Phonological Awareness and Executive Function in Children with Speech Sound Impairment

by

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ABSTRACT

A substantial amount of research demonstrates that preschoolers' phonological awareness skills are a robust predictor of children's later decoding ability. Several investigators examined performance of children with speech sound impairment (SSI), defined as inaccurate production of speech sounds in the absence of any etiology or communication impairment, on phonological awareness tasks. Investigators found that children with SSI scored below their typically developing peers (TD) on phonological awareness tasks. In contrast, others found no differences between groups. It seems likely that differences in findings regarding phonological awareness skills among children with SSI is the fact that there is considerable heterogeneity among children with SSI (i.e., speech errors can either be a phonological or articulation). Phonology is one component of a child's language system and a phonological impairment (SSI-PI) is evident when patterns of deviations of speech sounds are exhibited in a language system. Children with an articulation impairment (SSI-AI) produce speech sound errors that are affected by the movements of the articulators, not sound patterns. The purpose of the study was to examine whether or not children with SSI-PI are at greater risk for acquiring phonological awareness skills than children with SSI-AI. Furthermore, the phonological awareness skills of children with SSI-PI and SSI-AI were compared to those of their typical peers. In addition, the role of executive function as well as the influence of phonological working memory on phonological awareness task performance was examined.

Findings indicate that the SSI-PI group performed more poorly on an assessment of phonological awareness skills than the SSI-AI and TD groups. The SSI-PI group performed significantly more poorly on tasks of executive function and phonological working memory than the TD group. The results of this study support the hypothesis that children with SSI-PI may be more vulnerable to difficulties in reading than children with SSI-AI and children with TD.

DEDICATION

To my parents and husband, with love ~

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TABLE OF CONTENTS

Page

LIST OF TABLES viii

CHAPTER

1 A COMPREHENSIVE REVIEW OF THE LITERACY SKILLS OF CHILDREN WITH SPEECH SOUND IMPAIRMENTS 1

Introduction 1

Early Studies of Literacy Skills in Children with SSI 2

Recent Studies of Literacy Skills in Children with SSI 7

Classifying Children with SSI in a Subgroup of Phonological Impairment 11

Other Factors That Might Contribute to Phonological Awareness Skills 14

Inhibition 15

Working Memory 18

Self-Regulation 21

Executive Function and Phonological Awareness Skills 22

Phonological Working Memory and Phonological Awareness Skills 23

Executive Function in Children with SSI 24

Summary 27

References 30

CHAPTER Page

2 PHONOLOGICAL AWARENESS AND EXECUTIVE FUNCTION IN CHILDREN WITH SPEECH SOUND IMPAIRMENT 39

Introduction 39

Phonological Awareness Skills in Young Children with SSI 41

Executive Function 42

Summary and Hypotheses 44

Method 45

Participants 45

Classification of Group 46

Reliability 47

Scoring 48

Assessment of Phonological Awareness and Phonological Working Memory 48

Assessment of Executive Function 49

Assessment of Vocabulary 51

Results 51

Demographic Differences 51

Multivariate Analysis of Covariance 52

Phonological Awareness 52

Executive Function 53

Correlation Analysis 54

CHAPTER Page

Hierarchical Multiple Regression....54

Moderated Mediation....55

Discussion....56

Moderation....61

Limitations and Future Directions for Research....62

REFERENCES.... 64

APPENDIX

A FAMILY AND CHILD DEMOGRAPHIC QUESTIONNAIRE 80

B UNIVARIATE MAIN EFFECTS 83

LIST OF TABLES

Table Page

1. Case History Variables in the Two Speech Impairment Groups: Percent............... 70

2. Child and Family Demographic Variables In The Three Groups: Means, Standard Deviations (SD), and Percent 71

3. Means, Standard Deviations (SD) and Min/Max for the PLS-5 Screening Test and Expressive Vocabulary Measure (N=84) 72

4. Means, Standard Deviations (SD) and Min/Max for the Three Inventories of the BBTOP By Group 73

5. Phonological Processes Produced By Children with SSI-PI 74

6. Consonant Errors Produced By Children with SSI-AI 75

7. Means, Standard Deviations (SD) and Min/Max for All Outcome Measures By Group (N=84) 76

8. Multiple Comparisons and Mean Differences in Outcomes by Group Controlling for Age and Gender 77

9. Bivariate Correlations between All Outcome Measures among the Entire Sample (N=84) 78

10. Unique Contribution of Group, Phonological Working Memory and Executive Function to Phonological Awareness Composite.. 79

CHAPTER 1

A COMPREHENSIVE REVIEW OF THE LITERACY SKILLS OF CHILDREN WITH SPEECH SOUND IMPAIRMENTS

Introduction

Approximately 11-13% of young children are diagnosed with a speech sound impairment (SSI) (Shriberg, Tomblin, & McSweeney, 1999) and children with SSI constitute a large portion of speech-language pathologists' (SLPs') caseloads (Broomfield & Dodd, 2004b; Mullen & Schooling, 2010). There is evidence that about 20%–28% of children with SSI, defined as inaccurate production of speech sounds in the absence of any other developmental or communication impairment, demonstrate difficulties with literacy development (Pennington & Lefly, 2001) with some researchers reporting that more than half of children with SSI experience later academic difficulties (Catts, Adlof, Hogan, & Weismer, 2005; Lewis et al., 2006). More specifically, children with SSI are at risk for difficulties with phonological awareness (Leitao & Fletcher, 2004). Phonological awareness is the ability to attend to and make judgments about the sound structure of language including rhyming, counting syllables, sound segmentation, and the ability to identify individual phonemes in a word (Schuele & Boudreau, 2008). As children develop phonological awareness skills they are increasingly able to attend to speech sounds, discriminate between sounds, and hold sounds in their memory, all skills that are necessary to decode words when reading. Phonological awareness is a robust predictor of children's later decoding ability (Snow, Burns, & Griffin, 1998; Storch & Whitehurst, 2002). Risk associated with SSI has been studied extensively for over 70 years (Anthony et al., 2011; Bird et al., 1995; Hall, 1938; Preston & Edwards, 2010;

Yedinack, 1949). However, the findings from studies of children with SSI have been inconsistent and it is still unclear which children with SSI are at risk.

Early Studies of Literacy Skills in Children with SSI

Early studies of literacy skills in children with SSI include studies prior to the 1950s and were summarized in Winitz (1969). Hall (1938) investigated the perception, reading and speech skills of children in grades 2 through 6. Twenty-one children with SSI were paired with 64 control children based on gender, chronological age, and IQ. No language testing was included. Tests of reading and perception skills were chosen to require no spoken output. All children were required to pass a hearing test. The following assessments were used to assess perception, reading and speech skills:

(1) Travis-Rasmus Speech Sound Discrimination Test (Travis, & Rasmus, 1931). This is a standardized assessment of perception skills. Children heard two sounds and were asked to write 'S' or 'D' to indicate if the sounds were the same or if they were different.

(2) Complex speech sound discrimination test. This was an investigator developed assessment of perception skills. Nonsense words were used to rule-out familiarity with test items. Children heard the pronunciation of the 'correct' nonword. Then they heard two repetitions, one of which was this 'correct' word and another which contained an error in this nonword. Children circled either a '1' or '2' to indicate which repetition was correct. Children heard 10 items presented in this way. Next children heard 30 items in which three trial repetitions were given after the original 'correct' presentation. For these 30 items children had to circle either a '1', '2', or '3' to indicate which repetition was correct. The 'incorrect'

words varied from the ‘correct’ words on (a) change vowel, (b) change consonant, (c) omit sound, (d) add sound and (e) transpose sounds. All error types were used an equal number of times, and occurred with equal frequency at each position in the series. The artificial words were from one to three syllables in length.

(3) Speech sound memory test. This was an investigator developed assessment of perception skills. Children were asked to discriminate between sounds in a series (i. e., /b/, /s/, /g/, /t/) then hear a repetition of that series with 1 sound changed (i. e., /b/, /s/, /g/, /m/). Children were then asked to identify which sound was different than the original presentation. Lists were used that contained 2 consonants, 3 consonants, 3 vowels, 4 consonants and 4 vowels. This task could also measure working memory skills.

(4) Detroit Articulation test was used to assess articulation skills.

(5) Reading achievement tests given in the schools were obtained. These included (a) for grade 2, the Gates Primary Reading Tests, (b) for grades 3 – 5, the Gates Silent Reading Test and (c) for grade 6, the Iowa Silent Reading Test Form B.

Results indicated that none of the mean differences of the reading and perception assessments were significant. The experimental group had larger standard deviations on all the perception tasks but not on the reading assessments. This study found that children with SSI who have similar perception skills as do children without SSI also have similar reading skills. However, this study does not indicate if children who had significantly different perception or working memory skills would perform differently on reading measures. Other important considerations were (a) the children in this study were older (the mean age of children in the experimental group was 9;5) and (b) their articulation skills appeared to not be significantly impaired. For example, only one phoneme was mispronounced by over 50% of the children in the experimental group (i.e., /s/). Four phonemes were mispronounced by between 30% - 49% of the children in the experimental group (i.e., /z, ʤ, ʃ, ʧ/). It is possible that children who have one or only a few error sounds might not have difficulty with perception or learning the sound structure of their ambient language to be able to read because these children have learned to pronounce most of the sounds in their language.

Yedinack (1949) investigated the reading and speech skills of children in 2nd grade. Children were excluded if their IQ was less than 76 or if they were bilingual, therefore some children with a below average IQ score were included in the study. Preliminary tests were administered to determine eligibility (i.e., if a child had an articulation impairment and/or reading disability). These tests included the Gray's oral reading paragraphs test and Stinchfield's Handy-pack speech test (1936). Children were considered to have a SSI if they produced at least one error sound that was a frequent phoneme however, Yedinack did not define which phonemes were frequent. Next, to determine whether a child exhibited a reading disability or not, a cutoff grade level score of 2.1 was used to indicate appropriate reading skills. If a child had a grade level score of 2.1 and did not have a SSI, they were in the control group (74 participants). If a child had a grade level score of 2.1 and did exhibit a SSI, they were in the SSI -only control group (44 participants). Children whose grade level scores were less than 1.9 were included in the reading disability group (40 participants) or reading disability and SSI group if they demonstrated articulation errors as well (27 participants).

Yedinack used various reading assessments to analyze differences between groups. The Durrell-Sullivan Reading Capacity Test, Primary, Form A, Test 1, Word Meaning was used to measure receptive vocabulary and silent reading ability. A modification of McCarthy's articulation test was used to assess articulation skills. Gray's Standardized Oral Reading Paragraphs Test was used to measure oral reading ability. Rosenweig's Picture-Association Study for Assessing Reactions to Frustration was an assessment of oral language used to analyze length, complexity and completeness of responses.

Children with SSI were significantly different than controls on the measure of oral reading after controlling for IQ. However, Yedinack did not account for a child's speech errors on the oral reading task. Tasks that require spoken responses may confound results when assessing reading skills in children with SSI (Sutherland & Gillon, 2005). The range of reading scores did overlap between these two groups. After controlling for IQ there were no significant differences between the reading disability group and the reading- SSI disability groups on the oral reading measure. Analyzing the table of raw scores and standard deviations revealed that there was no overlap between performance of the reading disability group and the reading- SSI disability groups and either of control or SSI groups indicating that children in either reading disability groups performed differently from children in the two non-reading disability groups. It is important to note that the standard deviations of control and SSI groups were 2 – 3 times larger than that of reading and reading- SSI groups indicating more variability within the groups.

On the measure of silent reading, children with SSI were significantly different than controls after controlling for IQ. Differences between the control group and the reading-disability group and reading- SSI group were highly significant with the control subjects having higher grade level reading scores. Differences between the SSI group and the reading-disability group and reading- SSI group were highly significant with the SSI subjects having higher grade level reading scores. There were no significant differences between the reading-disability and reading- SSI groups possibly because the range of raw scores overlapped between the control, SSI, reading-disability and reading- SSI groups. The standard deviations of the control and SSI groups were about 3 times larger than that of reading-disability and reading- SSI groups.

