Knowledge and Competence Regarding Percentage of Consonants Correct: A National Survey of Speech-Language Pathologists

by

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Abstract

The purpose of the current national survey was to examine speech-language pathologists' (SLPs') competence and confidence regarding the use of Percentage of Consonants Correct (PCC). Comparisons were made between recent graduates (post 2005) and pre-2005 graduates to determine if differences existed in their academic and clinical experiences or their competence/confidence in calculating PCC. The majority of SLPs reported a lack of academic and clinical training in the area of PCC. Participants demonstrated limited knowledge of the rules for calculating PCC and decreased calculation ability, in addition to decreased confidence. Recent graduates were better at calculating PCC within the appropriate severity range at the sentence level; however no other significant relationships were found. Because PCC is well-validated, SLPs would benefit from increased clinical and academic exposure to the measure; however, as many SLPs report they do no not use PCC, this somewhat calls into question its' practicality for clinical purposes.

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Chapter 1

Introduction

Speech sound disorders are increasingly common, as it is estimated that they are found in up to 25 percent of children from 5 to 7 years of age (American Speech and Hearing Association [ASHA], n.d.). In fact, 56 percent of caseloads of school-based clinicians involve treatment of speech sound disorders (Mullen & Schooling, 2010). The large percentage of children with speech sound disorders indicates a need for knowledgeable clinicians who are competent in the assessment and treatment of this population.

ASHA (2004) has delineated a preferred practice pattern for the comprehensive assessment of speech sound disorders that includes the use of standardized and non-standardized measures such as articulation tests, spontaneous speech samples, analysis of error type, independent analysis (e.g., phonetic inventory), and relational analysis (e.g., phonological process analysis). In addition to the guidelines presented in the Preferred Practice Patterns document, ASHA offers a practice portal as a reference tool for clinicians in the assessment and treatment of speech sound disorders. The practice portal provides more detailed descriptions of comprehensive assessment procedures that include measures such as intelligibility, stimulability, and speech perception as recommended components of a comprehensive assessment. Furthermore, ASHA suggests that examiners should also make a determination concerning severity, a judgment which reflects the interaction of three constructs (i.e., disability, intelligibility, and handicap) when assessing a child's speech sound production (Shriberg & Kwiatkowski, 1982). The severity of a child's speech sound disorder is often judged on a continuum from mild to severe and may be assessed qualitatively or quantitatively; however,

there is currently no consensus among professionals regarding the best way to assess severity of involvement (ASHA, n.d.; Flipsen, Hammer, & Yost, 2005).

As an alternative to qualitative assessment of severity in which the clinician makes perceptual judgments regarding the extent of the client's speech sound disorder, ASHA supports the use of a quantitative evaluation of severity. One such approach is Percentage of Consonants Correct (PCC) developed by Shriberg and Kwiatkowski (1982). This measure yields a percentage of correctly articulated consonant sounds present out of all consonant sounds attempted during a five- to ten-minute conversational speech sample. The resulting percentage corresponds to a severity rating on a continuum from mild to severe. Shriberg and Kwiatkowski determined that PCC was a valid and reliable measure that closely aligns with listener perceptions of severity.

While the standards of speech sound disorder assessment are delineated by ASHA (2004; n.d.), there is little evidence as to whether these recommendations are being put into practice. Currently only two surveys investigated the practice patterns of speech-language pathologists as it pertains to the assessment of speech sound disorders in English-speaking children (McLeod & Baker, 2014; Skahan et al., 2007). The findings from these evaluations indicate clinicians typically rely on parent interviews, speech samples, commercially available measures, estimates of intelligibility, stimulability testing, hearing screenings, and informal assessment procedures to diagnose disorders of articulation and phonology, yet the use of a quantitative severity measure is frequently omitted. Although citation-form or single-word testing is commonly used to assess severity of involvement and subsequently determine eligibility and possible treatment goals, Stoel-Gammon (1987) contends that conversational speech sampling is preferable to single-word

articulation tests as it provides a more valid sampling context for children's speech, especially for those under the age of three.

The omission of a severity measure raises questions about the use of quantitative measures such as PCC in assessing the severity of speech sound disorders, along with practicing clinicians' level of training and competence surrounding use of the measure. Because evidence supports the use of PCC as a valid and reliable measure that yields an accurate determination of an individual's severity of involvement (Shriberg & Kwiatkowski, 1982), it is important that clinicians have the knowledge and competence to use it successfully during assessment of speech sound disorders. Additionally, as a quantitative measure of severity that closely corresponds with listener perceptions of severity, PCC is likely a more ecologically valid way to assess a child's functional speech production (Stoel-Gammon, 1987); furthermore, in some situations it may aid in determining eligibility for speech-language services when single-word articulation testing does not. To this end, further information is needed with regard to assessment procedures currently used by practicing clinicians and whether PCC is included among those measures. Of particular interest is their training received and skill level in using the metric as a quantitative approach to assessing the severity of speech sound disorders.

