8-2016

Nonword repetition and phonological awareness skills in preschoolers with and without speech sound disorders

Tesnime Selmane

Purdue University

Follow this and additional works at: https://docs.lib.purdue.edu/open_access_theses

Recommended Citation

https://docs.lib.purdue.edu/open_access_theses/1001

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.
This is to certify that the thesis/dissertation prepared

By Tesnime Selmane

Entitled
NONWORD REPETITION AND PHONOLOGICAL AWARENESS SKILLS IN PRESCHOOLERS WITH AND WITHOUT SPEECH SOUND DISORDERS

For the degree of Master of Science

Is approved by the final examining committee:

Françoise Brosseau-Lapré
Chair

Laurence B. Leonard
Co-chair

Lisa A. Goffman
Co-chair

To the best of my knowledge and as understood by the student in the Thesis/Dissertation Agreement, Publication Delay, and Certification Disclaimer (Graduate School Form 32), this thesis/dissertation adheres to the provisions of Purdue University’s “Policy of Integrity in Research” and the use of copyright material.

Approved by Major Professor(s): Françoise Brosseau-Lapré

Approved by: Keith Kluender 4/29/2016
Head of the Departmental Graduate Program Date
NONWORD REPETITION AND PHONOLOGICAL AWARENESS SKILLS IN PRESCHOOLERS WITH AND WITHOUT SPEECH SOUND DISORDERS

A Thesis
Submitted to the Faculty
of
Purdue University
by
Tesnime Selmane

In Partial Fulfillment of the Requirements for the Degree of
Master of Science

August 2016
Purdue University
West Lafayette, Indiana
For my parents, Abbas and Aicha whose encouragement and unconditional support has taught me to strive towards that which I aspire to achieve.

To my sisters, Romeissa, Zeineb and Nour who have never left my side.
ACKNOWLEDGEMENTS

Thank you to the families that participated in this research and to my friends, colleagues, and family who offered encouragement and intellectual support. Thanks in particular to my advisor, Dr. Françoise Brosseau-Lapré for her guidance, encouragement and support during the development of this work. I am appreciative of comments and feedback from my committee members, Dr. Larry Leonard and Dr. Lisa Goffman. I also thank the Child Phonology Lab for their assistance and support.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vii</td>
</tr>
<tr>
<td>CHAPTER 1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Speech Sound Disorders</td>
<td>1</td>
</tr>
<tr>
<td>1.1.1 Underlying causes of SSD</td>
<td>3</td>
</tr>
<tr>
<td>1.2 Phonological awareness</td>
<td>6</td>
</tr>
<tr>
<td>1.2.1 Relationship between PA and Speech Abilities</td>
<td>7</td>
</tr>
<tr>
<td>1.3 Nonword repetition</td>
<td>10</td>
</tr>
<tr>
<td>1.4 Current study</td>
<td>11</td>
</tr>
<tr>
<td>CHAPTER 2. EXPERIMENTAL PROCEDURES</td>
<td>13</td>
</tr>
<tr>
<td>2.1 Methods</td>
<td>13</td>
</tr>
<tr>
<td>2.1.1 Participants</td>
<td>13</td>
</tr>
<tr>
<td>2.2 Procedures</td>
<td>15</td>
</tr>
<tr>
<td>2.2.1 Assessment Tasks</td>
<td>15</td>
</tr>
<tr>
<td>2.2.2 Reliability</td>
<td>19</td>
</tr>
<tr>
<td>2.2.3 Data Analysis</td>
<td>20</td>
</tr>
<tr>
<td>CHAPTER 3. RESULTS</td>
<td>21</td>
</tr>
<tr>
<td>3.1 Results</td>
<td>21</td>
</tr>
<tr>
<td>3.1.1 SRT and Phonological Awareness</td>
<td>22</td>
</tr>
<tr>
<td>3.1.2 Error Types and Phonological Awareness</td>
<td>23</td>
</tr>
</tbody>
</table>
CHAPTER 4. DISCUSSION

4.1 Clinical Implications
4.2. Study Limitations and Future Directions
4.3 Conclusion

REFERENCE

APPENDIX
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Demographic data and test scores for all participants</td>
<td>14</td>
</tr>
<tr>
<td>2 Performance on the Syllable Repetition Task by all participants</td>
<td>21</td>
</tr>
<tr>
<td>3 Percentage of consonants correct and error type proportions for 10 preschoolers with SSD and 10 TD children</td>
<td>24</td>
</tr>
<tr>
<td>4 Hierarchical multiple regression to examine Error types and PA skills in all participants</td>
<td>26</td>
</tr>
<tr>
<td>5 Hierarchical multiple regression to examine Error types and PA skills in SSD children</td>
<td>27</td>
</tr>
<tr>
<td>6 Hierarchical multiple regression to examine Error types and PA skills in TD children</td>
<td>28</td>
</tr>
</tbody>
</table>
ABSTRACT


The aim of the current study was to investigate the relationships between phonological awareness (PA) skills, types of speech sound errors, and nonword repetition skills. Ten preschoolers with typically developing speech (TD) and ten preschoolers with speech sound disorder (SSD), aged 4;0 (years; months) to 6;6 participated in the study. Eligible participants did not present with neurological, cognitive, or developmental disabilities such as cleft palate or autism spectrum disorder. We calculated the correlation between PA skills and nonword repetition performance of the children. In addition, a regression model was used to evaluate the degree to which phonological awareness skills could be predicted by the types of speech errors produced by the participants (typical speech errors, atypical speech errors, and distortions). Nonword repetition was significantly correlated with performance on the PA test, such that in general, participants who obtained poorer nonword repetition scores were found to have poorer PA skills. With regards to error types and PA skills, atypical errors predicted 12.5% of the variance in PA skills among TD participants. However, in children with SSD atypical errors did not contribute significant and unique variance to PA skills after controlling for age and nonverbal IQ. This data suggests that PA skills cannot be only inferred through the use of other measurements such as the SRT or speech sound errors produced.
CHAPTER 1. INTRODUCTION