There were no significant differences between the groups on the vocabulary measure. The groups did not differ in mean length, complexity or completeness of response analyses. Additionally, none of the correlations between articulation scores and the measured outcomes was significant. This was possibly due to the fact that children with an SSI made more speech errors than those children in the reading- SSI.

Everhart (1953) analyzed the speech and reading skills of children in grades 1-6th. Speech skills of children who could read were assessed through a list of sentences that included ‘several’ (p. 333) examples of all the possible consonant sounds in initial, medial and final position. Children who could not read were shown pictures to name. Connected speech skills were assessed during conversations. Deviations ordinarily found in articulation patterns of normal and dialect were excluded. The language skills of the participants were not mentioned. It was reported that only errors of substitution, omission, and distortions were included. One hundred ten children with SSI were included in this study and 110 children with typical development (TD) were randomly chosen as controls. Reading age scores were attained through the Gates Reading Test

(Primary, Advanced, and Basic). No significant differences were found between articulation skills and reading. However, Everhart argued that the chi-square statistic approached significance and that the control children had higher reading scores. No tables or data were provided to know the rages of the groups.

Weaver, Furbee, and Everhart (1960) analyzed the reading skills of 475 children with SSI and 163 children with TD in 1st grade. Children were administered the Gates Reading Readiness Test and an articulation test that included words and connected speech. Children who produced at least one error sound were included in the SSI group. Number of speech errors ranged from one to 78. Weaver et al., (1960) reported that the difference between scores on the Gates Reading Readiness test between the two groups was about 15 percentiles. The correlation between the number of articulation errors and the reading readiness percentiles accounted for four percent of the variance among subjects. No tables or data were presented in the article to compare the reading ranges of the children with SSI and TD.

Recent Studies of Literacy Skills in Children with SSI

Recently, researchers focused on how children with SSI perform on literacy tasks and have examined various populations of children with SSI. Research has revealed considerable heterogeneity in children with SSI (Lewis & Freebairn, 1992; Shriberg, 1994) and SSI is conceptualized in a variety of ways. Some researchers distinguished speech errors such as a phonological (linguistic) impairment vs. an articulation (phonetic) impairment (Dodd, Russell, & Oerlemans, 1993; Rvachew, Ohberg, Grawburg, & Heyding, 2003). Children with a phonological impairment (SSI-PI) demonstrate sound pattern usage that simplifies the production of words that affect classes of sounds within a language, not just individual phonemes (Ingram, 1989). For example, all final consonants might be deleted or /s/ clusters may be reduced. When sound changes affect entire classes of sounds, as opposed to an individual phoneme, numerous sounds may be omitted or substituted, thereby affecting a child's speech intelligibility, and in turn the ability of a listener to understand what a child means to say. Children with SSI-PI demonstrate difficulty organizing speech sounds into patterns of sound contrasts (Ingram, 1989). Sounds need to contrast with each other, or be distinct from one another, in order to understand that sound contrasts also contrast meaning. For example, a child producing the phonological process of final consonant deletion will produce the word 'beak'-/bik/ as 'bee'/bi/, resulting in producing the same phonological form, /bi/, for two different words ('beak' and 'bee'). This is considered a homophonous word pair. The child needs to learn to reorganize their sound system to understand that adding the final /k/ in 'beak' will contrast it with the word 'bee'. Therefore, children with SSI-PI tend to be very difficult to understand and are frequently unintelligible to their listeners. It is important to note that SSI-PI does not affect articulatory movement. Rather, phonology is one component of a child's language system (Flipsen, Bankson, & Bernthal, 2009) and a SSI-PI is evident when patterns of deviations of speech sounds are exhibited in a language system (Hodson, 1998). More specifically, phonology is the system that generates and uses phoneme rules and patterns within the context of spoken language. Phonological errors result from impairments in the phonological representation of speech sounds (Chomsky & Halle, 1968; Stamp, 1969).

In contrast to children with SSI-PI, children with articulation impairment (SSI-AI) produce speech sound errors that may include sound omissions, substitutions, and distortions of specific phonemes, not sound patterns (Hegde, 1995). These sound errors can occur when speech production is affected by the movements of the articulators: tongue, lips, jaw, and velopharynx (Bernthal & Bankson, 1998). Speech errors tend to be on a limited number of phonemes (often /s/ or /r/) and errors are consistent whether production is spontaneous or imitated (Flipsen, Bankson, & Bernthal, 2009). Articulation errors do not result from impairments in the representations of speech sounds and do not tend to affect a child's intelligibility (Ingram & Ingram, 2001).

As investigators examined how children with SSI perform on phonological awareness tasks, they have included both children with SSI-PI and those with SSI-AI. Some studies have not distinguished between these two groups of children with SSI when examining early literacy skills (e.g., phonological awareness), treating children with SSI as a single group and may therefore include children with primary SSI-PI and children with primary SSI-AI. In other studies children with SSI falling within the SSI-PI subgroup have served as participants in the research.

Raitano, Pennington, Tunick, Boada, and Shriberg (2004) found that children with a history of SSI are at risk for difficulties with phonological awareness. Raitano et al., used a computerized system, Speech Disorders Classification System (SDCS), to classify children ages 5-6 with SSI as having either (a) normalized speech defined as having a history of SSI, but at the time of the study their speech no longer fell within the clinical disordered range, or (b) persistent SSI defined as having a history of SSI and continuing to demonstrate speech errors at the time of the study according to the SDCS. Phonological awareness was assessed by a rhyme judgment task and the elision and blending subtests of the Comprehensive Test of Phonological Processing (CTOPP;

Wagner, Torgesen, & Rashotte, 1999). Scores from the three phonological awareness tasks were combined to produce one phonological awareness composite score. Children with normalized speech were found to have deficits on phonological awareness tasks relative to peers with TD. There was no significant main effect for children with SSI on letter knowledge. The results of this study suggest that a history of SSI is a risk factor for deficits on phonological awareness tasks (Raitano et al., 2004).

Carroll and Snowling (2004) had similar findings in studying the phonological awareness skills of children with SSI. Seventeen children with SSI were paired with 17 children who had a parent or sibling with diagnosed dyslexia (i.e., family risk of dyslexia group) and 17 children with TD based on chronological age and educational experience. Phonological awareness was assessed by means of investigator developed tests of syllable, rime and initial phoneme matching. Children ages 4-6 with TD outperformed the SSI group on phonological awareness tasks of rime and initial phoneme matching. The SSI group did not differ from the family risk of dyslexia group on phonological awareness tasks. However, Carroll and Snowling (2004) reported that there was considerable variability in performance on phonological awareness tasks in all groups and Raitano et al. (2004) reported their results indicated that a history of SSI did not relate to deficits on all pre-literacy tasks. Classifying children with SSI in just one category did not allow these researchers to analyze differences within the two subgroups of SSI.

Anthony et al., (2011) analyzed the phonological awareness skills of 68 children with SSI in preschool compared to a group of language-matched peers and peers with TD. The elision and blending subtests of the Preschool Comprehensive Test of

Phonological and Print Processing (PCTOPPP; Lonigan, Wagner, Torgesen, & Rashotte, 2002) were used to assess phonological awareness. The first half of the elision and blending tests consisted of multiple-choice items (i.e., receptive items) and the second half of the items required spoken responses (i.e., expressive items). Children with SSI performed more poorly than the language-matched peers and peers with TD on receptive and expressive tasks of phonological awareness skills. Results indicated that children in preschool with SSI are at risk for difficulties with phonological awareness.

Classifying Children with SSI in a Subgroup of Phonological Impairment

Other researchers studied the phonological awareness skills of children with SSI-PI, as opposed to a more general category that classified all speech impairment in one category (Bird et al., 1995; Larrivee & Catts, 1999; Rvachew et al., 2003; Webster & Plante, 1992). Bird et al. (1995) studied children with SSI-PI on three occasions at mean ages of 7, 8, and 9. The researchers assessed phonology by having the children name a set of pictures common to most 3-year-olds and calculating the Percent Consonants Correct (PCC; Shriberg & Kwiatkowski, 1982a). Results indicated that the children's phonological impairments ranged from mild to severe. Phonological awareness was assessed by investigator developed measures of rime matching, onset matching, and onset and segmentation matching. Children with SSI-PI scored below their peers with TD on phonological awareness tasks. Children who had severe SSI-PI upon entry into school were at higher risk when compared to their peer group for reading and spelling problems (Bird et al., 1995).

Webster and Plante (1992) had similar findings when they compared the phonological awareness ability of children with TD to children with SSI-PI, defined as exhibiting two or more developmental process ratings of four on the Khan-Lewis Phonological Analysis (KLPA; Khan & Lewis, 1986). These researchers analyzed the impact of speech intelligibility on phonological awareness skills in children between the ages of 6;5 and 8;6. Phonological awareness was assessed by measures of pseudoword segmentation, sentence-word segmentation, and word phoneme segmentation. TD peers scored significantly higher on these phonological awareness measures compared to children with SSI-PI. Results indicated that speech intelligibility was a highly significant predictor of performance on all three measure of phonological awareness.

More recently, Preston and Edwards (2010) used a three-category system to capture the different features of sound errors (i.e., typical sound changes, atypical sound changes, and distortions) of children with SSI in preschool. Measures of phonological awareness included rhyme matching, onset matching, onset segmentation and matching, and blending. Children with TD were not included in this study, so it is not known if the phonological awareness skills of participants were significantly different than their peers. However, a significant relationship was found between phonological awareness and atypical sound changes, indicating that children who produced more atypical sound changes performed more poorly on the phonological awareness tasks. Atypical sound changes significantly predicted approximately 6% of the variance in phonological awareness over and above the variance accounted for by vocabulary and age.

In contrast to the above findings, other studies analyzed the phonological awareness skills of children with SSI compared to their peers with TD and have indicated no differences between groups. For example, Nathan, Stackhouse, Goulandris, and Snowling (2004) conducted a longitudinal study of children ages 4 to 7 with SSI defined as scoring one or more standard deviations (SD) below the mean on an articulation test. Measures of phonological awareness included rhyme production, rhyme detection, rhyme oddity, phoneme completion, and phoneme deletion. Results indicated that children with SSI did not perform significantly different from children with TD on phonological awareness tasks at ages 6 and 7. When the scores on the articulation test of the group with SSI was compared to the group of controls at ages 6 and 7, their means did not differ significantly. These researchers acknowledged that the children with SSI did not have speech errors as severe as the group with speech and language impairment. Therefore, if the children with SSI were not very severe at the time of the study, possibly this could account for why they performed better on the phonological awareness tasks.

Bishop and Adams (1990) found all but one child with SSI-PI at age 8-years-old performed equally as well on a measure of word reading compared to children with TD. Lewis and Freebairn (1992) had similar results to Bishop and Adams (1990) in their follow-up study of children with SSI-PI. A cross-sectional design was used with participants at preschool age, grade school age, adolescence, and adulthood. Results indicated that participants with histories of SSI-PI and additional language impairment scored more than one standard deviation below the mean on an elision task. Participants with SSI-PI alone scored within normal limits on the elision task and did not demonstrate difficulty with reading.

Rvachew, Chiang, and Evans (2007) investigated the relationship between phonological awareness and speech sound errors in children with SSI who demonstrated poor phonological awareness skills and children with SSI who demonstrated good phonological awareness skills. Results indicated that the child's pattern of errors was not a reliable indicator of which child would pass or fail the Phonological Awareness Test (PAT; Bird et al., 1995) as measured by rime matching, onset matching, and onset segmentation and matching in preschool or kindergarten. Indeed, simply analyzing individual errors or severity may not be the best indicator of who is at risk for difficulties with phonological awareness (Rvachew et al., 2007; Yedinack, 1949).