Chapter 2

Review of the Literature

This chapter describes literature relevant to the research purposes of this thesis. It is organized into the following sections: a) Typical Phonological Development; b) The Nature of Speech Sound Disorders; c) Preferred Practice Patterns; d) Assessment of Severity; e) Development of Percentage of Consonants Correct (PCC); and f) Previous Research Exploring SLPs' Assessment of Speech Sound Disorders.

Typical Phonological Development

Phonological development refers to the gradual acquisition of speech sound form and function within a language system (Bauman-Waengler, 2015). Phonological development begins before birth with the development of auditory perceptual skills during the prenatal period and continues through early childhood as the child first develops babbling, followed by words and more complex utterances as the child reaches school age. Throughout this developmental trajectory, the child works to tune his speech sound production to an adult model.

Perceptual development. The development of a functional sound system begins with the development of auditory perceptual skills. Although a child's ability to perceive changes in auditory stimuli begins to develop during the prenatal period (Birnholz & Benacerraf, 1983; DeCasper, & Fifer, 1980; Lecanuet, Granier-Deferre, & Bushnel, 1988), more advanced perceptual skills continue to develop during the postnatal period. Categorical perception, which refers to an individual's tendency to perceive certain speech sounds according to the phonemic categories of their native language, has been shown to emerge in infants as young as one month old based on changes in sucking rates when exposed to /b/ and /p/ phonemes (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). The ability to discriminate between two similar non-native speech

sounds, although present up to 6 to 8 months of age, disappeared in infants by 10 to 12 months of age, suggesting that experience and extended exposure to the child's native language may result in the loss of this ability (Best & McRoberts, 2003; Trehub, 1976; Werker & Tees, 1983).

Kuhl (2004) contends that this loss of skill in discriminating non-native speech sounds occurs during a critical period for language learning in young children. She suggests the neural circuitry and overall architecture in the infant brain is developed to detect the phonetic and prosodic patterns of speech (i.e., neural commitment). This structure, which promotes efficient processing of language, inhibits the learning of patterns that do not conform to a child's native language. While the critical period for phonetic learning occurs before the child's first birthday, syntactic learning occurs between the ages of 18 and 36 months. Although a child's vocabulary explodes around 18 months of age, vocabulary development continues through the lifespan as new items may be learned at any age.

At approximately the same time that infants cease to discriminate nonnative speech sounds, they begin to develop perceptual constancy, which refers to the ability to identify the same sound across different speakers and pitches. Perceptual constancy for vowels and consonants in different vowel contexts has been identified in children from 5 ½ to 10 months of age (Maye & Gerken, 2000; Werker & Fennell, 2004). Perception of phonemic contrasts has been studied in children from 10 to 22 months of age, though there was considerable variability as to which phonemic contrasts emerged first (Garnica, 1973; Shvachkin, 1973). Further studies have indicated a link between a child's perceptual abilities and later language development. Tsao, Liu, and Kuhl (2004) discovered that speech perception at 6 months of age predicted language development at two years of age, suggesting that phonetic perception plays a role in later language acquisition.

Prelinguistic Behavior. The development of language skills begins before the emergence of a child's first meaningful words. According to Stark (1986), prelinguistic behavior is divided into five overlapping periods of development: reflexive crying and vegetative sounds, cooing and laughter, vocal play, canonical babbling, and jargon. From birth to the age of two months, an infant produces primarily reflexive vocalizations (e.g., cries, coughs, grunts, and burps) that involuntarily reflect his physical state. Vegetative sounds include grunts and sighs associated with activity and clicks and other sounds associated with feeding. Stark suggests that the second stage, cooing and laughter, occurs from two to four months of age and is characterized by cooing sounds containing vowels and brief consonantal sounds produced at the back of the mouth; additionally, sustained laughter emerges in the later stage of this developmental phase (Gesell & Thompson, 1934). Vocal play emerges at approximately four to six months, with the child producing longer series of segments and prolonged vowel-like or consonant-like steady states, as well as extreme variations in pitch and loudness (Stark, 1986).