Children with speech sound disorders (SSD) have difficulty accurately producing speech sounds compared to children of the same age, often resulting in unintelligible speech. Although the prevalence of SSD varies widely in the literature, a significant proportion of preschool-age children present with this communication disorder. For instance, Campbell and colleagues (2003) estimated a prevalence of SSD of 16% in 3-year old children based on the children’s intelligibility levels in conversation. Beitchman et al. (1986) completed a two-stage process study to calculate the prevalence of speech disorders in children 5 years of age in the Ottawa-Carleton region of Canada. Stage one included a random screening of kindergarten children using an articulation test and voice and stuttering checklist; if the children performed poorly on these measures (below the 10th percentile) they completed stage two, which consisted of an extensive speech and language evaluation. Beitchman and colleagues found a prevalence of speech disorders of 11% in kindergarten-age children. In a follow-up study, Johnson et al. (1999) investigated the prevalence of SSD in children with no impairments secondary to speech and language impairments (i.e., impairments due to hearing impairments, cleft palate, autism, etc.) and found the prevalence rate for speech impairment without language difficulties to be 6.1% in 5-year-old children.
In a systematic review, Law, Boyle, Harris, Harkness and Nye (2000) found that the prevalence of SSD without concomitant language impairment, measured using a variety of receptive and expressive language assessments, ranged from 2.3% to 24.6% in children age 5 to 7 years. Notwithstanding the fact that the prevalence values found by different studies vary widely, SSDs are common communication disorders throughout childhood and comprise the largest proportion of cases seen by pediatric speech-language pathologists (Weiss, 2009). In addition, children with SSD are at an increased risk of later difficulties with literacy development, and more precisely both poor decoding skills and spelling difficulties (Bird, Bishop & Freeman, 1995). These difficulties with reading and writing often persist in adulthood. For instance, Lewis and Freebairn (1992) completed a cross-sectional study to examine individuals with a history of SSD at four different ages: preschool-age children, grade-school children, adolescents, and adults. Adolescents and adults with a history of SSD in preschool had inferior phonological processing skills as well as increased reading and spelling difficulties compared to adults without a history of SSD (Lewis & Freebairn, 1992). Moreover, adults with a history of childhood SSD performed worst on speech production tasks (i.e., rapid production of difficult articulatory sequences and tongue twisters) compared to adults without a history of SSD. In addition to their difficulties accurately producing speech sounds and their literacy difficulties, adults with a history of SSD have been found to limit their interactions and restrict involvement in extracurricular activities while attending university (Board of Regents of the University of Oklahoma, 2011). In brief, the prevalence of SSD is significant and there are long-term effects that negatively affect the academic career and quality of life of individuals with a history of SSD. Through early intervention, speech-
language pathologists have the opportunity to improve the speech production abilities of preschool-age children with SSD and minimize negative long-term academic outcomes of children with SSD.

### 1.1.1 Underlying causes of SSD

While some children present with SSD due to secondary causes such as hearing loss, structural abnormalities (e.g., cleft palate), cerebral palsy or cognitive impairment, most children with SSD do not have apparent sensory, structural, or neurological conditions (Gierut, 1998). In other words, the cause of SSD is unknown for most children (Broomfield & Dodd, 2004). In this thesis the focus is on the majority of children who have a SSD of unknown origin. Although children with SSD are heterogeneous in terms of the underlying cause of their SSD, the severity of their speech production difficulties, and the characteristics of their speech sound errors (Dodd, 2011), there is now increasing support for a deficit in phonological processing in the majority of children with SSD.

Munson and colleagues examined the articulatory knowledge, perceptual knowledge, and phonological knowledge of typically developing children and children with SSD. Phonological knowledge was measured in 40 three- to six-year old children with SSD compared to 40 typically developing peers, using a nonword repetition task (Munson, Edwards, & Beckman, 2005). The authors presented 11 pairs of disyllabic and 11 pairs of trisyllabic nonwords; each pair had one high probability phonotactic sequence that young children would be familiar with, while the other word contained a low probability sequence, consistent with English phonotactics, which occur in few words that young children would know. When repeating the low frequency words the children cannot rely on previous knowledge in their lexicon, since there is a low probability they
were previously exposed to these words in their input. The authors found that children with SSD were less accurate when compared to typically developing same-aged peers in repeating both low and high-frequency nonsense speech sounds. In addition, and contrary to children with typical speech and language development, children with SSD performed similarly on both high probability and low probability words, while the TD children performed better on the high probability words. This suggests that children with SSD have difficulty forming word representations in the perceptual domain; children are expected to perform better on high probability words due to their frequent input forming stronger underlying representations (Munson, Edwards, & Beckman, 2005).

Munson, Baylis, Krause, & Yim (2010) also examined the perceptual learning of children aged three- to seven-years with and without SSD. Perceptual learning was assessed by a long-term repetition priming task that examined the children’s ability to learn perceptual representations for novel words based on minimal exposure. The children were presented with nonwords auditorily, followed by a distraction task (oral motor examination). Once the distracter was complete, the children repeated 52 nonwords (26 were unprimed: not presented earlier in the study; 13 identically primed: presented earlier by the same speaker; and 13 form primed: presented earlier by a different speaker). TD children repeated identically primed nonwords and form-primed words more accurately than unprimed words. Children with SSD, however, did not show priming effects when completing the task. These findings suggest that children with SSD have a reduced ability to learn perceptual representations for nonwords based on minimal exposure. The authors hypothesized that children with SSD struggle to encode the input and have an incomplete or inaccurate acoustic-phonetic representation of words.
According to Munson and colleagues, the vast majority of children with SSD have difficulties producing speech sounds accurately due to poorer encoding skills than TD children.

More recently, Vick et al. (2014) investigated the underlying causes of SSD in 97 preschool children to determine whether distinct subgroups of children could be identified. The authors conducted fifty-three standardized and non-standardized kinematic, acoustic, and behavioral measures. Tasks to asses these measures include lexical stress task (i.e., five imitations of two lexical stresses), a conversational speech sample, a nonword repetition task, and a nonspeech task (e.g., position trace from the jaw, chewing, and vertical jaw oscillations). Results showed that children with SSD could be classified in two subgroups. The first subgroup, consisting of 76.2% of the participants, did not have characteristics that imply atypical motor control; rather they had difficulties with the underlying representations/encoding of the speech sounds. The second subgroup (10.3% of the participants) was found to have atypical speech motor control (i.e., motor speech disorder-not otherwise specified). Thirteen percent of the participants were not classified in either of these two groups. This suggests that the majority of children with SSD have difficulties encoding speech sounds.

In brief, SSD is an overarching term that encompasses difficulties with how speech sounds are perceived (speech perception), how speech sounds are articulated (motor production), and/or how speech sounds are represented (phonological representations), which impact the ability to accurately produce speech sounds, affecting intelligibility (ASHA, n.d.). The vast majority of children with SSD have been found to
present with difficulties encoding speech sounds (speech perception), and developing
detailed and accurate phonological representations for words.

1.2 Phonological awareness

Phonological awareness (PA) is a metalinguistic skill that involves the ability to
attend to the sound structure of spoken language (Preston, Hull, & Edwards, 2013). PA
skills in preschool children involve the awareness of syllables, rhymes, and initial
consonants and are a very strong predictor of early literacy skills, decoding and writing
abilities (Preston et al., 2013). Using longitudinal studies, previous researchers have
demonstrated that PA skills in kindergarten predict reading outcomes in second grade
(Catts, Fey, Zhang, & Tomblin, 2001); and that preschool awareness of rhyme and
alliteration was causally related to reading and spelling outcomes in grade 3 (Bradley &
Bryant, 1983). Recently, Anthony et al. (2011) compared the phonological, language, and
literacy skills of three groups of 68 English-speaking children aged 3;5 to 5;6: children
with SSD, children with normal speech matched on receptive vocabulary, and children
with normal speech and language skills. Children with SSD were found to have poorer
receptive and expressive PA skills, and poor phonological representations compared to
the other two groups of children. Children with SSD, compared to same-aged peers with
equivalent language skills, were found to have poorer PA, speech perception skills, and
speech production skills. According to the authors, the acoustic-phonetic representations
of children with SSD were not mature enough to allow them to recognize words with
slightly less redundancy of acoustic information (Anthony et al., 2011). These results
indicate that children with SSD have a core deficit in encoding of speech sounds and are
at increased risks for deficits in PA and reading acquisition independently of their
language abilities. PA skills in early childhood were found to be the best predictor of later reading abilities, since reading skills cannot be evaluated at the preschool level.