Other Factors That Might Contribute to Phonological Awareness Skills

Although types of SSI may explain inconsistent findings with regard to SSI and phonological awareness skills, there may also be components of executive function (i.e., attention, working memory and inhibition) that may contribute to the phonological awareness skills for children with SSI. Recent studies that applied factor analysis to children with TD in preschool found that measures of attention, working memory and inhibition form a unitary construct (Hughes, Ensor, Wilson, & Graham, 2010; Welsh, Nix, Blair, Bierman, & Nelson, 2010; Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011) suggesting that these three skills share considerable variance and have not been well differentiated at this young age. Collectively these three skills (i.e., attention, working memory and inhibition) have been referred to as executive function.

Wiebe et al., (2011) used confirmatory factor analysis to examine whether executive function in 3-year-old children with TD was characterized by a single factor. Three tasks were included to assess working memory (i.e., Nine Boxes, Nebraska Barnyard, and Delayed Alternation). Four tasks were included to assess inhibition (i.e., Big–Little Stroop, Go/No-Go, Shape School, and Snack Delay). The unitary model, where all seven tasks loaded on a single common factor fit the data best compared to a model that separated inhibition from working memory.

Self-regulation is represented in this unitary construct as well because it includes the multiple components of executive function (Cameron Ponitz, McClelland, Matthews, & Morrison, 2009). During the preschool years, executive function develops to form the critical foundation that will set the stage for the development of higher cognitive processes well into adulthood (Garon, Bryson, & Smith, 2008). A key finding from studies of executive function development is that these skills show marked improvements across the preschool period (Carlson, Mandell, & Williams, 2004; Hughes et al., 2010).

Inhibition. Inhibition refers to the ability to deliberately inhibit dominant or automatic responses (Stroop, 1935). There have been challenges in understanding inhibition because many of the tasks used to assess inhibition also involve working memory by examining a child’s ability to use a rule to exert control over behavior (Garon et al., 2008). Garon et al. refers to inhibition tasks that involve minimal working memory demands as simple response inhibition tasks and tasks that involve moderate working memory demands as complex response inhibition tasks. One of the most commonly used simple response inhibition tasks used with children in preschool is the delay of gratification task (Mischel, Ebbesen, & Zeiss, 1973; Mischel & Moore, 1973). The two main tasks of delay of gratification paradigms are (a) the waiting and (b) choice tasks (Mischel, 1974).

To assess waiting, children are shown two treats and told that if they wait the full time they will get the two treats but they can ring a bell at any time and get one treat. Carlson (2005) conducted a cross-sectional study of children from 24 months to 4 years old to analyze the length of time children were able to delay gratification for a treat. Whereas 85% of 3-year-olds suppressed the urge for 1 minute, 72% of 4-year-olds were able to suppress eating a treat for 5 minutes indicating that this ability appears to improve throughout the preschool years (Carlson, 2005).

The choice task involves preschoolers choosing between a small reward now and a larger reward later. Cross-sectional studies found age differences in the number of times a child chooses to delay for a larger reward from 3 to 5 years (Lemmon & Moore, 2007; Moore, Barresi, & Thompson, 1998). Children were presented with choices between a smaller immediate reward (i.e., one sticker) and larger delayed rewards varying in amount (i.e., two to five stickers). As the quantity of the delayed reward increased, 3-year-olds showed no increase in choosing the delayed option. Four-year-olds chose the future option significantly more often than did the 3-year-olds across all the trials.

Thompson, Barresi, and Moore (1997) found similar results in their study of delay of gratification. Children in preschool were presented with choices between one sticker now or two stickers a few minutes later at the end of the game. Four and 5-year-olds significantly chose the delayed reward more often than the 3-year-olds. However, there was no difference between the 4 and 5-year olds. These results indicate that inhibition as measured by delay of gratification improves during the preschool years.

Complex response inhibition tasks involve holding an arbitrary rule in mind, responding according to this rule, and inhibiting a dominant response (Garon et al., 2008). Tasks that have assessed this skill in children in preschool include asking children to perform the action suggested by one puppet and inhibit the actions suggested by another puppet (Reed, Pien, & Rothbart, 1984). Studies that have assessed complex response inhibition found significant age differences from 3 to 5 years (Carlson, 2005). Data suggests that the ability to coordinate inhibition and activation develops quickly during the third year of life because 51% of young 3s pass this task compared to 76% of older 3s (Carlson, 2005).

Studies that have used Stroop tasks suggest that as children get older, they can solve tasks involving larger degrees of conflict (Carlson, 2005; Carlson et al., 2004). However, studies have shown that depending on the specific Stroop task used, 3 year old children may or may not be expected to pass the task. For example, the reverse categorization task (Carlson et al., 2004) involves having children sort by putting small blocks in a small bucket and large blocks in a large bucket and then sorting in the opposite way. Carlson (2005) reported that 20% of 2-year-olds could pass this task and by age 3-years-old 85% of the children passed.

A more difficult Stroop-task is the grass-snow task in which children must point to white when they hear “grass” and point to green when they hear “snow.” Carlson (2005) found that only 45% of 3-year-olds passed this task compared to 80% of children age 4;6 passed the task. A similar task is the day-night task in which children must say "night" when shown a white-sun card and say "day" when shown a black-moon card. A longitudinal study found significant developmental improvements on the day–night task between ages 3;6 and 7 years (Diamond, Prevor, Callender, & Druin, 1997).

Working Memory. Short-term memory (STM) is specialized for the temporary storage of material within particular informational domains whereas working memory involves both storage and process of information (Gathercole & Alloway, 2006). There are several models that aim to explain the structure and function of working memory (Baddeley & Hitch, 1974; Cowan, 1988; Engle, Tuholski, Laughlin, & Conway, 1999). Cowan’s model of working memory is an embedded process model in which representations in working memory are a subset of the representations in long-term memory. Working memory is organized into two embedded levels; the first level consists of long-term memory representations that are activated and the second level is the focus of attention which is regarded as having a limited capacity (Cowan, 1988). Engle et al., (1999) proposed that working memory is a unitary, central workspace comprised of a limited-capacity for controlled, sustained attention while inhibiting irrelevant information. The model that will be discussed further is the model originally developed by Baddeley and Hitch (1974), and extended by Baddeley (2000). In particular, Baddeley's model of working memory was chosen to be the model of working memory for this review because (a) research supported this multicomponent model of working memory in preschoolers, (b) the phonological loop (responsible for the phonological working memory) is critical in the development of phonological awareness skills (Oakhill & Kyle, 2000) and (c) the phonological loop has a positive relationship with speech and language skills (Adams & Gathercole, 2000).

The revised model comprised a four part system which consists of the central executive supplemented by two subsidiary slave systems, the phonological loop and visuo-spatial sketch pad and the episodic buffer (Baddeley, Allen, & Hitch, 2010). The central executive is a flexible system responsible for the control and regulation of cognitive processes (Baddeley, 1998). These include a variety of regulatory functions including attentional control (i.e., focus attention, divide attention, switch attention) and providing an attentional link between working memory and long-term memory (Baddeley et al., 2010). The central executive coordinates the functions of the phonological loop and the visuo-spatial sketchpad. The episode buffer is a limited, passive store for bound features. For the purposes of the present study, only the phonological loop will be discussed henceforth.

The phonological loop is devoted to the temporary retention of verbal information and is characterized by two functions (a) passive storage which is limited in capacity and subject to decay and (b) rehearsal which can be used to restore decaying representations (Baddeley, 2000) thus making the phonological loop responsible for phonological working memory. Research supported that phonological working memory, working memory and phonological awareness skills are distinctly different components. Indeed, factor analysis of data from children with TD indicates that simple tasks in which information is held over a delay and more complex tasks requiring the updating and manipulation of information cluster into separate factors (Alloway, Gathercole, Willis, & Adams, 2004), supporting the differentiation between one underlying factor that accounts for short term memory (phonological loop) and another which involves manipulation (working memory).

Alloway et al. (2004) examined the organization of working memory and phonological awareness in 4- and 6-year-old children. Backwards digit recall, counting recall and sentence completion and recall were used to assess working memory. Measures of detection of rhyme and detection of initial consonants were used to assess phonological awareness. The phonological awareness tasks utilized pictures rather than spoken words only, to minimize the short-term memory burdens of the tasks. Digit recall, word recall and nonword repetition tasks were used to assess phonological working memory. Alloway et al. (2004) reported that a model consisting of separate factors corresponding to the central executive, phonological loop and phonological awareness ability provided the best fit to the data in young children. This model was a better fit than a model consisting of one factor representing working memory and phonological loop and a second factor representing phonological awareness. Furthermore, confirmatory factor analysis indicated that the processing components of working memory tasks were supported by a common factor (executive function), while storage aspects depended only upon domain-specific verbal or visuo-spatial resources in children 4 to 11 years old suggesting that all working memory components are in place by 4 years of age (Alloway, Gathercole, & Pickering, 2006). Results from these two studies support a multicomponent model of working memory.

Cross-sectional studies found that the number of items retained differs from 3 to 5 years of age, for both the verbal component as assessed by digit or word span tasks (Bull, Espy, & Senn, 2004; Gathercole, 1998) and visuo-spatial component as assed by spatial span tasks (Ewing-Cobbs, Prasad, Landry, & Kramer, 2004). The updating component of the model was shown to develop later than item retention. Cross-sectional studies suggest spatial working memory develops between 4 and 5 years of age (Luciana & Nelson, 1998). Spatial working memory was assessed by a self-ordered searching task in which children were shown colored squares and had to search for tokens. Children need to remember which squares they have found tokens under so as not to select them again. Children 5 years of age performed better than 4 year old children on the 3 and 4-item searches. These two age groups performed equally well on the 2-item search. Diamond et al., (1997) found similar results in a longitudinal study. Results indicated that 6-7 year old children performed better on a six box task than children 3;6 - 4 years old.

Additionally, complex working memory skills have been found to develop throughout the preschool period (Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Research indicates that children 5 years of age are able to keep track of and update a larger number of items in mind than children 3 years of age, 4.5 and 6.7 items respectively (Hongwanishkul et al., 2005). Backward span tasks in which children have to recall a sequence in reverse order are commonly used to assess the ability to manipulate information in mind. Carlson, Moses, and Breton (2002) found that the number of items that children can remember backward improves between the ages of 3 and 5 years from 1.58 to 2.88 items respectively. Gathercole (1998) found that the manipulation of verbal and visual information showed different developmental paths in school age children which support the theory of separate "slave" systems. However, this has not been tested in preschool age children.

Self-Regulation. Components of executive function, including attentional control, working memory, and inhibitory control, all contribute to successful self-regulation (Happaney, Zelazo, & Stuss, 2004). Self-regulation refers to a complex set of skills involved in controlling, directing, and planning one's cognitions, emotions, and behavior (Schunk & Zimmerman, 1997). Researchers suggested that executive function facilitates school readiness and early learning by supporting behavioral self-regulatory abilities (Blair, 2002; Hughes & Ensor, 2007). As mentioned earlier in inhibition and working memory, these skills develop throughout the preschool years (Carlson, 2005; Hongwanishkul et al., 2005). Moreover, gains in self-regulation over the prekindergarten years were found to predict greater gains in mathematics, literacy, and vocabulary skills after controlling for pre-performance levels (McClelland et al., 2007).

