** In the first study it can be concluded that individuals with dyslexia cannot decode nonsense or unfamiliar words as well as those that are at a similar reading level and are typically developing. In the second study it is of interesting note that individuals with dyslexia were only worse at repeating four syllable nonsense words as compared to their typically developing peers. This may be attributed to the fact however that the individuals were matched for reading level and not for age. These results also support the hypothesis that “dyslexics are subject to a subtle phonemic deficit which is noticeable even in speech, not only in grapheme-phoneme decoding task” (p. 231). Overall, individuals with dyslexia’s verbal deficits may be the result of a phonemic processing deficit.

**Relevance to the current study:** The second experiment in this study analyzed the amount of errors that typically developing children and individuals make when participating in a nonword repetition task. The current study is an in depth analysis of the types of errors (including substitutions, insertions, omissions, and transpositions) that individuals with dyslexia make as compared to their typically developing peers.


**Summary:** This paper discusses research findings that have been made regarding dyslexia, also known as specific reading disability, over the past forty years. It is a review of the literature that discusses what has historically been believed regarding dyslexia as well as current belief. This paper begins with a review of dyslexia, it then discusses the components that are associated with a successful reader and the sub skills that are absent in readers with dyslexia and how that manifests. The hypothesized underlying causes of dyslexia are also discussed. These include cognitive deficits in general learning, visual deficits, low-level visual deficits; language based deficits including semantic and syntactic deficits, phonological coding deficits, the double deficit hypothesis (phonological skills and/or reduced naming speed). Theories and research involving low-level auditory deficits as well as how dyslexia manifests/ difficulties faced by individuals with dyslexia in different languages are also discussed. Hypothesized underlying causes of
dyslexia in regard to biological factors are also discussed. In this section theories regarding neurobiological factors, brain structure and function, genetic studies as well as the impact of dyslexia across the lifespan are all discussed. The association between cognitive and biological causes are also compared with experiential and instruction based risk factors. The paper finishes by discussing the implications that this has for professionals researching and working with individuals with dyslexia. This paper is relevant to the current study as it discusses hypotheses that individuals have made over time to understand dyslexia. Current hypotheses, especially those discussing phonological deficits in individuals with dyslexia have helped develop the current hypothesis. Results from the current study may also further knowledge about how dyslexia manifests during certain tasks in the English language; this may provide additional insight into what underlying processes may be happening on the phonological level.
APPENDIX B

Stimuli*

Two Syllable Nonwords:
gEn_fad
n@m_bog
bIv_yEn
wIf_t@f

Three Syllable Nonwords:
gYm.tif_n^k
hWd_yek_gev
wiv_nck_tuf
yit_vcd_gum

Four Syllable Nonwords:
hOt_yek_wif_tcg
yek_bcn_tug_wiv
hUd_bek_tif_tag
wUd_wef_yip_gud

Five Syllable Nonwords:
gWt_y^k_weg_tif_fcd
hif_tUg_w^d_gWd_y^g
dUd_yid_f^d_n^t_wiv
wUk_wUd_gYp_duv_wim

*All nonwords are presented in Klattese. For reference see http://www.people.ku.edu/~mvitevit/Klatt_IPA.pdf
APPENDIX C

Parent Consent Form

Parent Consent Form

Study Title: Profiles of Working Memory and Word Learning for Educational Research
Principal Investigator: Dr. Tiffany Hogan
Description of Study Population: Second-grade Children

This is a consent form for research participation. It contains important information about this study and what to expect if you decide to let your child participate.

Why is this research being done?

We are conducting a project targeted at identifying the role that working memory plays in children’s word learning so that educational programs can be developed to address working memory and vocabulary learning problems.

What will my child do?

Your child’s participation is voluntary. If you permit your child to participate, you will be asked to sign this form and complete a questionnaire. You will receive a copy of the consent form. Your child will continue to participate in school just like all of the other children in his/her class. Your child will complete 1-2 assessment sessions and 6 remaining research sessions. We will schedule sessions during non-academic times based on school and family preferences. You will also have the option of bringing your child to the MGH Institute of Health Professions (MGH IHP) for participation after school or on weekends.

Participation in this project will require no more than ten hours to complete. This time will be divided into 6-8 sessions, depending on how quickly your child finishes each task.

During the assessment sessions, your child will be given standardized tests examining skills related to speech, oral language, nonverbal thinking, and reading. Additionally, your child’s hearing and vision will be screened to confirm that he/she is within a normal range. If your child wears glasses, he/she may wear them during the screening. You will be informed if the results suggest that your child may have a problem with his/her vision or hearing.

During the remaining research sessions your child will play a series of computer games assessing a variety of skills including: perception, auditory skills, visual-spatial skills, multi-
tasking, working memory, and word learning. These games vary from 2-15 minutes in length and are presented in the context of a pirate adventure game. Selected tasks will be audio and/or video recorded for research purposes.

**OPTIONAL GENETICS PARTICIPATION**

You also have the **option** of giving permission for your child to provide a saliva sample to send to a national database to learn more about the role that genes – the building blocks of your body – play in speech, language, and reading development. This **optional** genetics study is conducted by Dr. Christopher Bartlett at *The Research Institute at Nationwide Children’s Hospital*. If you choose for your child not to participate in this portion of the study, they will still be able to participate in all the other research activities without repercussion.

If you give your permission for your child to provide a saliva sample, your child will be asked to spit into a test tube during a research session. The amount of saliva required is less than ½ teaspoon. The saliva will be used to get DNA (the genetic material in our cells). The tube will be labeled with a participant code assigned in our lab at MGH Institute of Health Professions and sent to Dr. Bartlett at *The Research Institute at Nationwide Children’s Hospital*. The sample will be used only for research on language and related abilities. Your child’s sample will not be used for any other kind of non-research or medical testing. The sample will not be sold to anyone. It will be kept until it is no longer usable, which could be from two to twenty years.