1.2.1 Relationship between PA and Speech Abilities

According to Elbro and Pallesen (2002), the development of PA skills relies on accurate and distinct internal phonological representations, as well as the cognitive ability to access those representations explicitly. Children with SSD have difficulties with speech perception (e.g. Edwards, Fox, & Rogers, 2002; Rvachew, Ohberg, Grawburg, & Heyding, 2003) which results in inaccurate acoustic-phonetic representations (Munson, Baylis, Krause, & Yim, 2010). The acoustic-phonetic representations of children with SSD are not sufficiently detailed and mature to allow them to recognize words with slightly less redundancy of acoustic information (Anthony et al., 2011; Edwards, Fourakis, Beckman, & Fox, 1999; Shiller, Rvachew, & Brosseau-Lapré, 2010). These studies indicate that children with SSD have poor or imprecise phonological representations for words in their lexicon; in turn, this leads to poorer phonological awareness skills.

Although all young children omit or substitute sounds in certain words, children with SSD produce significantly more errors than is expected for their age (Preston et al., 2013). Maturation also plays a role in the development of speech production and perception. For instance, Hazan and Barrett (2000) investigated the development of speech perception through contrasting consonants in word initial position, in children 6 to 12 years old, finding that children in late childhood contrasted speech sounds with a greater accuracy compared to the younger children, especially fricatives. Studies have found that by age 2 years, children have the ability to contrast phonemes that differ by
one phonetic feature. As they mature into late childhood, children have an increasing ability to manipulate ambiguous acoustic features and assign them into discrete phonemic categories (Hazan & Barrett, 2000; Krause, 1982). This suggests that younger children may produce speech sound errors for two reasons: one, speech motor control does not reach adult-like levels until at least 16 years of age with jaw movements reaching adult-like consistency before lip movements (Smith & Zelaznick, 2004; Green, Moore & Reilly, 2002); and two, their speech perception abilities have not matured and reached adult-levels until early adolescence (Sanders, 1972). The majority of speech sounds are produced accurately at a young age in short words with simple syllable shapes; however, some speech sounds are not consistently produced accurately until 8 years of age (Sanders, 1972).

Researchers have investigated whether the type of speech errors produced by children with SSD can identify children who have particularly poor phonological awareness, and are at increased risk of ultimately presenting with literacy difficulties, in order to implement targeted early intervention. For instance, Rvachew, Chiang, and Evans (2007) examined the relationship between the PA skills and speech sound errors of children with SSD, ages 4 to 5 years, who either had poor PA skills or who had PA skills that were within normal limits. The participants included: (1) children with SSD and typically developing PA, and (2) children with SSD and delayed PA. In prekindergarten, the children with poor PA skills did not produce more atypical errors than children who obtained PA scores which were within normal limits. However, they did omit more consonants. One year later, the children with poor PA skills did produce significantly more atypical errors than children with average PA skills.
Preston and Edwards (2010) examined the types of speech sound errors produced by children with SSD through the use of a picture-naming task, which assessed each English consonant twice. The speech errors were classified as distortions (slight alteration in the production of the sound, such as a dentalization, resulting in the appropriate phoneme category but lacking precision), typical speech errors (produced by more than 4% of children) and atypical speech errors (rarely produced by children, central tendency less than 1%). Children with SSD exhibited more atypical (or unusual) errors, such as delinking of bilabials to [+continuant], substitution of glottals in the production of oral consonants, and delinking of onsets. Additionally, the participants with frequent atypical speech sound errors had lower PA scores (Preston & Edwards, 2010). The authors proposed that children with SSD who produce many atypical errors have poorer phonological representations, as it had been previously suggested in the literature (Leonard, 1985; Rvachew, Chiang, & Evans, 2007; Rvachew & Grawburg, 2006). In turn, these incomplete or inaccurate phonological representations may lead to long-term weaknesses in phonological processing, including phonological awareness.

Preston, Hull and Edwards (2013) completed a follow-up study that investigated the connection between PA skills and types of speech errors. In their study, atypical errors were the only preschool speech production variable that had an association with PA skills at a later time. Children who produced atypical errors had lower PA and literacy scores at 8 years of age (Preston et al., 2013). On the other hand, Rvachew et al. (2007) did not find a relationship between atypical errors and PA skills in preschool children, but found an association between atypical errors in preschool and PA skills one year later in kindergarten. Preston and colleagues suggested two reasons why no relationship was
found concurrently between atypical errors and PA skills in preschool by Rvachew and colleagues: one, due to their classification of speech errors, or two, the possibility that there is a weak connection between atypical errors and PA skills in preschool children but a stronger association with PA skills beyond preschool years.

1.3 **Nonword repetition**

Nonword repetition is a task that taps into phonological processing while reducing the semantic contribution, since real words that the child may be familiar with are not used (Kappes, Baumgaertner, Peschke, & Ziegler, 2009). Often the list of nonwords are similar to real words in that they follow the language’s stress patterns and phonotactic constraints, contain the most common number of syllables, number of consonant clusters, and have the most common voicing and manner of initial consonants (Edwards & Lahey, 1996). The task involves the child quickly developing a phonological representation based on auditory input and repeating the non-word appropriately without the confounding variable of word familiarity (Sutherland & Gillon, 2005). This task is considered to involve many cognitive processes, including discriminating the acoustic signal, encoding signal into a phonological representation, using working memory to hold the representation, motor planning, motor execution and lexical knowledge (Edwards & Lahey, 1998), potentially providing evidence of poor phonological representations, phonological memory, and an impaired lexical system (Sutherland & Gillon, 2005). If weakness is found through nonword repetition tasks, this may result in unsteady phonological representations for real words which has future implications of difficulty preparing articulatory codes for production (Sutherland & Gillon, 2005).
Current studies utilize receptive PA and speech perception tasks to assess phonological representations in children with SSD. Nonword repetition analyzes speech processes such as motor planning, phonological memory, and phonological representations. Until recently, many nonword repetition tasks consisted of phonemes that were commonly misarticulated by children with SSD making it difficult to assess the participant’s repetition abilities. Due to the need of a standardized nonword repetition task for children with SSD, Shriberg et al. (2009) developed the Syllable Repetition Task (SRT) for children with mild to severe speech sound disorders, with very limited or near complete speech sound inventories. The SRT, a two-minute assessment, consists of eight CVCV targets, six CVCVCV targets, and four CVCVCVCV targets. All of the target words of the SRT have equal stress on each syllable, which is another difference compared to most nonword repetition tasks commonly used with children with or without speech and/or language disorders. These items consist of five phonemes (/b/, /d/, /m/, /n/, /a/) which are considered “early” sounds, or phonemes that develop at an early age and can be articulated by young children and children with speech sound production deficits.