Executive Function and Phonological Awareness Skills

Executive function is associated with multiple aspects of learning, including reading and writing in school age children (Gathercole, Alloway, Willis, & Adams, 2006; Gathercole, Pickering, Knight, & Stegmann, 2004). Recently researchers have started exploring this relationship with children in preschool to determine if executive function enhances children's acquisition of key emergent literacy skills, such as phonological awareness. Welsh et al., (2010) assessed the executive function and phonological awareness skills of children 4-years of age in Head Start classrooms. A composite score, which averaged standardized scores on print knowledge, blending, and elision scales of the Test of Preschool Early Literacy (Lonigan, Wagner, Torgesen, & Rashotte, 2007) was computed to represent emergent literacy skills. Three measures were used to assess executive function (a) backward word span task which utilized working memory, (b) peg tapping task in which children were asked to tap their peg twice when the interviewer tapped once, and visa versa which utilized working memory and inhibitory control, and (c) a dimensional card sorting task in which children learned to sort the cards according to one dimension (i.e., shape or color) and then asked to sort the cards according to the other dimension which utilized working memory, inhibitory control, and set shifting skills. Exploratory factor analysis of the executive function tasks revealed a single factor consistent with other studies of children in preschool (Hughes et al., 2010; Wiebe et al., 2011). Therefore Welsh et al., created one composite measure of executive function by standardizing and averaging scores on the three tasks for each assessment period. A composite of the measures of executive function predicted phonological awareness skills at the end of both preschool and kindergarten after controlling for pre-phonological awareness skills.

Bierman, Nix, Greenberg, Blair, and Domitrovich (2008) studied the association between executive function and phonological awareness skills in children 4-years of age with TD. Three measures were used to assess executive function (a) backward word span task, (b) peg tapping task, and (c) a dimensional card sorting task. Phonological awareness was assessed through use of the Blending and Elision Scales of the TOPEL. Each of the three executive function measures made statistically significant unique contributions to the prediction of a phonological awareness outcome after controlling for gender, race, age, nonverbal cognitive ability, and pre-intervention scores on vocabulary, phonological awareness, and print knowledge.

Phonological Working Memory and Phonological Awareness Skills

Phonological working memory has been associated with multiple aspects of learning, including reading and writing in school age children with TD (Gathercole, Alloway, Willis, & Adams, 2006; Gathercole et al., 2004). Recently researchers have started exploring this relationship with children in preschool to determine if phonological working memory enhances children’s acquisition of key emergent literacy skills, such as phonological awareness skills, which are a strong predictor of later reading achievement (Lonigan, Burgess, & Anthony, 2000).

Phonological working memory was found to be highly correlated with (Mann & Liberman, 1984) and critical in the development of phonological awareness skills (Oakhill & Kyle, 2000). Indeed, some phonological awareness tasks require both the short-term retention of information and phonological analysis of phonemes (Oakhill &

Kyle, 2000). For example, phoneme deletion tasks have been shown to be less demanding of working memory skills than sound categorization tasks. Phoneme deletion requires a child to remember one target word and delete a phoneme from the target word (e.g., *say 'stop' without /s/* - correct answer 'top'). Sound categorization requires a child to identify which word in a list of four is different based on one phonemic difference (e.g., '*bat, cat, sit, hat'*) increasing the demand on working memory. In both of these tasks, a child needs to hold a correct representation of the target/s in memory and process information about that target/s (i.e., delete a phoneme or recognize phonemic differences).

Executive Function in Children with SSI

There have been limited investigations of the executive function and phonological working memory skills of children in preschool with isolated SSI. Because executive function and phonological working memory are highly correlated with phonological awareness tasks, it is possible that children with SSI who are at risk for difficulties with phonological awareness may have difficulties with working memory. A recent study found that children with SSI in 2^{nd} – 5^{th} grade performed more poorly than children with TD on measures of phonological working memory and working memory (Schussler, 2012). To assess phonological working memory, participants listened to lists of CVC nonwords increasing in length (i.e., 4 one-word lists, 4 two-word lists, 4 three-word lists, and 4 four-word lists) and were asked to repeat back the list. Working memory was assessed by use of a Henry task in which participants heard a list of real words varying in length from one to four syllables and as the word was presented, a blank white square appeared on the computer screen to serve as a spatial placeholder for that word. After a list was presented, the examiner repeated a word from the list and the child was instructed to point to the square which corresponded to the target word. Children with SSI performed significantly below children with TD on the 3- and 4- word conditions of the nonword repetition task and on the multi-syllabic condition of the Henry task.

Snowling and Hulme (1989) found that poor nonword repetition was related to SSI, which in turn related to difficulties in reading. Snowling and Hulme (1989) conducted a case study of an 8 year old boy (JM) with SSI whose language skills were reported to be good. He was compared to children with TD at his reading level, which was 7 years. JM was able to read 60% of regular and irregular words but was unable to read any of the nonwords. The authors determined that JM had a sight vocabulary but could not use decoding skills. JM had serious difficulty repeating words and nonwords of three syllables. No comment was made regarding his repetition of words of other syllable length and because he produced speech errors it is expected that he would have difficulty with pronunciation. His verbal short-term memory was assessed through a word repetition task. He had serious difficulty with this task and his performance was judged to be comparable to that of 5-year-old children with TD. The author's hypothesis was that JM's difficulty with output phonology impeded his acquisition of reading and spelling skills.

One study found that subgroups of children with SSI (i.e., consistent atypical speech disorder or inconsistent speech disorder) in preschool performed more poorly than children with TD on measures of executive function (Crosbie, Holm, & Dodd, 2009). Children with an inconsistent speech disorder had an inconsistent speech disorder score of 40% or more on the DEAP (Diagnostic Evaluation of Articulation and Phonology) Phonology Assessment (Dodd, Zhu, Crosbie, Holm, & Ozanne, 2002) and children with consistent atypical speech disorder had a score of less than 40%. The Flexible Item Selection Test (FIST; Jacques & Zelazo, 2005) was used to measure executive function. Results indicated that children with consistent speech disorder performed significantly less well on both selections of the FIST task than the children with TD and children with inconsistent speech disorder. There was no statistically significant difference between the performance of the children with TD and the children with inconsistent speech disorder. While this study did not assess the phonological awareness skills of these children, Crosbie, Holm, and Dodd (2009) suggested that executive function might underlie acquisition of early literacy skills. This possible association needs to be empirically tested as well as further research is needed to understand the relationship between SSI, phonological working memory and executive function.

Furthermore, Adams and Gathercole (1995) examined the speech production skills of children in preschool who had high phonological memory and those with low phonological memory as defined by computing z-scores for two phonological memory tasks (digit span and nonword repetition) then establishing groups on the basis of maximizing the difference in these z-score estimates. Results indicated that children with low phonological memory produced more speech sound errors in spontaneous speech, although this finding was not statistically significant. However, a standardized measure of speech skills was not used and the speech sample used was not phonetically transcribed. Research is necessary to examine the phonological working memory skills of children with SSI in preschool and evaluate any potential relationships between phonological working memory, type of SSI (i.e., SSI-PI vs. SSI-AI) and phonological awareness.

Summary

Studies of children with SSI have been challenging to compare because (a) of the variation in the methods researchers have used to determine SSI, (b) some investigators analyzed subgroups of SSI while others have not, and (c) executive function and phonological working memory skills that might account for differences between groups have not been extensively investigated in children with SSI. Most researchers who classified children in a global category of SSI analyzed children's speech by using a simple articulation test in which each consonant was examined once in each position in which they occur in simple (mostly monosyllabic) words. An articulation test determines whether or not a child has a SSI, but does not indicate specific types of phonological processes (i.e., sound patterns). Indeed, Larrivee and Catts (1999) suggest that articulation tests are not the most appropriate way to evaluate phonological ability and severity may not be evident on a typical test of articulation that does not analyze phonological processes.

Given the current state of research, it is not clear which children with speech production errors are at risk for difficulties with phonological awareness. A child with SSI-PI who struggles to use sound patterns and phonemic contrasts in speech may struggle to learn how sound patterns and contrasts are used in phonological awareness tasks (e.g., *Tell me what word I have if I add /s/ to the beginning of the word 'nail'* – correct response *'snail'*). In this task, the child learns that adding the phoneme (i.e., /s/) to the beginning of the word 'nail' now establishes a contrast which changes the meaning (i.e., 'snail'). Understanding phonological rules may directly apply to phonological awareness tasks. Because phonology is a part of language, children with a SSI-PI might be at greater risk for problems with phonological awareness tasks in contrast to children with SSI-AI. Types of speech errors produced (phonological in contrast to articulation) may directly predict performance on phonological awareness tasks because investigators have suggested that deficits in the phonological system are associated with difficulty acquiring phonological awareness skills (Larrivee & Catts, 1999).

Although types of SSI may explain inconsistent findings with regard to SSI and phonological awareness skills, components of executive function (i.e., attention, working memory and inhibition) may contribute to children's speech and/or phonological awareness skills. Executive function of preschool children with TD predicted performance on phonological awareness tasks (Bierman et al., 2008) and this may also be the case for children with SSI. Additionally, it is possible that executive function may moderate the relationship between SSI and phonological awareness tasks. If executive function is a moderator, it may explain why some children with SSI are at risk for difficulties with phonological awareness and others are not.

Relevant to the phonological awareness skills of children with SSI is the phonological loop which is a subprocess of working memory and is responsible for phonological working memory (Baddeley & Hitch, 1974). Phonological working memory may directly predict performance on phonological awareness tasks because children need to use their phonological store to remember target word/s and phonological working memory has been found to be highly correlated with phonological awareness tasks (Kamhi & Catts, 1986). Research is necessary to examine the executive function and phonological working memory skills of children with SSI in preschool to evaluate any potential relationships between executive function, phonological working memory, type of speech sound errors and phonological awareness skills.

To analyze if there are within group differences in phonological awareness tasks, detailed assessment is necessary in order to differentiate between types of SSI (i.e., SSI-PI vs. SSI-AI) so as to analyze whether or not a child's type of SSI would predict their phonological awareness abilities. A comparison of children with SSI-PI and SSI-AI could help clarify which children are more likely to be at risk for difficulties in reading. Because research showed that not all children with SSI have difficulty reading, if children with one type of SSI tend to have more difficulty with phonological awareness skills, then this will assist speech-language pathologists in determining who may benefit from phonological awareness intervention.

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CHAPTER 2

PHONOLOGICAL AWARENESS AND EXECUTIVE FUNCTION IN CHILDREN WITH SPEECH SOUND IMPAIRMENT

Introduction

A substantial amount of research demonstrates the relationship between early literacy skills developed during the preschool years and subsequent reading success, both for reading decoding (i.e., word attack skills) and reading comprehension (National Early Literacy Panel [NELP], 2009). In particular, preschoolers' phonological awareness skills are a robust predictor of children's later decoding ability (Lonigan, 2003; Snow, Burns, & Griffin, 1998; Storch & Whitehurst, 2002). As early predictors of decoding skills are more clearly understood, increasing attention has focused on preschool children who are at risk for later reading difficulties. It is now well established that children entering school with language impairment (LI) experience lower levels of reading success than their peers with typical development (Peterson, Pennington, Shriberg, & Boada, 2009; Strickland & Shanahan, 2004; Westby, 2005).

Similarly, reading risk has been noted for approximately 20%–28% of children with speech sound impairment (SSI), defined as inaccurate production of speech sounds in the absence of any etiology or communication impairment (Pennington & Lefly, 2001). Some researchers report that more than half of children with a history of, or presenting with SSI, experience difficulties with decoding skills (Catts, Adlof, Hogan, & Weismer, 2005; Lewis et al., 2006). Several investigators examined performance of children with SSI on phonological awareness tasks. Some found that children with SSI scored below their typically developing peers (TD) on phonological awareness tasks (e.g., Anthony et al., 2011; Preston & Edwards, 2010). In contrast, others found no differences between groups (e.g., Bishop & Adams, 1990; Lewis & Freebairn, 1992).