Canonical babbling, which includes both reduplicated and nonreduplicated babbling, begins to emerge at approximately six months of age and continues until a child produces his first true word. Stark (1986) describes reduplicated babbling as the production of similar strings of consonant-vowel combinations in which the consonant remains the same (e.g., mama). Nonreduplicated babbling refers to a variation in the production of vowels and consonants from syllable to syllable (e.g., /bada/), with smooth transitions between vowel and consonant productions. The final stage of prelinguistic development is the jargon stage, which occurs in infants ten months and older. It is characterized by strings of babbled utterances accompanied by eye contact, gestures, and intonation patterns resembling adult speech. These later babbling periods are characterized by the child's use of vocoids and contoids, productions that cannot yet

be considered true vowels or consonants. With regard to syllable shape, the later babbling periods are characterized by primarily open syllables, including V, CV, VCV, and CVCV structures (Kent & Bauer, 1985).

The Linguistic Phase. The linguistic phase begins at approximately one year of age upon the emergence of the child's first meaningful words. Owens (2008) describes a child's first word as a stable phonetic form that is consistently used in a particular context and is related to the adult form of the word. The beginning of the linguistic phase is often termed the "first-50-word stage" and lasts from the emergence of first words until the child begins to put two words together. The child's phonological development during this period is influenced by the individual words the child is acquiring. Ingram (2010) termed this the presystematic stage, in which the child acquires contrastive words rather than contrastive phones. This is similar to the "item learning" and "system learning" stages as described by Cruttenden (1981). Item learning refers to the acquisition of words as unanalyzed units, while system learning refers to the acquisition of phonemic principles. The first-50-word stage is characterized by phonetic variability and limitation of syllable structures and sound segments. Phonetic variability refers to the unstable nature of the child's early productions. Although the type of syllable structure used varies with each child, the most frequently occurring syllable shapes include CV, VC, CVC, and CVCV (Ferguson & Farwell, 1975; French, 1989; Ingram, 1974; Menn, 1971; Stoel-Gammon & Cooper, 1984; Velten, 1943). Although there is great individual variability in the acquisition of phonemes, some generalizations exist regarding consonant inventories. During this period in both English- and non-English speaking children, consonant production is limited to labials (e.g., /p/ and /m/) followed by /t/ and /k/; fricatives are present only after their homorganic stops have emerged (Jakobson, 1968; Jakobson & Halle, 1956). The first vowel that typically emerges is /a/,

followed by /i/ or /u/ (Jakobson, 1968; Jakobson & Halle, 1956; Ingram, 1974; Menn, 1971; Velten, 1943). Ferguson and Farwell (1975) described a salience factor in phoneme acquisition, which refers to a child's active selection of sounds that are important or salient to the child. The researchers also describe an avoidance factor in which a child avoids words that contain sounds outside of the child's phonetic inventory.

Stoel-Gammon (1985) conducted a longitudinal study of thirty-four children between the ages of 15 and 24 months examining the range and type of speech sounds produced in the meaningful speech of this population. Data was collected in three month intervals at 9, 12, 15, 18, 21, and 24 months of age. Results of the study indicated that children possess a larger inventory in the word-initial position than the word-final position; additionally, voiced stops emerged prior to voiceless stops in the word-initial position, with the reverse occurring in the word-final position. Stoel-Gammon's findings closely align with Jakobson's (1968) statements that children acquire phonemes in a universal pattern in which front consonants precede back consonants, while stops and nasals precede fricatives and liquids. Liquid /r/ almost always emerged first in the word-final position. At least 50% of the 24-month-old children who participated in the study produced /h, w, b, t, d, m, n, k, g, f, s/ in the word initial position and /p, t, , n, r, s/ in the word-final position.

The preschool period occurs from the end of the first-50-word stage to the beginning of the child's fifth year and is characterized by large gains both in the child's phonological system and in other linguistic areas (e.g., semantics and syntax). The development of vowels during this period has been studied by Irwin and Wong (1983). According to Irwin and Wong (1983), children acquired the vowels /a, ʊ, i, ɪ, ʌ/ with 70% accuracy by 18 months of age; the only

vowels that were not produced with 70% accuracy by 24 months of age were /ɚ, ɝ/. By three years old, all vowels were produced with virtually no errors.

Vihman and Greenlee (1987) conducted a longitudinal study examining the phonological development of ten 3 year-old children. The researchers found that the children substituted stops or other fricatives for both /ɵ/ and /ð/. More than half of the participants exhibited the phonological process of gliding, in which sounds are substituted for liquids /r/ and /l/; additionally, these children also exhibited palatal fronting, in which an alveolar sound (e.g., /s/) is substituted for a palatal sound (e.g., /ʃ/). Vihman and Greenlee found a greater degree of variability in the phonological system of two of the children. Overall, 73% of the children were judged to have intelligible speech as rated by three separate unfamiliar listeners; children with more errors were judged to be less intelligible, as were those who used more complex sentences.