1.4 Current study

The current study had two aims. The first aim was to investigate the relationships between nonword repetition performance and PA skills. It was hypothesized that poor performance on the SRT would correlate to poor performance on PA tasks. The second aim of the study was to investigate the relationships between speech error types and PA skills in preschoolers with SSD and preschoolers with typical speech abilities. More specifically, our second hypothesis was that children with SSD who produced more atypical speech sound errors would have poorer phonological awareness skills.
This study has diagnostic clinical implications since children with SSD have been found to have poorer PA skills than children with typical speech and language skills, and are at risk for future reading difficulties (Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Rvachew, 2006). Beginning readers and adults who are illiterate provide evidence that literacy and PA skills are in a bi-directional relationship, with PA influencing the acquisition of literacy and literacy influencing the acquisition of PA (Barron, 2002). While it is known that children with SSD have poorer PA skills than children with typical speech and language skills, at the moment very few speech-language pathologists assess the PA skills of preschool-age children with SSD (Skahan et al., 2007). Brumbaugh and Smit (2013) found that only 36% of clinicians frequently provide PA evaluation and intervention to children ages 3-6 years with SSD. If found to be a good predictor of PA skills, the SRT, which takes only 3-5 minutes to administer and is freely available, could be administered routinely by clinicians in order to determine which children with SSD should complete a full PA assessment.
CHAPTER 2. EXPERIMENTAL PROCEDURES

2.1 Methods

2.1.1. Participants

Data from 20 native English speakers (4;0 to 6;11 years old) who participated in a larger study on phonological processing and speech sound production were included in the current study: 10 preschoolers with normal speech (TD) and 10 preschoolers with SSD. The children were assessed by a certified SLP, or by graduate speech-language pathology students under the supervision of the SLP. The assessment sessions took place in a quiet room in the Department of Speech, Language, and Hearing Sciences at Purdue University.

Eligible participants did not present with neurological, cognitive or developmental disabilities that might cause SSD, such as sensory-neural hearing loss, craniofacial anomalies, or other medical conditions. Children needed to pass a hearing screening, as well as the Oral Speech Mechanism Screening Examination-3 (St-Louis & Ruscello, 2000) to ensure they did not present with gross structural or functional anomalies of the oral mechanism. In terms of their performance on the diadokokinesies and alternate motion rate tasks, children were excluded from the current study if their results were consistent with dysarthria. In addition, children were assessed on measures of receptive vocabulary (Receptive One-Word Picture Vocabulary-4; Brownell, 2010); and nonverbal
I.Q. (nonverbal subtest of the Kaufman Brief Intelligence Test-2nd edition; Kaufman & Kaufman, 2004). A standard score of at least 80 on each of these two measures was required for inclusion in the study. Finally, parents completed a detailed case history including language exposure; the participants were all monolingual English speakers.

The participants’ PA skills were assessed using the three PA core subtests (elision, blending words, and sound matching) of the Comprehensive Test of Phonological Processing – Second Edition (CTOPP-2; Wagner, Torgesen, Rashotte, & Pearson, 2013). Participants were classified as presenting with SSD if they obtained a standard score below 80 on the Goldman-Fristoe Test of Articulation, 2nd edition (Goldman & Fristoe, 2000). Children with suspected childhood apraxia of speech or with concomitant receptive and/or expressive language impairments were not excluded from the study. Participant details can be seen in the following table (Table 1):

### Table 1

**Demographic data and test scores for all participants**

<table>
<thead>
<tr>
<th></th>
<th>SSD (n=10)</th>
<th>TD (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (months)</td>
<td>58.30</td>
<td>9.83</td>
</tr>
<tr>
<td>Nonverbal IQ (SS)</td>
<td>99.10</td>
<td>9.52</td>
</tr>
<tr>
<td>Rec. Vocabulary (SS)</td>
<td>111.20</td>
<td>8.53</td>
</tr>
<tr>
<td>Articulation (SS)</td>
<td>64.90</td>
<td>7.25</td>
</tr>
</tbody>
</table>

*Note.* Nonverbal IQ measured by KBIT-2, receptive vocabulary measured by the ROWPVT, and articulation measured by GFTA-2.

Ten of the children with SSD were matched on age and receptive vocabulary to typically developing children. Children were considered to match if: (1) the age
difference was 3 months or less; and (2) the difference in standard points on the receptive vocabulary measure was 10 points or less. T-tests were performed and indicated that the two groups did not differ significantly with regards to age (t(18)=0.16, p =0.87); nonverbal IQ (t(18)=1.58, p=0.13); or receptive vocabulary (t(18)=-0.99, p=0.33). However, as seen in Table 1 the two groups differed significantly with regards to speech production accuracy in the single-word articulation test (t(18)=10.66, p=0.00). In terms of phonetic inventories derived from the GFTA-2, six of the ten children with TD had complete inventories; two children were missing /θ/ and /ð/, one child was missing /ð/, and one child was missing /ʒ/, /θ/ and /ð/. Regarding the children with SSD, two children had complete inventories; two were missing only one consonant (/ʃ/ or /θ/), two children were missing two consonants (/ʃ/, /ʒ/, /θ/ or /l/), two children were each missing five consonants (/ʃ/ or /ʒ/, as well as /v/, /ʃ/, /θ/ and /ð/), and two children were missing seven and nine consonants, respectively (/g/, /ʃ/, /ʒ/, /θ/, /ð/, as well as /v/, /r/ or /k/, /f/, /l/, /z/).

2.2 Procedures

2.2.1. Assessment tasks

**K-BIT-2.** The Matrices subtest of the Kaufman Brief Intelligence Test, 2nd Edition (Kaufman & Kaufman, 2004) measures non-verbal intelligence using 46-items. Children were presented color plates with a target picture at the top, and six pictures at the bottom. The test used visual stimuli, both meaningful (people and objects) and abstract (designs and symbols), to assess nonverbal reasoning and problem-solving strategies. Participants were asked to point to the picture or say the letter that went with the target. According to the test manual instructions, the practice items of each section were administered.
**ROWPVT.** The Receptive One-Word Picture Vocabulary-4 (Brownell, 2010) includes 190 full-color plates presented in developmental sequence. The children were shown full-color plates with four pictures and asked to point to the word named by the examiner. The four practice items were given before the test, and then the examiner started testing at the suggested age-based starting point.

**OSMSE-3.** The Oral Speech Mechanism Screening Examination, Third Edition (St. Louis & Ruscello, 2000) assesses the structure and function of the lips, tongue, jaw, teeth, palate, pharynx, velopharyngeal mechanism, breathing, and DKRs and AMRs. The screening tool was administered according to the manual and was video-recorded. Participant’s responses were rounded to the nearest tenth when calculating repetition rates. The minimum age to use the OSMSE-3 norms is 5;0; however, many of the participants were younger than the minimum age. Younger children had more difficulty completing the required number of repetitions (16 for single syllables, 12 for [pata] and 8 for [pataka]) but age was not correlated with performance with regards to repetition rates in syllable/seconds for any of the isolated syllables or syllable sequences. Therefore the repetitions/second for each child was calculated, and prorated the pass criteria for the required number of repetitions. Pass standards were 2.9; 2.3; 2.7; 1.7; 0.95 repetitions/second for [pa], [ta], [ka], [pata] and [pataka] respectively for children up to the age of 55 months, and 3.2; 2.5; 2.9; 1.7; 1.0 for children aged 66 to 71 months.