It seems likely that differences in findings regarding phonological awareness skills among children with SSI is due to the fact that there is considerable heterogeneity among children with SSI (Lewis & Freebairn, 1992; Shriberg, 1994). Indeed, SSI is conceptualized in a variety of ways. Some researchers distinguish speech errors such as either a phonological (linguistic) or an articulation (phonetic) impairment (Dodd, Russell, & Oerlemans, 1993; Rvachew, Ohberg, Grawburg, & Heyding, 2003). Children with a phonological impairment (SSI-PI) demonstrate sound pattern usage that simplifies the production of words that affect classes of sounds within a language, not just individual phonemes (Ingram, 1989). For example, all final consonants might be deleted or /s/ clusters may be reduced. It is important to note that SSI-PI does not affect articulatory movement. Rather, phonology is one component of a child's language system (Flipsen, Bankson, & Bernthal, 2009) and a SSI-PI is evident when patterns of deviations of speech sounds are exhibited in a language system (Hodson, 1998). More specifically, phonology is the system that generates and uses phoneme rules and patterns within the context of spoken language. Phonological errors likely result from impairments in the phonological representation of speech sounds (Chomsky & Halle, 1968; Stamp, 1969).

In contrast to children with SSI-PI, children with articulation impairment (SSI-AI) produce speech sound errors that may include omissions, substitutions, and distortions of specific phonemes, not sound patterns (Hegde, 1995). These sound errors occur when speech production is affected by the movements of the articulators: tongue, lips, jaw, and velopharynx (Bernthal & Bankson, 1998). Speech errors tend to affect a limited number of phonemes (often /s/ or /r/) and errors are consistent, whether production is spontaneous or imitated (Flipsen et al., 2009). Articulation errors do not result from impairments in the representations of speech sounds. In applying this distinction between SSI-PI vs. SSI-AI to research on phonological awareness skills of children with SSI, it is apparent that some investigators (e.g., Anthony et al., 2011; Raitano, Pennington, Tunick, Boada & Shriberg, 2004) have not or did not differentiate these groups. In other studies (e.g., Bird, Bishop, & Freeman, 1995; Webster & Plante, 1992), children with SSI-PI have been identified as participants in the research.

Phonological Awareness Skills in Young Children with SSI

Raitano et al., (2004) analyzed the conversational speech samples of 101 children ages 5-6 with a history of SSI. Children with normalized speech with a history of SSI demonstrated significant deficits on phonological awareness tasks when compared to peers with TD. The results of this study indicated that a history of SSI was a risk factor for deficits on phonological awareness tasks. Similar findings were noted by Anthony et al., (2011) when comparing 68 preschoolers with SSI to a group of language-matched peers and peers with TD. The elision and blending subtests of the Preschool Comprehensive Test of Phonological and Print Processing (PCTOPPP; Lonigan, Wagner, Torgesen, & Rashotte, 2002) were used to assess phonological awareness. Children with SSI performed more poorly than the language-matched peers and peers with TD on receptive and expressive tasks of phonological awareness skills. In both the Raitano et al. and Anthony et al. investigations, children with SSI demonstrated considerable variability in performance on phonological awareness tasks, which may be attributable to the fact that the children's data was reported as a single group of children with SSI and this group may have included children with SSI-PI and SSI-AI.

Studies of phonological awareness skills in children with SSI-PI have also found different results. Some found that children with SSI-PI scored below their peers on phonological awareness tasks (Bird et al., 1995; Webster & Plante, 1992). In contrast, Bishop and Adams (1990) found all but one child of the 12 children with SSI-PI in their study at age 8 performed equally as well on a reading and decoding task compared to children with TD; however, isolated SSI-PI was uncommon in this sample and rarely persisted beyond 5 years of age. Nathan, Stackhouse, Goulandris, and Snowling (2004) conducted a longitudinal study of children ages 4 to 7 with SSI, measuring rhyme production, rhyme detection, rhyme oddity, phoneme completion and phoneme deletion. Results indicated that children with SSI did not perform significantly differently from children with TD on phonological awareness tasks at ages 6 and 7. Lewis and Freebairn (1992) had similar results in their follow-up study of children at preschool age, grade school age, adolescence, and adulthood with SSI-PI using a cross-sectional design. They found that children with SSI-PI scored within normal limits on a measure of syllable segmentation.

Executive Function

Collectively, attention, working memory and inhibition have been referred to as executive function. During the preschool years children's emerging executive functions form the critical foundation that will set the stage for the development of higher cognitive processes well into adulthood (Garon, Bryson, & Smith, 2008). Although types of SSI may contribute to inconsistent findings with regard to SSI and phonological awareness skills, research suggests that executive function may contribute to the phonological awareness skills in children with SSI. Executive function, as measured by backward word span, peg tapping and dimensional change card sorting, was found to predict performance on phonological awareness tasks of preschool children with TD (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008) and this may also be the case for children with SSI. Further, executive function may moderate the relationship between SSI and performance on phonological awareness tasks. If executive function is a moderator, it may explain why some children with SSI are at risk for difficulties with phonological awareness and others are not.

Relevant to the phonological awareness skills of children with SSI is the phonological loop which is a subprocess of working memory that forms the basis for phonological working memory (Baddeley & Hitch, 1974). The phonological loop is devoted to the temporary retention of verbal information and is characterized by two functions including (a) passive storage which is limited in capacity and subject to decay and (b) rehearsal which is used to restore decaying representations (Baddeley, 2000). Phonological working memory is highly correlated with and critical in the development of phonological awareness skills (Kamhi & Catts, 1986; Mann & Liberman, 1984; Oakhill & Kyle, 2000). Phonological working memory may predict performance on phonological awareness tasks because children need to use their phonological store to remember target words. Because children with SSI in 2^{nd} – 5^{th} grade performed more poorly than children with TD on measures of phonological working memory and working memory (Schussler, 2012), this may also be the case for children with SSI in preschool. Research is necessary to examine the executive function and phonological working memory skills of children with SSI in preschool to evaluate any potential relationships between executive function, phonological working memory, type of speech sound errors and phonological awareness skills.

Summary and Hypotheses

Given the current state of research, it is not clear which children with speech production errors are at risk for difficulties with phonological awareness. Because phonology is a part of language, children with SSI-PI might be at greater risk for problems with phonological awareness tasks in contrast to children with SSI-AI. Indeed, it is suggested that deficits in the phonological system are associated with difficulty acquiring phonological awareness skills (Larrivee & Catts, 1999). The purpose of this study is to examine variables that may differentiate risk among children with SSI.

The present investigation extends current literature by examining the phonological awareness skills, executive function and phonological working memory of children with (those with SSI-PI and those with SSI-AI) and without SSI. Specific hypotheses are:

1. Hypothesis 1 (HI): Children with SSI-PI will perform poorer on phonological awareness measures than the children with SSI-AI and children with TD. There will be no differences between children with SSI-AI and children with TD.
2. Hypothesis 2 (H2): Children with SSI-PI will perform poorer on executive function tasks than the children with SSI-AI and children with TD. There will be no differences between children with SSI-AI and children with TD.

3. Hypothesis 3 (H3): It is hypothesized that performance on executive function tasks will predict and/or moderate a relationship between type of SSI and performance on phonological awareness tasks.

Method

Participants

Eighty-four children (44 boys and 40 girls) ranging in age from 4;0 to 5;7 (*M* = 4;11) were recruited for participation from two University preschool programs and 11 schools within a local school district. Participants were recruited by their teachers who were asked to identify children who (a) did not have any known developmental disorders (e.g., autism), genetic syndromes (e.g., Down syndrome), or neurological disorders (e.g., cerebral palsy) and (b) demonstrated normal speech or speech errors. Parents indicated their willingness to allow their child's participation in the study by signing a consent form and completing a questionnaire. The child history questionnaire can be found in Appendix A and descriptive statistics for participants are reported in Table 1. Teachers reported that all children passed hearing screenings within their schools and were native speakers of Standard American English (this was also informally confirmed in the screening). Seven children were from a low-household income (< 35,600), 34 were from a mid-household income (< 35,600-99,999), 13 were from a high-household income (> 99,999), and 30 families preferred not to answer. Demographics are reported in Table 2.

All children were required to demonstrate language skills within normal limits as determined by passing the Preschool Language Scales – Fifth Edition Screening Test (PLS-5 Screening Test; Zimmerman, Steiner, & Pond, 2012). The screening was conducted by a certified speech-language pathologist. Only children who passed the screening test were included in the study. Three of the 87 recruited children were excluded from the study because they did not pass the screening. Table 3 summarizes the performance of these 84 participants on the screening tool.

Forty-one of the 84 participants demonstrated some speech errors, with 22 determined to have a primary SSI-PI and 19 determined to have a primary SSI-AI. Procedures for classification are described below. The remaining 43 children were included in the group with TD because they (a) were not receiving speech therapy, (b) had no history of speech and/or language disorder and (c) did not produce any speech errors during the screening. Seventy-one percent of children with SSI were receiving speech therapy and 44% had a history of speech and/or language impairment in their family. Children with SSI had been receiving therapy ranging from 7 months to 43 months (*M* = 19 months).

Classification of Group

Children identified by the classroom teachers as having possible speech errors and who demonstrated speech errors during the language screening were each administered the Bankson-Bernthal Test of Phonology (BBTOP; Bankson & Bernthal, 1990). Table 4 summarizes the performance of the participants on the BBTOP. The BBTOP assessed a total of 80 words chosen to elicit certain speech sounds in initial and final position in words. These 80 words were analyzed in three different inventories, each based on one of the following sets of raw scores: (a) Word Inventory – number of words produced without any consonant misarticulation, (b) Consonant Inventory – number of sounds in error, and (c) Phonological Process Inventory – number of errors reflecting one or more of 10 phonological processes listed in Table 5. Children's responses on the BBTOP were transcribed using the phonetic symbols of the International Phonetic Alphabet. Samples were recorded directly onto a digital voice recorder with RCA Digital Voice Manager Software ™. Recordings were saved in an uncompressed PCM wave (.wav) format, sampled at 44.1 kHz, with a 16-bit resolution.

Inaccurate production of speech sounds was confirmed for children who scored 1 SD or greater below the mean on at least one of the inventory scores on the BBTOP. Children who primarily produced sound errors that affected entire classes of sounds as demonstrated by a score of 1 SD or greater below the mean on the phonological process inventory of the BBTOP were classified as having a phonologically-based speech impairment (SSI-PI). Table 5 summarizes the phonological processes produced by the children in the SSI-PI group. Children in this group produced multiple phonological processes during the assessment and where therefore determined to have a primarily SSI-PI. Children who scored within normal limits on the phonological process inventory of the BBTOP were classified as having an articulatory-based speech impairment (SSI-AI). Table 6 summarizes the consonant errors produced by the children in the SSI-AI group. Two children produced one phonological process in over 40% of all occurrences. These two children were determined to have a primarily SSI-AI because they produced multiple consonant errors that were not affecting entire classes of sounds across several phonological processes and their score on the phonological process inventory was in the average range.

Reliability.

Twenty percent of each child’s phonetic transcriptions of the BBTOP were reviewed by two independent observers who were graduate students in the Speech and

Hearing Science department. The observers were asked to phonetically transcribe the words. Calculation of sound by sound agreement with the primary transcriber was 95% on word transcriptions.

Scoring

Some tasks that required spoken responses may confound results when assessing phonological awareness skills in children with inaccurate speech production (Sutherland & Gillon, 2005). In a recent investigation, scores on tasks that required spoken responses were adjusted based on the pattern of speech errors (Schussler, 2012). Those scoring guidelines were utilized in this study. For tasks that required spoken responses (e.g. Nonword Repetition task), all words were scored by examining each child's speech sounds (for SSI-PI or SSI-AI). For example, if a child responded to "*cat"* by answering "tat" instead of "cat" the researcher examined his/her BBTOP results to determine if substituting /t/ for /k/ was a consistent error pattern (i.e., used in over 50% of all occurrences). If it was a consistent error pattern, the item was marked correct to reflect this child's current production of /k/.