During the preschool stage, children learn to suppress certain phonological processes, although some may remain. Syllable structure processes, including reduplication, weak syllable deletion, final consonant deletion, and cluster reduction, refer to the child's tendency to reduce words to basic CV syllable structures. Final consonant deletion is an early process that has typically disappeared by the age of three; although weak syllable deletion, however, lasts until approximately four years of age (Ingram, 1989; Grunwell, 1987). Cluster reduction commonly lasts until five years of age, though it may be present in children up to eight or nine years of age (Haelsig & Madison, 1986; Roberts, Burchinal, & Footo, 1990; Smit, 1993). Substitution processes include stopping, fronting, and gliding. The disappearance of stopping varies depending on the individual phoneme, although most stopping is suppressed by the age of five (Smit, 1993). Fronting, which is the substitution of alveolar consonants for palatals and velars, is mostly suppressed by the age of three years, six months, although some researchers note limited

fronting up until the age of five (Lowe, Knutson, & Monson, 1985; Smit, 1993). Gliding is a process that occurs beyond the age of five up until the age of seven (Roberts et al., 1990; Smit, 1993).

By the time a child enters school around the age of five, the phonological system has progressed considerably, though it still differs a great deal from the adult norm. This stage is characterized by development in both the perceptual and productional facets of the child's phonological system. Phonemic categorization develops until the age of fourteen, when children have the ability to give categorical responses to synthetic stimuli (Fourcin, 1978). The perceptual constancy of these phonemic categorizations varies between the ages of five and nine (Tallal, Stark, Kallman, & Mellits, 1980), and the child's ability to recognize and process speech sounds under both normal and challenging listening environments improves through age fifteen (Elliott et al., 1979; Elliott, 1979).

Children experience productional development during the school-age stage in addition to perceptual development. The majority of available information on productional abilities of children is based on the results of articulation tests, which reveal that children do not achieve acceptable production of certain sounds until four years, six months and six years (Lowe, 1986, 1996; Templin, 1957). Later-developing sounds include /Θ, ð, ʒ, r, z, v/ (Sander, 1972; Ingram, Christensen, Veach, & Webster, 1980), which are typically acquired by age seven at the latest; however, dentalized /s/ has been noted in 10% of nine-year-old children (Smit, 1993). Smit (1993) found that production of consonant clusters is also difficult for school-age children, as children may exhibit consonant cluster reduction, epenthesis, or lengthen elements of the cluster until the age of five years, six months. A child's timing of certain sounds within the cluster may not match the adult norm until age eight (Gilbert & Purves, 1977; Hawkins, 1979), and his or her

production of consonant clusters may not match the adult norm even through age nine (Smit, 1993).

The existing literature suggests that phonological development extends throughout the school-age years and that the rate of acquisition varies for each particular child. Some children, however, achieve these phonological milestones at a slower rate than their same-aged peers. These children with atypical or delayed phonological development are said to exhibit a speech sound disorder. Speech sound disorders are relatively common among young children, with approximately 2 to 25 percent of children from 5 to 7 years of age (Law, Boyle, Harris, Harkness, & Nye, 2000).

The Nature of Speech Sound Disorders

According to the American Speech-Language-Hearing Association, a speech sound disorder refers to any condition resulting in reduced intelligibility due to deficits in speech perception, motor production, or phonological representations of speech sounds and segments (n.d.). ASHA defines two primary categories of speech sound disorders: articulation disorders and phonological disorders. Articulation disorders include those that affect the form of the speech sounds and are typically caused by motor-based or structural deficits, while phonological disorders result from impairments with the structure and function of its sound system at both the phonetic and phonemic level (Bauman-Waengler, 2012; Shriberg & Kwiatkowski, 1982).

Articulation Disorders. The term "articulation" encompasses all motor processes involved in the planning and carrying out of speech. Structural deficits (e.g., cleft palate), motor-based deficits (e.g., apraxia), syndromes or condition-related disorders (e.g., Down syndrome and metabolic conditions), and sensory-based deficits (e.g., hearing impairment) are known causes of speech sound disorders (ASHA, n.d.). Characteristics of an articulation disorder

include deficits in the motor production of speech acts or the inability to produce certain speech sounds (Elbert & Gierut, 1986). For example, a frontal lisp is a common articulation error in which a fricative, such as the lingua-alveolar /s/, is produced with the tongue thrust forward rather than contacting the alveolar ridge. Articulation is typically classified by a child's age and corresponding stage of development, with certain errors considered typical or atypical based on their appropriateness for the child's age.