**GFTA-2.** The Goldman-Fristoe Test of Articulation, 2nd edition (Goldman & Fristoe, 2000) is a test of articulation accuracy that examines an individual’s articulation of consonants in Standard American English. A total of 53 words, found on full-color photos, were used to elicit the articulation of 61 consonants in initial, medial and final
position and 16 consonant clusters in initial position. The GFTA was used to evaluate the
presence of errors and to classify an individual with SSD. Examiners used questions and
carrier phrases to elicit spontaneous productions of the target words; if the child did not
answer, delayed imitation techniques such as providing the target word first followed by
a description was used. Immediate imitation was used as a last resort to ensure data sets
were complete. Administration of the GFTA was video-recorded using a Toshiba
Camileo X200 Camcorder and PMD661 MK II Marantz recorder. The audio files were
extracted and saved as .wav files.

**Single Words Elicitation Task.** The Single Word Elicitation Task consists of a 60-word
picture naming task that was developed to compare production of similar words in
English and Spanish for use in the larger study on phonological processing and speech
production. In English, the task assesses articulation of all English consonants (except
/ð/) and many consonant clusters in either short words (1 or 2 syllables) or multisyllabic
words (3 syllables and more). Consonant errors were categorized according to Preston
(2008) who considered syllable structure, place of articulation, manner of articulation,
and voicing and classified each consonant as either a correct production, distortion,
typical sound error (e.g., final consonant deletion, liquid cluster reduction, stopping,
deaffrication, initial voicing), or atypical sound error (e.g., deleted consonant from a
strong syllable, glottal replacement, palatalization, fricatives replacing stops). We coded
all consonants as Preston (2008), with the addition that all voicing errors were considered
typical due to their frequency in the current sample. The occurrence of each error type
was calculated as the number of distortions per consonant, the number of typical errors
per consonant, and number of atypical errors per consonant for each child. For example,
if the word *tomatoes* /təˈmeɪtəʊz/ was produced as [təˈgetʊoz], the dentalized /z/ was considered a distortion, while the backing of /m/ to a /g/ was classified as an atypical error. For *tomatoes*, a word with four target consonants, there would be 1/4=0.25 distortions per consonant, 0/4= 0 typical errors per consonant, and 1/4=0.25 atypical errors per consonant. The child’s total score of these three categories was based on their productions of consonants attempted in the 60-word picture-naming task. Administration of the Single Words was video-recorded using a Toshiba Camileo X200 Camcorder and PMD661 MK II Marantz recorder. The audio files were extracted and saved as .wav files.

**CTOPP 2.** The Comprehensive Test of Phonological Processing-Second Edition (CTOPP-2; Wagner, Torgesen, Rashotte, & Pearson, 2013) is a norm-referenced assessment designed to measure phonological processing skills, including phonological awareness and phonological memory. The CTOPP-2 has been standardized for ages 4 to 24 years, with the majority of the age groups having a standardization sample of at least 200 individuals. The sample is a representation of the 2010 U.S. Census based on geographic region, gender, ethnicity, Hispanic status, exceptionality status, income, and education of parents. It is an assessment used by speech-language pathologists, reading specialists, school psychologists and clinical psychologists to identify children who are at risk of a reading deficit (Dickens, Meisinger, & Tarar, 2015). Additionally, the CTOPP-2 provides professionals with a profile of an individual’s strengths and weaknesses in phonological processing, contrasting features of phonological awareness, phonological memory, and rapid naming skills to be utilized or targeted during intervention (Dickens et al., 2013).
The current study focuses on the PA composite score of the CTOPP-2, which consists of the total scaled scores of each of the three PA subtests of the test, namely Elision, Blending words, and Sound matching. In the elision task the participants were required to delete sounds from words, such as “Say popcorn. Now say popcorn without saying corn”, and later asked to delete a phoneme from a word, such as “Say tiger. Now say tiger without saying g”. The blending words task involves participants combining sounds to form words, such as in “ham-er”. Lastly, the sound matching subtest instructs the participant to match sounds in initial and final position; children are presented with pictures, and asked to identify one of three items which starts or ends with the same sounds as the first picture.

**SRT.** The Syllable Repetition Task was administered using the PowerPoint audio presentation and scored according to the instructions provided by Shriberg & Lohmeier (2008). As described by Shriberg, Lohmeier, Strand and Jakielski (2012) the competence scores of the SRT are determined by the number of consonants produced accurately by the child; the specific error types are not taken into consideration.

### 2.2.2. Reliability

The graduate speech-language pathology students completed narrow phonetic transcriptions of the participants’ responses on the GFTA, Single Word Elicitation Task, and SRT based on the audio recordings. Audio files were reviewed at least two times for each child. In the case that a child produced the same target word more than once, the more accurate production was used. Another graduate speech-language pathology student independently transcribed 15% of the total GFTA, Single Word, SRT task (3 participants out of 20). When consonant transcriptions differed, the two transcribers listened to the
video recording and reached consensus on the final transcription. The mean transcription agreement for narrow transcription of the target consonants was 91.7% for the GFTA, 96.4% for the Single Word, 100% for the SRT. The mean transcription agreement for error coding was 100% for the 60-word picture naming task.

2.2.3 Data Analysis

It was hypothesized that children with SSD, regardless of their severity level, would have poorer nonword repetition skills than TD children and would obtain lower PA scores. A Pearson’s correlation coefficient was computed to investigate the relationship between performance on the nonword repetition task and PA skills. It was expected that TD children would present with normal PA skills. A regression model was used to evaluate the degree to which PA skills, as measured by the CTOPP-2, could be predicted by the types of speech errors produced by the participants (typical speech errors, atypical speech errors, and distortions), through the use of SPSS, version 23 for Windows.
CHAPTER 3. RESULTS

3.1 Results

The first goal of the present study was to compare the performance of the two groups of participants on the SRT and the PA task to see if performance on the SRT correlates with PA skills. Table 2 presents the SRT scores for all the participants.

Table 2

*Performance on the Syllable Repetition Task (SRT) by all children*

<table>
<thead>
<tr>
<th>SRT Item Length</th>
<th>SSD (n=10)</th>
<th>TD (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>2 Syllable</td>
<td>91.88</td>
<td>7.82</td>
</tr>
<tr>
<td>3 Syllable</td>
<td>75.00</td>
<td>15.77</td>
</tr>
<tr>
<td>4 Syllable</td>
<td>61.88</td>
<td>16.52</td>
</tr>
<tr>
<td>total</td>
<td>76.40</td>
<td>10.28</td>
</tr>
</tbody>
</table>

T-tests were conducted to compare performance on the SRT in the SSD group and TD group. There was no significant difference in the performance on the 2 syllable items of the SRT in children with SSD and TD, t(18)=0.519, p=0.610, nor was there a significant difference for the 3 syllable items; t(18)=1.020, p=0.321. However, the two groups performed significantly differently on the 4 syllable items, with children with SSD performing at a lower level than the TD children; t(18)=2.622, p=0.017. Overall, the
two groups did not differ significantly with regards to their Competence Score on the SRT (total performance); t(18)=1.739, p=0.099.