Please check one of the following boxes and sign your initials below.

- I give permission for my child to provide a saliva sample.
- I **DO NOT** give permission for my child to provide a saliva sample.

Parent/guardian Initials: ___________________

If this portion is left incomplete, your child will **not** be asked to provide a saliva sample.

**How will the information be collected and kept confidential?**

Your child will be given a unique identification number that will be used. All information will be kept in locked drawers in a secure research lab. This information will be available only to the project staff and will be destroyed following completion of the project. Any audio collected will be carefully protected by research staff, stored in a secure location. With your permission (see below), these audio and video recordings may be used indefinitely for teaching and training purposes (i.e. training research staff, professional presentations).
Risks and Benefits

There are no known risks associated with your child’s participation in this study. It is possible that your child may become bored or tired during a session. Children will be given breaks as needed. You are invited to observe any session. If you provide permission for your child to provide a saliva sample for the optional genetics component, it is possible that your child may not want to spit into the test tube. Children will not be coerced into providing a saliva sample.

You are free to decide not to participate in this study. You can also withdraw at any time without harming your relationship with the researchers, the MGH Institute of Health Professions, or your child’s school.

If you consent for your child to participate in this study and he/she is selected, your child will receive incentives for participation. Your child will receive small incentives (i.e. stickers, pencils, etc) during all research sessions. Additionally, he/she will choose a $15 gift card to one of the following stores: Barnes and Noble, Target, or Walmart.

There are no direct benefits for taking part in this research study. However, your participation and your child’s participation will make an important contribution to improving what we know about language and reading skills in children.

Questions and Concerns

For questions or concerns about the study, you may contact the Project Director, Dr. Katy Cabbage, at the Speech and Language Literacy Lab, MGH Institute of Health Professions, 617-643-4821 or kcabbage@mghihp.edu. You may also contact the Principal Investigator for this study, Dr. Tiffany Hogan, at 617-724-1054 or thogan@mghihp.edu.

For questions about your child’s rights as a research participant or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact MGH’s Institutional Review Board at 617-952-6182.

To consent for your child to participate, please:

1. Sign where indicated in the box below.
2. Complete the Parent Questionnaire.
3. Put all completed forms into the research envelope and return to your child’s teacher

OR mail materials directly to the Speech and Language Literacy Lab at the following address:

Speech & Language Literacy Lab
ATTN: Katy Cabbage
36 1st Ave
Boston, MA, 02129
Signing the consent form

I have read (or someone has read to me) this form and I am aware that I am being asked to provide permission for my child to participate in this research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I am not giving up any legal rights by signing this form.

Consent to Participate

Please initial one of the following options and sign below.

☐ YES, I want my child to participate in this project.

☐ NO, I do not want my child to participate in this project.

Audio/Video Recording Release

I give permission for the researchers affiliated with the present research study to archive the following recordings of my child for future teaching and training purposes. Check one of the options below:

☐ Audio recordings only
☐ Video recordings only
☐ Audio AND video recordings

☐ I do not give permission for researchers affiliated with the present research study to archive audio and video recordings of my child for future teaching and research purposes.

(If no choice is indicated, your child’s audio and video recordings will not be archived for future teaching and training purposes.)

______________________________
Child’s Name

______________________________
Printed name of Parent/Guardian authorizing permission

______________________________ Date
Signature of Parent/Guardian authorizing permission
APPENDIX D

Child Assent Form

Research Assent Form
Brigham and Women’s Hospital
Dana-Farber Cancer Institute
Massachusetts General Hospital
Version IIIa August 1998

Imprint Patient ID Number

Protocol Title: Profiles of Working Memory and Word Learning for Educational Research

Principal/Overall Investigator: Dr. Tiffany Hogan

Site-Responsible Investigator(s)/Institution: Dr. Tiffany Hogan

Description of Subject Population: Second-grade Children

This is a study that will help us learn more about how children learn. To be in this study, you will look at pictures, tell me the names of pictures, do some reading, and play games on a computer. Some of the activities are easy and some might be hard. We will give you breaks between activities. We will audio or video record some of our activities. It will take about 6-8 different days for you to participate in this study. There is nothing dangerous about participating in this study. There are no benefits for you for participating in this study but you will help us learn about how children learn. Your mom/dad/legal guardian has said that it was okay for you to participate in our study.

OPTIONAL PORTION (to be read if parents have given permission for child to provide a saliva sample for the genetics portion of the study)

Another part of this study will help us learn more about genes (the kind of genes in your body, the building blocks of your body) and language and reading ability. To be in this part of the study, you will drink some water and then a little later you will spit into a test tube. We don’t need very much spit, just a little. Your mom/dad/guardian have said that it was okay for you to participate in this study. Before we do this, we want you to decide whether or not you want to spit into the tube. You do not have to be in this part of the study if you don’t want to. If you decide you don’t want to, you can still do all of the other activities in the study.

Please check one of the boxes below:

☐ I DO want to be in the part of the study where I spit into a test tube.

☐ I DO NOT want to be in the part of the study where I spit into a test tube.

______________________ Subject’s Initials
The information collected about you during this study will be kept safely locked up, and nobody will know who you are except the people doing the research. If we write an article about what we learn from the study, we will not use your name.

Before you decide to take part in this study, we will answer any questions you have. You can also talk to your mom or dad, or your doctor. You do not have to be in this study, it is okay to say no. If you decide to be in this study, you can change your mind and stop being part of it at any time.

You will be given a copy of this form to keep for yourself.

If you decide to be in the study, please sign your name below.

Subject’s Signature ______________ Date ______________