Phonological Disorders. Phonology is the study of a language's sound system, along with the component sound segments and the rules governing their use. A phonological disorder refers to an impairment in the comprehension and use of the sound system of a language and the rules governing its use (ASHA, 2008; ASHA Ad Hoc Committee on Service Delivery in the Schools, 1993). Although some researchers limit phonological disorders to those concerning underlying representations and phonological rules (Shelton & McReynolds, 1979), others contend that a phonological disorder encompasses the entire speech production process, including underlying representations, phonological rules, and the behaviors that produce speech (Shriberg & Kwiatkowski 1982). Some common examples include stopping of fricatives (/ti/ for "see"), deletion of final consonants (/haʊ/ for "house"), consonant cluster reduction (/tap/ for "stop"), and fronting of velar or palatal phonemes (/tʌp/ for "cup"). While an articulation disorder represents a disturbance in the peripheral motor process involved in speech sound production, phonological disorders represent deficits in the organization and function of the child's phonological system.

Etiology of Speech Sound Disorders. While some speech sound disorders appear to have no known etiology, impairments can occur as a result of various causes, including genetic factors or syndromes, developmental disorders, neurological disorders, illness, or a hearing loss

(ASHA, n.d.). Research indicates that speech sound disorders occur in between 2 to 25% of children aged 5 to 7 years (Law, Boyle, Harris, Harkness, & Nye, 2000). In fact, 56 percent of the caseloads of school-based clinicians involve the treatment of speech sound disorders (Mullen & Schooling, 2010), with 93% of school-based SLPs reporting that they work with students with articulation/phonology delays or disorders (ASHA, 2014).

Preferred Practice Patterns for the Assessment of Speech Sound Disorders

Speech sound assessments often include formal articulation and phonological measures, collection of a continuous speech sample, or evaluation of related language domains as well as the structure and function of anatomical systems that contribute to speech sound production. ASHA (2004) outlines preferred practice patterns for the assessment of speech sound disorders, including articulation tests, spontaneous speech samples, analysis of error type, independent analysis (e.g., phonetic inventory), and relational analysis (e.g., phonological process analysis). Specific components of speech sound assessment suggested in the ASHA Practice Portal include initial screening measures as well as more comprehensive assessment measures based upon screening results. Suggested comprehensive assessment practices include: obtaining a thorough case history; conducting an oral mechanism exam; performing a hearing screening; completing a speech sound assessment that includes measures of severity, intelligibility, stimulability, and speech perception; and conducting supplemental assessments including spoken language and literacy assessments.

Screening. A screening is performed when a child displays characteristics of a possible speech sound disorder in order to identify the need for further evaluation. Procedures include a hearing screening, oral mechanism exam, formal or informal screening measures, and screening of comprehension and production of spoken and written language. The results of the screening

procedure may indicate the need for further speech and language evaluation, referral for special services, or continued monitoring of the child's speech and language development (ASHA, n.d.). If the results of the screening indicate a need for further evaluation, a comprehensive speech and language assessment that accounts for cultural and linguistic diversity will typically be performed.

Comprehensive Assessment. A comprehensive speech sound assessment is recommended in cases where a clinician is concerned that an individual may have a speech sound disorder based on his or her performance on the speech sound screening. Best practice dictates that a comprehensive assessment uses both standardized instruments and non-standardized sampling procedures to distinguish between atypical speech errors and those that occur during typical development (ASHA, n.d.).

Case History and Initial Information. This comprehensive assessment protocol begins with collecting a thorough case history, including the family's concerns, medical history, history of middle ear infections, family history of speech and language impairments, the primary language spoken by the child and in the home, and observers' perceptions of intelligibility, including teachers, family, and other communication partners (ASHA, n.d). An effective case history can be an invaluable tool, as the identification of risk factors such as family history and perinatal history (e.g., prematurity, low birthweight) have been found through systematic review to be associated with speech and language delay (Nelson, Nygren, Walker, & Panoscha, 2006).

The oral mechanism examination serves to determine whether oral and facial structures and functions are adequate for speech-sound production; a typical oral mechanism examination includes assessment of occlusion, dentition, hard palate, soft palate, tongue, velum, lips, and jaw. McCauley and Strand (2008) reviewed six standardized measures of nonverbal oral and speech

motor performance in children: the Apraxia Profile (AP) Preschool and School-Age Versions (Hickman, 1997); Kaufman Speech Praxis Test for Children (KSPT; Kaufman, 1995); Oral Speech Mechanisms Screening Examination, Third Edition (OSMSE3; St. Louis & Ruscello, 2000); Screening Test for Developmental Apraxia of Speech, Second Edition (STDAS2; Blakeley, 2001); Verbal Dyspraxia Profile (VDP; Jelm, 2001); and the Verbal Motor Production Assessment for Children (VMPAC; Hayden & Square, 1999). The researchers found the VMPAC to be the most reliable and valid measure of nonverbal oral and speech motor performance in children.