### 3.1.1 SRT and Phonological Awareness

A Pearson product-moment correlation coefficient was computed to assess the relationship between nonword repetition and PA skills in all 20 participants. There was a significant positive correlation between performance on the SRT (Competence score) and total PA performance (CTOPP-2 Total), $r = .527$, $p=.017$, with high nonword repetition skills correlating with higher PA skills. Among the 10 children with SSD only, there was no significant correlation between the Competence score on the SRT and PA skills. Since the correlation between nonword repetition competence and PA abilities was significant only when considering all the 20 participants together, we investigated the individual performance of each of the children who participated in the study. Individual results on the SRT and CTOPP for the 20 children are presented in Figure 1. As seen in the figure, the relationship between nonword competence and PA skills is not straightforward, especially so in the children with SSD. While some of them performed poorly on both the SRT and the CTOPP-2, some children with SSD obtained low SRT scores but nonetheless obtained a PA score above the mean, while one child with SSD obtained a score on the SRT above 90% but obtained a score on the CTOPP-2 which was below the mean.
Since the correlation between nonword repetition competence and PA abilities was not significant in the SSD participants, we examined only the 4-syllable item length in the SRT in the SSD participants since this variable was significantly different when comparing the TD to the SSD children. After investigating the relationship between PA skills (CTOPP Total) and the 4-syllable item length, no significance was found in the 10 children with SSD, r = .291, p = .415.

3.1.2 Error Types and Phonological Awareness

The second goal of the current study was to determine if speech error types, particularly the number of atypical speech errors, predicted performance on the PA task. Percent Consonants Correct (PCC) was calculated for each child with errors coded as...
distortions, atypical or typical errors, as described earlier. Higher values on the distortion, typical and atypical errors indicate more errors for each of these respective types of speech sound errors, and therefore less accurate speech production (and lower PCC values). The results are presented in Table 3. None of the 20 participants produced all consonants of the single words (short and longer words) accurately. Both groups of children produced distortions relatively infrequently. While both groups of children produced more typical speech sound errors per consonant compared to atypical errors per consonant, TD children produced 2.5 times more typical errors than atypical errors, whereas as a group, children with SSD produced almost as many atypical errors as typical errors.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>SSD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Consonant Correct (PCC)</td>
<td>60.21 10.93 46.61-78.90</td>
<td>84.50 8.38 69.20-94.94</td>
</tr>
<tr>
<td>Distortions per Consonant</td>
<td>0.048 0.033 0.017-0.110</td>
<td>0.032 0.034 0.0-0.114</td>
</tr>
<tr>
<td>Typical errors per Consonant</td>
<td>0.188 0.064 0.076-0.292</td>
<td>0.088 0.061 0.025-0.224</td>
</tr>
<tr>
<td>Atypical errors per Consonant</td>
<td>0.161 0.082 0.025-0.292</td>
<td>0.034 0.021 0.004-0.075</td>
</tr>
</tbody>
</table>

T-tests were conducted to compare PCC, Distortions, Typical errors, and Atypical errors in the two groups of children. There was a significant difference in PCC,
t(18)= -5.58, p<.000. No significant difference was found in distortions per consonant, t(18)=1.06, p=.302. As for typical and atypical errors per consonant, significant differences were found between the two groups, with children with SSD producing more errors; t(18)=3.59, p=.002 for typical errors, and t(18)=4.70, p=.001 for atypical errors. Raw error data for each individual can be found in the Appendix.

Hierarchical linear regression was performed using SPSS to examine the contribution of atypical and typical errors on phonological awareness skills. A change in $R^2$ (or $\Delta R^2$) of at least 0.10 was considered significant, as in Preston (2008). We first controlled for receptive vocabulary and nonverbal IQ, since each variable contributed at least 10% of the variance in PA performance in all 20 participants; children with higher receptive vocabulary skills and nonverbal IQ had higher PA skills. Receptive vocabulary and nonverbal IQ were therefore forced in the first step of the regression analysis. The contribution of atypical errors was then assessed in the second step. The results of the atypical error analysis can be found in Table 4; in all participants, atypical errors accounted for 9% of the variance in PA performance. Typical errors only contributed 2.2% of unique variance to PA skills and distortions contributed 0.1% of the variance in PA skills after controlling for receptive vocabulary and nonverbal IQ. None of the error types contributed a significant and unique amount of variance in PA skills in the participants.
Table 4

*Hierarchical multiple regression to examine contribution of speech error types to PA skills in all participants*

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Final $\beta$</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Receptive Vocabulary</td>
<td>0.487</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Nonverbal IQ</td>
<td>0.332</td>
<td></td>
<td>0.110</td>
<td>0.153</td>
</tr>
<tr>
<td>2</td>
<td>Total Atypical Errors</td>
<td>-44.426</td>
<td>0.090</td>
<td>0.090</td>
<td>0.199</td>
</tr>
</tbody>
</table>

Additionally, hierarchical linear regressions were performed for each group of participants. In the case of the children with SSD, age and nonverbal IQ together accounted for 64.3% of the variance in PA skills and these variables were forced into the first step of the regression analysis. Children with higher nonverbal IQ obtained higher PA scores, as did younger children. Atypical errors were forced into the second step of the regression analysis. The contribution of typical errors and distortions was also calculated by forcing each of them in turn in the second step of the analysis once controlling for age and nonverbal IQ. The results for the participants with SSD are presented in Table 5. Atypical errors only accounted for 4.3% of the variance in PA skills. On the other hand, typical errors only contributed 1.5% of unique variance to PA skills and distortions contributed 6.8% of the variance in PA skills after controlling for nonverbal IQ and age. None of the error types contributed a significant and unique amount of variance in PA skills in the children with SSD.
Table 5

*Hierarchical multiple regression to examine contribution of speech error types to PA skills in SSD children*

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Final $\beta$</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nonverbal IQ</td>
<td>0.904</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Age</td>
<td>-1.167</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.643</td>
<td>0.643</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Total Atypical Errors</td>
<td>-36.342</td>
<td>0.597</td>
<td>0.043</td>
<td>0.017</td>
</tr>
<tr>
<td>2</td>
<td>Total Typical Errors</td>
<td>-31.340</td>
<td>0.659</td>
<td>0.015</td>
<td>0.011</td>
</tr>
</tbody>
</table>

Finally, hierarchical linear regressions were performed for the children with typical speech development. In their case, receptive vocabulary and age together accounted for 23.6% of the variance in PA skills and these variables were forced into the first step of the regression analysis; atypical errors were forced into the second step. The results for the TD participants are presented in Table 6. Atypical errors accounted for 12.5% of the variance in PA skills after controlling for receptive vocabulary and age. Typical errors only contributed to 7.4% of unique variance to PA skills while distortions contributed 2.5% of the variance in PA skills.
Table 6

*Hierarchical multiple regression to examine contribution of speech error types to PA skills in TD children*

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Final $\beta$</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Receptive Vocabularly</td>
<td>0.296</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Age</td>
<td>0.573</td>
<td>0.236</td>
<td>0.236</td>
<td>0.155</td>
</tr>
<tr>
<td>2</td>
<td>Total Atypical Errors</td>
<td>-187.084</td>
<td>0.125</td>
<td>0.125</td>
<td>0.315</td>
</tr>
<tr>
<td>2</td>
<td>Total Typical Errors</td>
<td>-48.892</td>
<td>0.074</td>
<td>0.074</td>
<td>0.448</td>
</tr>
</tbody>
</table>