Assessment of Phonological Awareness and Phonological Working Memory

The Comprehensive Test of Phonological Processing - Second Edition (CTOPP-2; Wagner, Torgesen, Rashotte & Pearson, 2013) was used to assess phonological awareness and phonological working memory skills. According to the manual, reliability coefficients for the internal consistency for the CTOPP-2 subtests exceeded .80 for all except Nonword Repetition with an alpha of .77. The average internal consistency coefficients for the composites were all .85 or higher. The averaged coefficients for the

CTOPP-2 subtests relationship to reading were reported to range from .49 to .84. Test was administered according to the test manual.

Three subtests (i.e., elision, blending words and sound matching) assessed phonological awareness skills. In each subtest items were presented in increasing order of difficulty. In the elision subtest, children were asked to omit sounds from stimulus items of varying syllabic length to identify a new word. In Blending Words, children were asked to blend sounds to form words presented via CD (e.g., What word do these sounds make /m-a-d/?). In Sound Matching, children were asked to indicate which of three words started or ended with the same phoneme as the target word (e.g., "Which word starts with the same sound as pan? Pig, hat, or cone?"). Each of the words was pictured in a stimulus book. Standard scores for each sub-test and two composite scores were obtained. The Phonological Awareness Composite (PACom) included Elision, Sound Matching and Blending Words.

Two subtests (i.e., Memory for Digits and Nonword Repetition) of the CTOPP-2 assessed phonological working memory. In Memory for Digits, children were asked to repeat increasingly longer lists of numbers in the exact order as presented on a CD. In Nonword Repetition, children listened to one nonword at a time via CD and then repeated it aloud. The Phonological Memory Composite (PMCom) included Memory for Digits and Nonword Repetition. Table 7 summarizes the performance of the participants on the CTOPP-2.

Assessment of Executive Function

Recent studies that have applied factor analysis to data of children with TD in preschool found that measures of attention, working memory and inhibition form a unitary construct (Hughes, Ensor, Wilson, & Graham, 2010; Welsh, Nix, Blair, Bierman, & Nelson, 2010) suggesting that these three skills share considerable variance and have not been well differentiated at this young age. The Head-Toes-Knees-Shoulders task (HTKS; Cameron Ponitz, McClelland, Matthews, & Morrison, 2009) was chosen for this study because it is an assessment that integrates the three components of executive function (i.e., attention, working memory and inhibition) for children ages 4-6. Cameron Ponitz et al., (2009) reported that scores on this task demonstrate good inter-rater reliability (alpha = .93 overall) and have been significantly correlated with the eight behavioral items of the Child Behavior Rating Scale (Bronson, Tivnan, & Seppanen, 1995). Furthermore, the HTKS task measured in prekindergarten predicted children's gains in mathematics, vocabulary, and literacy (McClelland et al., 2007).

In this task, children were asked to play a game where they are instructed to touch their head when asked 'touch your head' and then to do the opposite and touch their toes when asked 'touch your head.' After two questions to check understanding, children were given four practice items. Instructions were repeated up to three times during the practice items. During the first trial ten test commands were given verbally. Next, children completed an advanced trial where the knees and shoulders items were added. During this trial, children were asked to touch their knees when asked 'touch your shoulders' and then to do the opposite and touch their shoulders when asked 'touch your knees.' After two questions to check understanding, children were given four practice items. During the second trial ten test commands were given verbally. Children received two points for a correct response, one point for a self-corrected response, and zero points for an incorrect response. The total possible for all trails was 40 points. Table 7 provides means and SDs for participants on the HTKS task.

Assessment of Vocabulary

All children completed the Expressive Vocabulary subtest of the Clinical Evaluation of Language Fundamentals-Preschool Second Edition (CELF-P2; Wiig, Secord, & Semel, 2004). The CELF-P2 manual indicates Cronbach's coefficient alpha for the subtest was .82, indicating good internal consistency. The test-retest reliability, correct for the variability of the standardization group, was .90 for the Expressive Vocabulary subtest. Sensitivity of the Core Language Score, which includes the Expressive Vocabulary subtest, was reported as .85; the specificity was .82. Children were shown one picture at a time and asked to name it. Test was administered according to the test manual. Scores for the Expressive Vocabulary subtest are reported in Table 3.

Results

Demographic Differences

Analysis of variance (ANOVA) was used to examine group differences among demographic variables to determine possible covariates. The between subject factor was group, with three levels – SSI-PI, SSI-AI and TD. The groups did not differ on vocabulary, F (2, 81) = 1.68, p = .19, income, F (2, 81) = 2.72, p = .07, maternal education, F (2, 81) = 2.21, p = .12 or paternal education, F (2, 81) = 1.01, p = .37. The groups did differ on age, F (2, 81) = 3.13, p = .05. Because age was significant and this variable can account for variance in phonological awareness skills (e.g., McDowell, Lonigan, & Goldstein, 2007), it was added as a covariate in subsequent analyses. There was also a difference in the male-to-female ratio in the group with SSI-PI (boys = 18, girls = 4) and SSI-AI (boys = 12, girls = 7) when compared to the group with TD (boys = 14, girls = 29). Because gender was not balanced, it was included as an additional covariate in the analyses.

Multivariate Analysis of Covariance

Performance among the three groups (i.e., SSI-PI, SSI-AI, and TD) on the phonological awareness, phonological working memory, and HTKS tasks was analyzed using multivariate analysis of covariance (MANCOVA) with age and gender as covariates. The between subject factor was group, with three levels – SSI-PI, SSI-AI, and TD. An alpha of .05 was used for statistical significance testing. To control for type I error for the number of *F*-tests examined, the Sidak correction for multiple comparisons (Sidak, 1967) was applied to the measures. Because there were unequal sample sizes, Hedges' *g* (1981) was used to report effect size. A one-way MANCOVA revealed a statistically significant multivariate main effect for group, Wilks' $\lambda = .43$, F (8, 148) = 9.62, $p < .001$, partial $\eta^2 = .34$. The multivariate main effect for group by gender (1 = male) interaction was not significant, Wilks' $\lambda = .84$, F (8, 148) = 1.73, $p = .10$, partial $\eta^2 = .09$. Given the significance of the overall test for group, the univariate main effects were examined. Univariate main effects are presented in Appendix B.

Phonological Awareness.

Analyses revealed a statistically significant univariate main effect for group on the PACom of the CTOPP-2, F (2, 83) = 26.68, $p < .001$, partial $\eta^2 = .41$. Comparisons of main effects analyses using the Sidak test for significance are presented in Table 8. The SSI-PI group scored significantly lower on the PACom than the TD and SSI-AI groups. The difference between the TD and SSI-PI groups was 2.189 standard deviation units, g =

2.189. This was a large effect. The difference between the SSI-AI and SSI-PI groups was 2.427 standard deviation units, $g = 2.427$, which was a large effect. No significant group differences were found between the SSI-AI and TD groups. The difference between the TD and SSI-AI groups was -0.312 standard deviation units, $g = -0.312$. This was a small effect.

Executive Function.

Memory for Digits and Nonword Repetition were separated in the analyses. Analyses revealed a statistically significant difference between the groups on the Memory for Digits task of the CTOPP-2, F (2, 83) = 3.79, $p = .03$, partial $\eta^2 = .09$. Comparisons of main effects analyses using the Sidak test for significance are presented in Table 8. As shown, the SSI-PI group performed significantly more poorly on the Memory for Digits task than the TD and SSI-AI groups. The difference between the TD and SSI-PI groups was 0.845 standard deviation units, $g = 0.845$. This was a large effect. The difference between the SSI-AI and SSI-PI groups was 0.905 standard deviation units, $g = 0.905$, which was a large effect. No significant group differences were found between the SSI-AI and TD groups. The difference between the TD and SSI-AI groups was -0.121 standard deviation units, $g = -0.121$. This was a small effect.

Analyses revealed a statistically significant difference between the groups on the Nonword Repetition task of the CTOPP-2, F (2, 83) = 12.09, $p < .001$, partial $\eta^2 = .24$. Comparisons of main effects analyses using the Sidak test for significance are presented in Table 8. As shown, the SSI-PI and SSI-AI groups performed significantly more poorly on the Nonword Repetition task than the TD group. The difference between the TD and SSI-PI groups was 1.208 standard deviation units, $g = 1.208$. This was a large effect. The difference between the TD and SSI-AI groups was 0.962 standard deviation units, g = 0.962, which was a large effect. No significant group differences were found between the SSI-PI and SSI-AI groups. The difference between the SSI-AI and SSI-PI groups was 0.152 standard deviation units, $g = 0.152$. This was a small effect.

Analysis revealed significant group differences on the HTKS task, F (2, 83) = 3.01, $p = .05$, partial $\eta^2 = .07$. Comparisons of main effects analyses using the Sidak test for significance are presented in Table 8. As shown, the SSI-PI group performed significantly more poorly on the HTKS task than the TD group. The difference between the TD and SSI-PI groups was 0.810 standard deviation units, $g = 0.810$. This was a large effect. No significant group differences were found between the SSI-AI group and SSI-PI and TD groups. The difference between the SSI-AI and SSI-PI groups was 0.573 standard deviation units, $g = 0.573$. This was a moderate effect. The difference between the TD and SSI-AI groups was 0.203 standard deviation units, $g = 0.203$, which was a small effect.

Correlational Analysis

Table 9 demonstrates the results of the Pearson correlations between all of the measures among the entire sample. As shown, significant relationships were found between the phonological awareness, executive function and vocabulary tasks for the entire sample of the study. The PLS-5 Screening Test was significantly correlated with the HTKS task.

Hierarchical Multiple Regression

Several hierarchical regression analyses were conducted to examine the unique contribution of each predictor variable in phonological awareness performance after controlling for age. Change in R^2 statistics were computed by entering predictor variables into the analyses at different steps. Because the order of entry of variables is known to influence the outcome of regression analyses, four models were considered to determine the amount of variance in PACom performance accounted for by (a) group after age, Memory for Digits, Nonword Repetition and HTKS were partialed out (Model 1), (b) Memory for Digits after age, group, Nonword Repetition and HTKS were partialed out (Model 2), (c) Nonword Repetition after age, group, Memory for Digits, and HTKS were partialed out (Model 3), and (d) HTKS after age, group, Nonword Repetition and Memory for Digits were partialed out (Model 4). Results are presented in Table 10.

Group accounted for a significant 6% of the variance in phonological awareness after controlling for age, Memory for Digits, Nonword Repetition and HTKS. Memory for Digits accounted for a significant 8% of the variance in phonological awareness after controlling for age, group, Nonword Repetition and HTKS. Nonword Repetition accounted for a non-significant 0.1% of the variance in phonological awareness after controlling for age, group, Memory for Digits and HTKS. HTKS accounted for a significant 12% of the variance in phonological awareness after controlling for age, group, Nonword Repetition and Memory for Digits. Collectively, all four variables accounted for a significant portion of the variance in phonological awareness after controlling for age R^2 change = .55, F (5, 83) = 30.25, $p < .001$.

Moderated Mediation

The hypothesis that executive function may moderate the relationship between group and phonological awareness skills was analyzed by examining the strength and direction of the relation between these variables. More specifically, moderation is often tested as interaction effects (Aiken & West, 1991). No significant interaction was found between group and HTKS indicating that there was not a moderating effect, F (2, 84) = 0.33, p = .72. No significant interaction was found between group and Memory for Digits indicating that there was not a moderating effect, F (2, 84) = 0.31, p = .74. Furthermore, no significant interaction was found between group and Nonword Repetition indicating that there was not a moderating effect, F (2, 84) = 1.05, p = .36.

Discussion

In this study measures of executive function, phonological working memory and phonological awareness in children with speech errors were examined to determine if there were differences among groups with SSI-PI, SSI-AI and TD. Observed results support the first hypothesis (H1) which was that the SSI-PI group would perform poorer than the TD and SSI-AI groups on the phonological awareness composite score (PACom) and that no differences between the SSI-AI and the TD group would be detected.