If a hearing screening was not conducted during the speech screening, it is integrated into the comprehensive assessment and typically includes otoscopic examination, pure tone audiometry, and assessment of middle ear function. Hearing is critical for the development of speech and language, as it dictates the sounds included in the child's repertoire. Children with hearing loss are unable to perceive certain sounds, such as /s, sh, f, t, k/, and therefore may not include them in their own speech (ASHA, n.d.). The degree of articulatory impairment and speech intelligibility is directly related to the degree of hearing impairment (Eriks-Brophy, Gibson, & Tucker, 2013).

Speech Sound Assessment. Both single-word measures and connected speech sampling are recommended in order to adequately demonstrate a full representation of the child's speech sound production abilities. This typically involves the use of both standardized assessments and sampling procedures. Morrison and Shriberg (1992), for example, suggest that the two forms of speech sound assessment yield performance differences at the linguistic levels of sound class, manner feature, phonological process, phoneme, error type, word position, and allophone. Morrison and Shriberg's findings suggest that neither sampling context is superior to the other as

differences in performance exist across individuals. While single-word testing allows for assessment of all of the sounds in a language in all word positions, it may not provide a true representation of a child's production in connected speech. A continuous speech sample, however, is an ecologically valid measure that provides information about the child's speech sound production in connected speech using a variety of speaking tasks and conversational partners (Morrison & Shriberg, 1992; Stoel-Gammon, 1987).

While a variety of formal articulation measures are available, in a national survey of speech-language pathologists, Skahan and colleagues (2007) found that the most commonly used single-word assessment measure is the *Goldman-Fristoe Test of Articulation, Second Edition (GFTA-2;* Goldman & Fristoe, 2000*).* The *GFTA-2* assesses children's proficiency in articulating the 23 consonant sounds of Standard American English. The *GFTA-2* is normed for children ages 2.0 through 21.0 and is composed of three sections: Sounds-in-Words, Sounds-in-Sentences, and Stimulability. The *GFTA-2* provides information on children's spontaneous and imitative sound production at the word level and in conversational speech. The *GFTA-2* possesses high internal, test-retest, and interrater reliability as well as adequate content and construct validity.

When assessing a child's speech sound system, sounds that the child produces correctly are typically analyzed in terms of word position, phonetic context, phoneme sequences, and syllable shape (ASHA, n.d.). Those produced incorrectly are analyzed by error type and distribution, and it is determined if the sound errors are consistent with preserved phonetic contrasts; additionally, utterances are examined for the presence of error patterns (ASHA, n.d.; Bauman-Waengler, 2012). Other formal articulation assessments include the *Clinical Assessment of Articulation and Phonology-Second Edition* (Secord & Donohue, 2013), the *Diagnostic*

Evaluation of Articulation and Phonology (Dodd et al., 2006), the *Arizona Articulation Proficiency Scale-Third Edition* (Fudala, 2000), the *Structured Photographic Articulation Test-Second Edition* (Dawson & Tattersall, 2001), the *McDonald Deep Test of Articulation* (McDonald, 1964), and the *Photo Articulation Test-Third Edition* (Lippke, et al., 1997).

Results of Skahan and colleagues' 2007 survey found the *Khan-Lewis Phonological Analysis-Second Edition* (*KLPA-2;* Khan & Lewis, 2002) to be the most commonly used phonological assessment (2007). The *KLPA-2* is a norm-referenced, standardized test used to assess phonological process usage. It is a complementary tool for the *GFTA-2*, and it uses 53 target words from the Sounds-in-Words subtest of the *GFTA-2* to offer more diagnostic information. It is normed for ages 2.0 to 21.11 and based on the *GFTA-2* standardization. Ten phonological processes that derive a normative score are separated into three categories: reduction processes, place and manner processes, and voicing processes. Reduction processes include deletion of final consonants, syllable reduction, stopping of fricatives and affricates, cluster simplification, and liquid simplification. Place and manner processes include velar fronting, palatal fronting, and deaffrication, while voicing processes include initial voicing and final devoicing. Finally, there are an additional 34 phonological processes not included in the scoring system that may occur and can be used to further assess the child's phonological skills The *KLPA-2* was determined to be a reliable and valid measure, with high internal, test-retest, and interrater reliability, as well as high content and construct validity. Other formal assessments of phonological processes include the *Bankson-Bernthal Test of Phonology* (Bankson & Bernthal, 1990), the *Hodson Assessment of Phonological Patterns-Third Edition* (Hodson, 2004), the *Clinical Assessment of Articulation and Phonology-Second Edition* (Secord & Donohue, 2013), and the *Diagnostic Evaluation of Articulation and Phonology* (Dodd et al., 2006).