The results of the hierarchical analysis performed on all 20 children together demonstrated the impact of receptive vocabulary and nonverbal IQ on PA skills, with these two variables accounting for 11% of the variance. When analyzing error productions in all of the participants’, no error type was found to significantly contribute to PA performance. After analyzing each group separately (SSD versus TD), receptive vocabulary, nonverbal IQ or age were found to significantly account for the degree of variance found in PA skills. None of the error types contributed a significant amount of variance to PA skills in children with SSD. However, age contributed a very high amount of unique variance in PA skills in children with SSD, with younger children performing better on the PA task. In the children with typical speech, atypical errors were the most significant contributor to PA skills.
Because Rachew et al (2007) had found a relationship between speech errors that change the structure of the word (most often omissions of consonants); we also analyzed the feature-match ratios (FMR) for each consonant in all 20 participants. Matches and mismatches were coded for the major sound class features [+consonantal] and [+sonorant]; for the manner class features [+nasal], [+continuant], and [+voice]; and for the place nodes Labial, Dorsal, and the place feature [-anterior]. A consonant produced accurately resulted in a match for all associated features and place nodes; an omission resulted in a mismatch for all features and place nodes associated with the phoneme. In the case of substitutions, only common features between the target and the child’s production resulted in matches. In TD children, lower matches for [+consonantal] errors were the most significant contributor to PA skills with it contributing to 28.5% of the variance. In other words, TD children who omitted more consonants and/or glided more liquids obtained lower PA scores. Lower level features such as [+lateral], [dorsal], [coronal], etc. were also significant contributors to PA skills, which is not surprising since all features associated with a consonant receive a mismatch when the child omits the target consonant. No feature was a significant contributor to variance in PA skills in the SSD children.
CHAPTER 4. DISCUSSION

The aim of the current study was to investigate the relationships between phonological awareness (PA) skills, nonword repetition, and types of speech sound errors. By completing this study, we hoped to identify a short and quick assessment tool which would help speech-language pathologists working in schools identify children who are likely to have poor PA skills. For instance, the Syllable Repetition Task is a quick, free assessment that can be given, or describing the types of speech errors produced by the child, which is usually completed by the speech-language pathologist as part of current assessment practices when assessing children for suspected speech and language impairments. While a significant correlation was found between performance on the nonword repetition task and the PA task in all 20 participants, performance varied greatly among the children. In addition, while atypical errors were found to contribute to PA performance, particularly for TD children, other variables contributed more significantly to PA skills.

Children with SSD are heterogeneous in nature; although previous research indicated that most children with SSD have poor phonological awareness skills, some children with severe SSD have PA skills which are within normal limits, and children who no longer have difficulties producing speech sounds accurately but did present with a SSD at an earlier age are likely to have PA deficits (Rvachew, Ohberg, Grawburg, &
Heyding, 2003). This suggests that the variability in PA skills does not coincide with the severity of the SSD. In the current study, participants’ phonological awareness skills varied tremendously, with CTOPP-2 standard scores ranging from 75-114, and with only four children with SSD falling more than 1 standard deviation below the mean. Five of 10 children with SSD obtained a score ≤1 SD below the mean on at least one PA subtest of the CTOPP-2. Although children’s abilities to accurately produce speech sounds has been found to be related to their PA skills, other factors, such as nonverbal IQ and receptive vocabulary skills, have also been found to influence PA skills (Walley, Metsala, & Garlock, 2003). In our ten participants with SSD, 4 presented with low PA skills (standard scores of 85 or below on the CTOPP-2), and 4 presented with high PA (standard scores of 100 or higher on the CTOPP-2). Participants with SSD and lower PA skills were found to have lower nonverbal IQ scores than children with SSD and high PA, whereas their receptive vocabulary scores were very similar. Although the difference in nonverbal IQ was not statistically significant, this may account for some of the variability found in PA scores and is a variable to explore.

Even though previous studies reported a wide range of PA skills in their participants with SSD, all children in the current study performed better than anticipated on the CTOPP-2. Additionally, when analyzing PA skills in children with SSD the most significant contributor to PA performance was age, with younger children performing significantly better on the CTOPP-2. One possibility is that there is a recent and much greater emphasis on PA skills in preschools and daycares, leading to overall higher scores for children ages 4-5 years on the CTOPP-2 (published in 2013; however, the normative data were collected in 2008-2009). Currently, the national reading standards anticipate all
children to master phonological awareness by the end of kindergarten. The Department of Education expects Kindergarten children to display an increased awareness in several reading areas including phonological awareness, phonics, word recognition, fluency, etc. The National Governors Association Center for Best Practices & Council of Chief State School Officers (2010) published the Common Core State Standards for English language arts, which was adopted by 43 states. These standards include demonstrating understanding of spoken words, syllables, and sounds by: a) recognizing and producing rhyming words, b) counting, pronouncing, blending, and segmenting syllables in spoken words, c) blending and segmenting onsets and rimes of single-syllable spoken words, d) isolating and pronouncing the initial, medial vowel, and final sounds in CVC words, and adding or substituting individual sounds (phonemes) in simple, one-syllable words to make new words. The 2014 Indiana Department of Education standards, K.RF.3.1-K.RF.3.5, are similar to the national common core standards with few wording differences. Children attending daycares and preschools may therefore be introduced to formal PA instruction at earlier ages than were the children who were part of the standardization sample of the CTOPP-2 in 2008-2009. In other words, the normative data from the CTOPP-2 may no longer be representative of children who are currently 4 to 5 years of age and have attended daycare or preschool and have been formally exposed to PA. The significant contribution of age in predicting PA performance in the participants was surprising, since standard scores were used in the analysis.

Investigating the relationship between performance on the SRT and PA skills was the first goal of the study and the data suggested a moderate positive correlation in all 20 participants; higher nonword repetition skills correlated with higher PA skills. However,
this relationship was not found in the SSD children due to the variability in their PA performance. When focusing on the SRT task, there was a significant difference on the 4-syllable task item between the SSD and TD children. After exploring the association between the increased syllable length and PA skills no relationship was found. This suggests that the SRT is not sensitive to picking up differences in PA skills in the SSD population alone.

The second aim of this thesis was to analyze speech sound errors to determine if they are predictive of a child’s performance on PA tasks. In particular, previous researchers (e.g. Preston & Edwards, 2010) found that atypical speech sound errors were particularly indicative of poor phonological representations, and would be predictive of poor PA skills. According to the data collected in the current study, nonverbal IQ, receptive vocabulary, and age contributed to the variance in PA scores, in addition atypical errors, which only contributed to the variance in PA skills in the TD children. The influence of receptive vocabulary on PA skills was not surprising since Chiang and Rvachew (2007) found a similar relationship between vocabulary skills and PA skills. As for children with SSD, in this study age played the largest and most prominent role in PA skills. Severity of SSD did not contribute to PA skills, which corresponds to findings from Rvachew et al. (2003) who also found that children with severe SSD, as a group, did not have poorer PA skill compared to children with mild SSD. Overall, examining the participants as a group, atypical errors were found to be indicative of, but not very predictive, of poorer PA skills.