It is likely that the SSI-PI group performed poorer on phonological awareness tasks than those with SSI-AI due to the phonological nature of their SSI. Phonology is a component of language and children with SSI-PI demonstrate difficulty using contrasts to discern meaning in language. Children rely on their phonological representations and spoken output skills when completing phonological awareness tasks involving pictures or auditory input. Sound changes that affect phonological rules and result from impairments in the phonological representations of speech sounds are likely to contribute to challenges in a child's development of phonological awareness skills.

In further support of the first hypothesis is the fact that, no differences were found between the SSI-AI group and TD group and as noted above, both of these groups outperformed the SSI-PI group. This finding is consistent with prior research where differences were noted between children with TD and SSI (Anthony et al., 2011). At the same time, because the SSI-AI and TD groups did not perform differently in the present investigation, the results also support previous work where no differences were found between children with SSI and those with TD. It appears that with preschool children, differentiation of the type of SSI as linguistic (SSI-PI) or motoric (SSI-AI) is important when appraising phonological awareness.

The second hypothesis (H2) focused on executive function and it was expected that any group differences would be consistent with those noted for phonological awareness. In support of this hypothesis, the SSI-PI group performed poorer than the SSI-AI and TD groups on the Memory for Digits task while no differences were detected between the SSI-AI and TD groups. However, unexpectedly, children from both of the SSI groups demonstrated significantly lower performance on the Nonword Repetition task when compared to the TD group and performance between the SSI-PI and the SSI-AI groups did not differ significantly.

These mixed results relative to the second hypothesis are surprising because both tasks rely on the same underlying process of the phonological loop (e.g., rehearsal). The phonological loop is devoted to the temporary retention of verbal material and is composed of a short-term phonological store, which is limited in capacity, in addition to a subvocal rehearsal process that can be used to restore decaying representations within the store. For the SSI-PI and SSI-AI groups, the rehearsal process of the phonological loop might be diminished due to their speech production errors, explaining why the TD group performed significantly better on the Nonword Repetition task than the SSI-PI and SSI-

AI groups. These results may also indicate that the quality (i.e., strong or weak) of underlying representations, which are stronger for familiar words, influences the rehearsal process on such tasks. Gathercole, Hitch, Service and Martin (1997) suggested that nonword repetition provides a purer assessment of phonological working memory than digit span because lexical representations are not used to supplement temporary representation during rehearsal. It is highly likely that this sample of preschools had strong lexical representations for the Memory for Digits stimuli which are very familiar to them. Thus, children in preschool will likely have stronger lexical representations for those words, and will have more accurate responses for tasks involving digits. In comparison, the stimuli for the Nonword Repetition task were novel. Perhaps the performance on the Memory for Digits task indicates that the SSI-AI group has more accurate responses to tasks that tap into strong lexical representations. Future work could control for lexical characteristics (familiarity, neighborhood density) to examine how both SSI groups perform on these tasks.

The findings are consistent with previous research that focused on the role of the articulatory rehearsal mechanism as a part of the phonological loop in that articulation rate contributes to the ability to retain information in phonological working memory (Baddeley, 2007). Potentially the speech errors of both groups of children with SSI slow their rate of rehearsal which may reduce their phonological working memory capacity. It is also possible that speech *accuracy* could contribute to retention. One possibility is that weak phonological working memory causes weak phonological representations and weak phonological representations lead to poor speech accuracy. Another possibility is that when phonemes are produced incorrectly, perhaps those phonemes have weak phonological representations and cause difficulty with storage or retrieval in phonological working memory. This relationship is likely reciprocal because if a word is not stored or retried from working memory, the production of the phonemes within that word may be produced incorrectly. Future studies are needed to examine the role of speech rate in children with SSI-AI and SSI-PI on their phonological working memory skills independent of speech accuracy.

Consistent with prior work (Schussler, 2012), it appears that both groups of children with SSI may have reduced phonological working memory capacity in addition to rehearsal. A reduced phonological working memory capacity would be suggested by significantly poorer repetition of the longer items (3- or more-syllable items) versus shorter items (Montgomery, 2003). Possible sensitivity to the effects of word length may explain the group difference on the Nonword Repetition task where most of the children from all 3 groups were administered 3- and 4-syllable words. The Memory for Digits task contains eight 1-syllable words (e.g., one, two, three) and one 2-syllable word (i.e., seven). Short words reduce working memory load, which could potentially explain the discrepancy in performance the group with SSI-PI and SSI-AI on Memory for Digits and Nonword Repetition. Though syllable length was not a factor of interest in the current study, examining syllable length in future studies may shed light on these results.

It is surprising that the Nonword Repetition task did not explain the differences in phonological awareness between the group of children with SSI-PI and SSI-AI because phonological awareness tasks require both the short-term retention of information and phonological analysis of phonemes (Oakhill & Kyle, 2000). This may be for two reasons. First, the phonological working memory load was not very difficult in the sound matching task used in this study. Sound matching tasks have been found to be more demanding of working memory skills than phoneme deletion tasks (Oakhill & Kyle, 2000). However, in this study the sound matching task was supported with pictures, decreasing the phonological working memory load needed to complete the task. It would be interesting to use a sound matching task that required more use of a child's phonological working memory to determine if this could explain group differences. Second, nonword repetition tasks are not actually demonstrating how a child uses their representations of phonology to complete phonological awareness tasks because they do not rely on prior lexical knowledge.

In the present investigation the SSI-PI group performed poorer than the TD group on another a task of executive function (i.e., HTKS), a finding that is in line with previous research (Schussler, 2012) and offers partial support for H2. In additional support of H2, the SSI-AI group did not perform significantly different than the TD group. These results indicate that the SSI-PI group may have deficits in executive function in addition to deficits in the phonological loop whereas the SSI-AI group may have deficits that tend to be isolated in the phonological loop, specifically the function responsible for rehearsal. Deficits in executive function may also explain why the SSI-PI group performed more poorly on phonological awareness tasks. Investigators found that children with SSI performed significantly less well on executive function tasks than the children with TD (Crosbie, Holm, & Dodd, 2009). While the study did not assess the phonological awareness skills of these children, Crosbie, Holm, and Dodd (2009) suggested that executive function might underlie acquisition of early literacy skills.

The finding that the SSI-PI and SSI-AI groups did not differ significantly on the HTKS task does not support H2. An explanation for this finding may be the considerable variation within both groups on this task suggesting that these skills are still emerging. However, the SSI-AI group performed better on the HTKS tasks than the SSI-PI group. Perhaps the SSI-PI group has difficulty with only one of the components of executive function (i.e., attention, inhibition and working memory). Differences may be found between older children with SSI-PI and SSI-AI when each component of executive function can be assessed individually.

Moderation

Results for the third hypothesis (H3) where performance on executive function tasks was expected to predict and/or moderate a relationship between type of SSI and performance on phonological awareness tasks were mixed. In support of this hypothesis, Group, Memory for Digits and HTKS each accounted for unique variance to the prediction of phonological awareness performance after controlling for age. Nonword Repetition did not account for unique variance, a finding that does not support this hypothesis. As previously mentioned, nonword repetition tasks do not rely on phonological representations which might explain why it did not predict performance on the phonological awareness task. Furthermore, executive function (i.e., HTKS) accounted for more of the variance in phonological awareness than group, Memory for Digits or Nonword Repetition, after controlling for age. Obviously, there was remaining variance that was not captured by the executive function measure included in the study. However, the results indicate that phonological awareness, at least as tested by the CTOPP-2, relies more on executive function.

No moderation effects were found to explain the relationship between group and phonological awareness skills, a finding that does not support H3. This finding indicates that the association between group and phonological awareness does not vary depending on group membership. Because executive function accounted for the most variance in phonological awareness, there may be moderation effect that could further explain how these skills interact. Future studies are needed to examine additional interaction effects.

Limitations and Future Directions for Research

Various limitations to the findings of the present investigation should be noted. First, many different phonological awareness skills have been described in the literature (i.e., rhyme detection) and the CTOPP-2 assessed three different phonological awareness skills. The CTOPP-2 was chosen for this investigation because the CTOPP-2 was developed in a manner consistent with theoretical assumptions about the nature of phonological awareness deficits (Wagner et al., 2013). Specifically, the CTOPP-2 manual states the most common forms of reading problems are caused by deficits in one or more aspects of phonological awareness skills assessed by this measure (i.e., phoneme segmentation and the synthesis of sounds into words). Another limitation is the validation data for the HTKS task is still emerging. There was considerable variation across groups on this task suggesting that the executive function results may be a factor of the small sample size of the groups of children with SSI-PI and SSI-AI. Furthermore, the results of the moderation analysis should be considered preliminary. Moderation is a more complicated analysis and larger sample sizes allow for a more powerful detection of an interaction effect. Replication of these results with a similar but larger sample of children would validate the existence of a relationship between SSI-PI and challenges on phonological awareness, phonological working memory and executive function tasks.

The results of the present investigation indicate that children with SSI-PI may be more vulnerable to difficulties in reading than children with SSI-AI. Specifically, results found that the SSI-PI group demonstrates challenges in acquiring phonological awareness skills, a necessary component of subsequent reading fluency. These data provide a preliminary guideline to assist speech-language pathologists (SLPs) in their assessment of children with SSI in identifying children with SSI-PI who are at risk for developing phonological awareness skills. Additionally, a comprehensive assessment of phonological working memory, executive function and speech production (including phonological processes) may be helpful for early screening purposes. Although the current study was not causal or predictive in nature, therapy services could be provided earlier for children at-risk as opposed to the "wait-and-see" model, which results in many children with SSI struggling with articulation and decoding, throughout elementary school (Preston & Edwards, 2007; Roulstone, Miller, Wren, & Peters, 2009).

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Table 1

Case History Variables in the Two Speech Impairment Groups: Frequency and Percent

Question	SSI-AI (n =19) # (%)	SSI-PI (n =22) # (%)
Does your child receive speech therapy?		
Yes	11 (58)	18 (82)
No	2 (11)	1 (5)
Missing/Response not given	6 (31)	3 (13)
When did your child start speech therapy?		
7 months ago	-	1 (5)
9 months ago	3 (16)	5 (22)
10 months ago	1 (5)	-
13 months ago	1 (5)	1 (5)
16 months ago	-	1 (5)
20 months ago	3 (16)	1 (5)
21 months ago	1 (5)	2 (8)
24 months ago	-	2 (8)
26 months ago	1 (5)	-
28 months ago	1 (5)	1 (5)
30 months ago	-	1 (5)
32 months ago	-	1 (5)
39 months ago	-	1 (5)
43 months ago	-	1 (5)
Missing/Response not given	8 (43)	4 (17)
Is there a history of speech and/or language impairment in your family?		
Yes	9 (47)	9 (41)
No	9 (47)	13 (59)
Missing/Response not given	1 (6)	-
Does your child appear to be aware of their speech errors?		
Yes	4 (21)	8 (36)
No	14 (74)	14 (64)
Missing/Response not given	1 (5)	-
Does your child have a history of chronic ear infections?		
Yes	2 (11)	1 (5)
No	16 (84)	21 (95)
Missing/Response not given	1 (5)	-

Note. SSI-AI = articulation impairment; SSI-PI = phonological impairment.