Severity. The severity of a speech sound disorder is a qualitative judgment that indicates the impact of the disorder on the child's daily communication functioning (ASHA, n.d.). Severity of involvement is one of the factors considered when determining the need for intervention (Bernthal, Bankson, & Flipsen, 2013). Although quantitative measures such as Percentage of Consonants Correct (PCC) have been developed that closely align with listeners' perceptions of severity (Shriberg & Kwiatkowski, 1982), clinicians frequently make an impressionistic judgment as to the degree of impairment based on a continuum of severity ranging from mild to severe (Flipsen, Hammer, & Yost, 2005). Flipsen and colleagues discovered that determination of severity of involvement is an area in which there is little consensus among professionals. The researchers found that clinicians tend to use judgments of both individual segments and whole words in making severity determinations, and that perceptual severity ratings varied among even the most experienced clinicians.

Intelligibility. Intelligibility is a perceptual judgment used to determine how well the child's conversational speech is understood by the listener, and it is often a factor in judging the severity of a speech sound disorder (Kent, Miolo, & Bloedel, 1994). Quantitative measures have also been developed for intelligibility, including calculating the percentage of intelligible words in a continuous speech sample. A guideline in determining how intelligible a child should be when speaking to an unfamiliar listener can be determined for example by dividing the child's age in years by 4 and then presenting it as a percentage. Therefore at one year of age a child would be expected to be 25% intelligible (i.e., 1 divided by 4) and at two the same child, if typically developing, would be expected to be 50% intelligible (i.e., 2 divided by 4). With this in mind a child at 4 would be expected to be 100% intelligible (Coplan & Gleason, 1988; Flipsen 2006). Even with this guideline in mind ASHA (n.d.) guards against choosing one intelligibility

measure as appropriate for all children, as factors such as speaking rate, known versus unknown context, and amount of background noise can all have an impact on the ease of understanding a child's spontaneous speech production.

Stimulability. The assessment of stimulability is also recommended to determine the individual's ability to produce or imitate a previously misarticulated sound with the aid of a model, and it is helpful in determining appropriate targets for therapy and predicting future success (ASHA, n.d.).While there are few standardized procedures for assessing stimulability (e.g., the Scaffolding Scale of Stimulability), many clinicians assess stimulability using non-standardized measures (Glaspy & Stoel-Gammon, 2007). Some standardized test batteries include stimulability measures, such as the *GFTA-2* (Goldman & Fristoe, 2000), which contains a stimulability subtest that is completed based on the results of the assessment. Speech perception testing aids the clinician in determining whether a child can distinguish between a correctly produced sound and his own error production; it can be assessed through auditory discrimination, picture identification, and pronunciation accuracy (ASHA, n.d.).

Supplemental Assessments. Spoken language testing is included in speech sound assessments due to the high co-occurrence of language and speech sound disorders (Bishop & Adams, 1990; Lewis et al., 2006; Shriberg & Austin, 1998; Shriberg & Kwiatkowski, 1982; Shriberg, Tomblin, & McSweeny, 1999). It is estimated that 6% to 21% of children exhibit comorbid speech sound and receptive language disorders, while 38% to 62% of children have comorbid expressive language disorders (Shriberg & Austin, 1998). Language assessment typically begins with a screening of receptive and expressive language abilities, with the performance of a full language assessment battery dependent upon the results of the screening (Shriberg & Austin, 1998). Commonly used assessments such as the *Preschool Language Scale,*

Fifth Edition (PLS-5; Semel, Wiig, & Secord, 2013*)* and *Clinical Evaluation of Language Fundamentals, Fifth Edition (CELF-5*; Zimmerman, Steiner, & Pond, 2011*)* provide comprehensive information about the child's receptive and expressive language abilities.

Phonological processing is the ability to use phonemes to process written and spoken language; these skills include phonological awareness, phonological working memory, and phonological retrieval (Wagner & Torgesen, 1987). The *Phonological Awareness Test 2* (*PAT 2*), for example, is a valid and reliable standardized assessment designed to test the phonological awareness, phoneme-grapheme correspondences, and phonetic decoding skills of school-aged children (Robertson & Salter, 2007).