Preston, Hull and Edwards (2013) found that atypical errors were the only preschool speech production variable that had an association with PA skills. However,
Rvachew et al. (2007) did not find a relationship between atypical errors and PA skills in preschool children, but found an association between atypical errors in preschool and PA skills one year later in kindergarten. This suggests that speech errors in preschool may not predict concurrent PA, but rather predict future PA skills. Rvachew et al. (2007) also completed logistic regression analyses and found that the frequency of atypical segment and syllable structure errors in children’s speech reflected the age of the child and the severity of the child’s speech deficit rather than fundamental differences in the cause or nature of the child’s speech deficit. In this respect, conducting a longitudinal study would help better understand the predictive value of atypical speech errors to PA skills, and/or later reading and spelling skills.

4.1 Clinical Implications

Ultimately, the current study adds to an increasing body of literature pointing to the importance of testing phonological processing skills directly in children with a history of SSD, past or current. PA skills cannot be only inferred through the use of other measurements such as the SRT, or the frequency of atypical vs. typical errors. If a child failed any component of a screening (vocabulary, language, production of speech sounds, nonword repetition, etc.), then a complete assessment of speech, language and phonological processing skills should be completed. If the child’s SRT competence score is lower than average, or if the child failed the speech component of the screening, then further testing should be completed, including administering a phonological awareness test.
4.2 Study Limitations and Future Directions

The primary limitation of this study is that it is underpowered. Participants in the current study consisted of 10 children with SSD and 10 typically developing children. There may be some sampling error given the small number of participants in the current study size, and the fact that although both groups of participants did not differ significantly in terms of nonverbal IQ, there was a trend for children with SSD to present with lower nonverbal IQ. With the heterogeneous nature of children with SSD, ideally a larger population will be necessary. Future directions for the current research is to increase the SSD group size to 32 to 40 participants, ideally with half of them presenting with low PA skills and half presenting with high PA skills. Additionally, it would be preferable if children with and without SSD could be matched on nonverbal IQ in addition to age and receptive vocabulary skills since nonverbal IQ contributed to PA skills.

Another limitation of the current study was the stimuli used to assess error types, which did not control for lexical frequency, neighborhood density, or systematically vary the word length and syllable shape in which each of the consonants appeared. Additionally, future research should continue to analyze error types by identifying atypical sound changes as errors that are unusual versus developmentally inappropriate. It is hypothesized that children with low PA skills make errors that are never categorized as typical, developmentally, such as initial consonant deletion, which is not seen in younger, typically developing children. Furthermore, Preston (2008) classified errors based on a consonant’s individual features and whether the child’s production matched an adult model; in this case each syllable is examined individually and the word length is ignored.
More contemporary normative data is needed which would examine the context in which errors are more likely to be produced, such as the length of the word, the complexity of the word shape, and stress, may shed light on the relationship between error types and PA skills. The suggestion is to move away from segmental error coding and adopt a coding system such as multilinear analysis that incorporates segments, syllable, prosody, word position, individual features of the segments, and the relationship between these levels. For instance, speech errors could be analyzed based on syllable structure to examine total errors in strong syllables, which are prominent in speech, compared to weak syllables, which are unstressed. A future direction is to better assess the impact of syllabic and prosodic influences on speech production errors is needed.

Furthermore, the SSD participants in this study had average receptive vocabulary skills, but previous studies have identified high comorbidity between language impairments and SSD (Baker & Cantwell, 1982). To make this study more generalizable, two groups of participants should be recruited: children with SSD and children with SSD and language impairments since these two groups encompass the majority of children on a pediatric SLP’s caseload. Analyzing nonword repetition skills and PA skills in children with both SSD and language impairments can provide additional information on the correlation between these variables for children on the common caseload.

4.3 Conclusion

The results of this study demonstrate the importance of studying PA skills in the preschool population to allow SLPs to plan intervention for children with SSD. There is a need to identify diagnostic measures to analyze PA skills in a quick manner to facilitate intervention at an early age. Ultimately, we do not want SLPs to wait until formal literacy
instruction has begun to identify children who are particularly at risk of presenting with reading and/or spelling disorders. Collecting normative data on the production or multi-syllabic words may aid in this goal. Investigating the interaction between syllables, segments, stress patterns, and word shapes in multi-syllabic words may provide us with further information on PA skills.
REFERENCES
REFERENCES


Sander (1972). When are speech sounds learned? *Journal of Speech and Hearing Disorders, 37*.


APPENDIX
APPENDIX: Raw Error Data

<table>
<thead>
<tr>
<th>Participant Number</th>
<th>Age</th>
<th>Gender</th>
<th>Number of Total Errors Produced (out of 237)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children with SSD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1012</td>
<td>4;4</td>
<td>F</td>
<td>101</td>
</tr>
<tr>
<td>1013</td>
<td>5;8</td>
<td>F</td>
<td>69</td>
</tr>
<tr>
<td>1014</td>
<td>5;5</td>
<td>M</td>
<td>65</td>
</tr>
<tr>
<td>1019</td>
<td>4;4</td>
<td>F</td>
<td>114</td>
</tr>
<tr>
<td>1020</td>
<td>4;2</td>
<td>F</td>
<td>111</td>
</tr>
<tr>
<td>1022</td>
<td>4;0</td>
<td>M</td>
<td>120</td>
</tr>
<tr>
<td>1025</td>
<td>4;9</td>
<td>F</td>
<td>86</td>
</tr>
<tr>
<td>1026</td>
<td>4;7</td>
<td>F</td>
<td>126</td>
</tr>
<tr>
<td>1028</td>
<td>4;2</td>
<td>F</td>
<td>50</td>
</tr>
<tr>
<td>1029</td>
<td>5;4</td>
<td>F</td>
<td>104</td>
</tr>
<tr>
<td>Children with Typical Speech</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1001</td>
<td>6;4</td>
<td>F</td>
<td>12</td>
</tr>
<tr>
<td>1002</td>
<td>4;1</td>
<td>F</td>
<td>36</td>
</tr>
<tr>
<td>1006</td>
<td>4;9</td>
<td>F</td>
<td>23</td>
</tr>
<tr>
<td>1008</td>
<td>4;1</td>
<td>F</td>
<td>26</td>
</tr>
<tr>
<td>1011</td>
<td>5;3</td>
<td>F</td>
<td>44</td>
</tr>
<tr>
<td>1015</td>
<td>4;8</td>
<td>M</td>
<td>35</td>
</tr>
<tr>
<td>1017</td>
<td>5;9</td>
<td>M</td>
<td>43</td>
</tr>
<tr>
<td>1018</td>
<td>4;1</td>
<td>M</td>
<td>61</td>
</tr>
<tr>
<td>1023</td>
<td>6;6</td>
<td>F</td>
<td>73</td>
</tr>
<tr>
<td>1030</td>
<td>5;1</td>
<td>F</td>
<td>12</td>
</tr>
</tbody>
</table>

*Note: Total errors consist of the sum of typical errors, atypical errors, and distortions.*