Table 2

Child and Family Demographic Variables in the Three Groups: Means, Standard Deviations (SD), and Frequency

	TD (n = 43)		SSI-AI (n = 19)		SSI-PI (n = 22)	
Variable	*M* (*SD*)	#(%)	*M* (*SD*)	#(%)	*M* (*SD*)	#(%)
Child Age in Months	58.09(5.11)		57.79(5.34)		61.00(3.77)	
Maternal Education						
Grade school/Some high school		2(5)		-		-
High school degree		-		2(10)		3(14)
Some college/Associate degree		9(21)		5(26)		4(18)
Bachelor's degree		9(21)		6(32)		10(45)
Graduate degree		13(30)		4(21)		4(18)
Missing/blank		10(23)		2(11)		1(5)
Paternal Education						
Grade school/Some high school		1(2)		-		-
High school degree		3(7)		-		2(9)
Some college/Associate degree		6(14)		4(21)		11(50)
Bachelor's degree		14(33)		5(26)		3(14)
Graduate degree		9(21)		7(37)		4(18)
Missing/blank		10(23)		3(16)		2(9)
Ethnicity						
White		25(58)		11(58)		13(59)
Hispanic		8(19)		5(26)		-
Black/African American		1(2)		2(11)		2(9)
Asian		3(7)		-		3(14)
Native American		-		-		-
Multiracial		6(14)		1(5)		4(18)

Note. TD = typical development; SSI-AI = articulation impairment; SSI-PI = phonological impairment.

Table 3

Means, Standard Deviations (SD) and Min/Max for the PLS-5 Screening Test and Expressive Vocabulary Measure (*N* = 84)

	TD (*n* = 43)		SSI-AI (*n* = 19)		SSI-PI (*n* = 22)	
Assessment	*M* (*SD*)	*Min/Max*	*M* (*SD*)	*Min/Max*	*M* (*SD*)	*Min/Max*
PLS-5	5.12 (0.50)	4-6	5.16 (0.83)	4-6	5.05 (0.72)	4-6
Vocabulary	10.49 (1.94)	7-15	10.42 (2.59)	7-17	9.55 (1.62)	7-13

Note. PLS-5 = Preschool Language Scales – Fifth Edition Screening Test; Vocabulary = Expressive Vocabulary subtest; SSI-AI = articulation impairment; SSI-PI = phonological impairment; TD = typical development.

Table 4

Means, Standard Deviations (SD) and Min/Max for the Three Inventories of the BBTOP By Group

	SSI-AI (*n* = 19)		SSI-PI (*n* = 22)	
Inventory	*M* (*SD*)	*Min/Max*	*M* (*SD*)	*Min/Max*
Word	82.63 (2.409)	77-87	72.73 (5.444)	<65-87
Consonant	81.05 (5.592)	<65-90	71.41 (5.342)	<65-82
Phonological Processes	86.89 (2.580)	85-94	71.95 (5.057)	<65-82

Note. BBTOP = Bankson-Bernthal Test of Phonology; SSI-AI = articulation impairment; SSI-PI = phonological impairment.

Table 5

Phonological Processes Produced By Children with SSI-PI

	Phonological Process										
Child	Assim.	FRO	FCD	WSD	STOP	GL	CR	DeP	DeA	Voc	Errors
5	√	√	√					√			/ð/
22			√						√		/r, z, ɵ, ð/
24			√		√	√					/t, tʃ, ɵ, ð/
25			√				√		√		/ɵ, l, ʃ/
26	√		√		√	√				√	/l, v, ɵ, ð/
33			√		√	√	√			√	/s, ɵ, ð/
45		√	√	√	√		√	√		√	/l, k, ɵ, ð/
46	√		√		√			√		√	/s, z, ɵ, ð/
47			√		√	√	√	√		√	/z, tʃ, ʃ, ɵ/
48			√							√	/z, ɵ, ð/
49			√		√	√				√	/z, ʤ, ɵ, ð/
51			√			√	√			√	/ʃ, tʃ, ɵ, ð/
52			√		√	√	√	√		√	/ʃ, ɵ, ð/
65	√		√		√	√	√	√			/ʃ, tʃ, ɵ, ð/
66		√	√	√	√	√	√	√	√	√	/tʃ, ʤ, ɵ, ð/
67		√	√	√	√	√		√	√		/tʃ, ʤ, ɵ, ð/
69						√		√			/ʃ, l, ɵ, ð/
77			√	√	√					√	/ʃ, ʤ, ɵ, ð/
78					√	√		√			/ʃ, tʃ, ɵ, ð/
82			√		√	√	√	√	√		/tʃ, ʤ, ɵ, ð/
86	√				√						/ʃ, ɵ, ð/
87			√		√		√	√			/ʃ, ɵ, ð/

Note. SSI-PI = phonological impairment; FCD = final consonant deletion; WSD = weak syllable deletion; DeP = depalatalization; DeA = deaffrication; Voc = vocalizing; errors = sound errors produced in over 50% of all occurrences.

Table 6

Consonant Errors Produced By Children with SSI-AI

Child	Consonant Errors	Phonological Process
9	/p, l, z, ʃ, ð/	
11	/j, k, r, tʃ, z, ɵ, ð/	
23	/p, t, l, k, g, z, ɵ, ð/	
27	/m, d, l, t, r/	Vocalization
42	/t, r, s, ɵ, ð/	
53	/d, t, r, z, ɵ, ð/	
54	/f, t, j, z, ʤ, ɵ, ð/	
57	/p, r, z, ɵ/	
59	/t, j, v, r, z, ɵ, ð/	
61	/p, f, l, t, r, ɵ, ð/	Gliding
70	/m, s, ʃ, tʃ, ɵ, ð/	
71	/t, d, f, v, s, ɵ/	
72	/j, k, t, f, v, ɵ, ð/	
79	/t, l, s, ɵ, ð/	
80	/k, g, t, r, s, ɵ, ð/	
81	/f, r, ʤ, ɵ, ð/	
83	/j, t, l, ɵ, ð/	
84	/t, r, ɵ, ð/	
85	/b, l, r, ɵ, ð/	

Note. SSI-AI = articulation impairment; Phonological Process = a phonological process that was produced in over 40% of all occurrences.

Table 7

Means, Standard Deviations (SD) and Min/Max for All Outcome Measures By Group (*N* = 84)

	TD (*n* = 43)		SSI-AI (*n* = 19)		SSI-PI (*n* = 22)	
Measure	*M* (*SD*)	*Min/Max*	*M* (*SD*)	*Min/Max*	*M* (*SD*)	*Min/Max*
PACom	102.65 (9.35)	80-125	104.68 (10.06)	84-131	81.95(8.91)	69-98
MD	8.42 (1.82)	5-12	8.42 (1.98)	4-13	6.59 (1.92)	2-10
NR	9.58 (2.93)	2-15	6.16 (3.35)	1-13	4.45 (2.58)	1-12
HTKS	26.26(10.90)	0-40	22.95 (11.83)	0-35	17.23(11.25)	0-36

Note. PACom = phonological awareness composite score; MD = Memory for Digits; NR = Nonword Repetition; HTKS = Head-Toes-Knees-Shoulders task; SSI-AI = articulation impairment; SSI-PI = phonological impairment; TD = typical development.

Table 8

Multiple Comparisons and Mean Differences in Outcomes by Group Controlling for Age and Gender

					Sidak Adjusted 95% CI	
Outcome	Mean Difference	Standard Error	*p*	Hedges' *g*	Lower Bound	Upper Bound
PACom						
TD vs. SSI-AI	-3.024	2.649	.590	-0.312	-9.490	3.442
TD vs. SSI-PI	20.403	3.073	< .001	2.189	12.902	27.904
SSI-AI vs. SSI-PI	23.427	3.474	< .001	2.427	14.947	31.907
Memory for Digits						
TD vs. SSI-AI	-.229	0.551	.967	-0.121	-1.575	1.116
TD vs. SSI-PI	1.604	0.640	.042	0.845	0.043	3.165
SSI-AI vs. SSI-PI	1.833	0.723	.039	0.905	0.069	3.598
Nonword Repetition						
TD vs. SSI-AI	2.984	0.759	< .001	0.962	1.131	4.838
TD vs. SSI-PI	3.443	0.881	< .001	1.208	1.293	5.593
SSI-AI vs. SSI-PI	0.459	0.996	.956	0.152	-1.972	2.889
HTKS						
TD vs. SSI-AI	2.298	3.171	.852	0.203	-5.441	10.038
TD vs. SSI-PI	9.024	3.678	.048	0.810	0.045	18.002
SSI-AI vs. SSI-PI	6.725	4.158	.295	0.573	-3.424	16.875

Note. HTKS = Head-Toes-Knees-Shoulders task; SSI-AI = articulation impairment; SSI-PI = phonological impairment; TD = typical development. Comparisons based upon MANCOVA adjusted means.

Table 9

Bivariate Correlations between All Outcome Measures among the Entire Sample (N = 84)

Measure	1	2	3	4	5
1. PLS-5	-				
2. Expressive Vocabulary	-.010	-			
3. Memory for Digits	-.078	.409**	-		
4. Nonword Repetition	.040	.291**	.464**	-	
5. PACom	.017	.462**	.567**	.558**	-
6. HTKS	.220*	.480**	.284**	.410**	.546**

* $p < .05$.
** $p < .01$.
Note. PACom = Phonological Awareness Composite; PMCom = Phonological Memory Composite; HTKS = Head-Toes-Knees-Shoulders task.

Table 10

Unique Contribution of Group, Phonological Working Memory and Executive Function to Phonological Awareness Composite

Predictors	B	β	R^2 change	*p*
Model 1: Age, MD, NR, HTKS				
Group	-5.035	-.322	.064	<.001
Model 2: Age, Group, NR, HTKS				
MD	2.036	.314	.075	<.001
Model 3: Age, Group, MD, HTKS				
NR	-.122	-.034	.001	.724
Model 4: Age, Group, NR, MD				
HTKS	.451	.397	.117	<.001

Note. MD = Memory for Digits; NR = Nonword Repetition; HTKS = Head-Toes-Knees-Shoulders task.

APPENDIX A

FAMILY AND CHILD DEMOGRAPHIC QUESTIONNAIRE

Dear Parents,
Thank you for your interest in participating in our research project.
Please remember that all responses are confidential.
Thanks again!

Child's name: ___________________________ Child's date of birth: ____________

Today's date: ___________________________

1. When did your child start receiving speech therapy services?

2. Is there a history of speech and/or language impairment in your family? If yes, please explain.

3. Does your child appear to be aware of their speech errors? If yes, please explain.

4. Does your child have a history of chronic ear infections? If yes, please explain.

5. What is the total gross household income before taxes in the current year?

Select one:

1 Less than $10,399
2 $10,400-13,999
3 $14,000-17,599
4 $17,600-21,199
5 $21,200-24,799
6 $24,800-28,399
7 $28,400-35,599
8 $35,600-64,999
9 $65,000-99,999
10 $100,000 or more
11 I prefer not to answer

6. What is the highest education level the child's <u>mother/female guardian</u> has reached? 1 Grade School 2Some High School 3High School Degree 4Some College, No Degree (1-3 years) 5Associate Degree in College (2 years) 6Bachelor's Degree (e.g. BA, AB, BS) 7Master's Degree (e.g. MA, MS, MBA) 8Doctorate/Professional Degree (e.g. PhD, MD, JD)
7. What is the highest education level the child's <u>father/male guardian</u> has reached? 1 Grade School 2Some High School 3High School Degree 4Some College, No Degree (1-3 years) 5Associate Degree in College (2 years) 6Bachelor's Degree (e.g. BA, AB, BS) 7Master's Degree (e.g. MA, MS, MBA) 8Doctorate/Professional Degree (e.g. PhD, MD, JD)

APPENDIX B

UNIVARIATE MAIN EFFECTS

Table 11

Univariate Main Effects between Groups for All Outcomes Controlling for Age and Gender

Outcome	Sum of Squares	*df*	*Mean Squares*	*F*	*p*	partial η^2
Phonological awareness	4508.68	2	2254.34	26.68	<.001	.41
Memory for Digits	27.73	2	13.87	3.79	.03	.09
Nonword Repetition	167.98	2	83.99	12.09	<.001	.24
HTKS	729.09	2	364.55	3.01	.06	.07

Note. HTKS = Head-Toes-Knees-Shoulders task.