Because deficits in the speech processing system can inhibit the development of literacy skills, a literacy assessment is included in the comprehensive speech sound assessment (Anthony et al., 2011; Leitão & Fletcher, 2004; Lewis et al., 2011). Assessments such as the *Gray Diagnostic Reading Tests, Fourth Edition (GDRT-4*; Bryant, Wiederholt, & Bryant, 2004*), Gray Oral Reading Tests, Fourth Edition (GORT-4*; Wiederholt & Bryant, 2001*),* and the *Test of Written Language, Fourth Edition (TOWL-4*; Hammill & Larsen, 2009*)* are designed evaluate literacy skills including print awareness, alphabet knowledge, sound-symbol correspondence, reading, decoding, spelling, reading fluency, and reading comprehension.

Collection of a spontaneous speech sample. While standardized speech sound assessments are essential components of a comprehensive assessment protocol, collection of a spontaneous speech sample provides information regarding speech performance that a single-word measure is unable to reveal. In fact, it has been suggested that "citation-form testing yields neither typical nor optimal measures of speech performance" (Morrison & Shriberg, 1992, p. 271). Shriberg and Kwiatkowski have developed a procedure for assessing the severity of

involvement of individuals with speech sound disorders which begins with obtaining and recording a continuous speech sample on which to perform a phonetic, phonologic, and prosodic analysis (1982; 1985).

The guidelines for obtaining an optimal continuous speech sample are delineated in Shriberg and Kwiatkowski's 1985 study. The authors proposed five sampling conditions used in the collection of spontaneous speech samples: free, story, routines, interview, and scripted. Two examiners used the five sampling conditions to sample the speech of 12 children with delayed phonological development. All five sampling conditions were administered in succession during a 45-minute session, with each sampling condition lasting approximately eight minutes. The spontaneous speech samples were transcribed using narrow transcription one month following their collection and processed for phonetic and phonologic analysis.

Shriberg and Kwiatkowski (1985) found that the productivity of a speech sample may be increased when the examiner is able to successfully alter the sampling conditions to promote and maintain the child's interest in speaking. Regarding the frequency of occurrence of the Standard American English phonemes, the researchers noted that frequency of occurrence fluctuated based on the child's interest level in the stimulus materials and the clinician's prompting, indicating that the frequency of occurrence of phonemes in a given speech sample is rather unpredictable. The authors also observed that "proportional distributions of parts of speech, word forms, and consonants" found in continuous speech samples was similar across typical clinical sampling environments (p. 329). The researchers also examined the relationship between characteristics of the children's speech register and their phonetic accuracy. Reduced register, in which the children were whispering, mumbling, or using low-intensity speech, was suggested to indirectly affect the perceived intelligibility of the children's speech. Shriberg and Kwiatkowski theorized

that the decrease in intelligibility resulted from the children's less accurate consonant productions, which occurred when their attention was directed elsewhere during play. Another factor resulting in decreased intelligibility was the increased vigilance required of the clinicians for accurate transcription.

As a result of their research, Shriberg & Kwiatkowski (1985) determined that several factors contributed to the success of a continuous speech sample. The clinician's flexibility and ability to keep the child talking, by introducing interesting stimuli and directing the conversation as needed, is essential to obtaining a productive speech sample. Additionally, increasing control over the content of the utterances may lead to increased intelligibility; data from a child whose utterances are largely unintelligible and only approximately 66% glossable may need to be supplemented with data from a formal test of articulation. The clinician should monitor the child's repeated use of certain vocabulary and manipulate stimuli to increase the variety of word types and subsequently phonemes used by the child, ensuring that the proportion of occurrence of different word forms is similar to that found in normative data. Finally, the clinician should be aware of the effect that the child's affective and cognitive states may have on the productivity of the sampling procedure. Shriberg and Kwiatkowski (1985) state that when these considerations are in place during continuous speech sampling, the procedure "should yield valid and reliable data" (p. 331).

Assessment of Severity

Of the recommendations set forth by ASHA regarding the assessment of speech sound disorders, one area in which there is no clear consensus among professionals is development of a defined procedure for determining the severity of the disorder (Flipsen, Hammer, & Yost, 2005). Many clinicians rely on qualitative assessments of severity in which children's speech is rated on

a continuum from mild to severe based on perceptual judgments, though some use quantitative measures such as Percentage of Consonants Correct (PCC), in which the percentage of correctly articulated consonants is calculated based on the total number of consonants correctly produced out of the total number of consonants produced. Due to this variability in service delivery among practicing clinicians, models of severity assessment and SLPs' current assessment patterns regarding severity of involvement are of particular interest.

Prezas and Hodson (2010), who advocate a cyclical approach to the treatment of phonological disorders, rate a child's severity of involvement on a continuum from mild to severe; a child whose speech is mildly impaired (i.e., rare omissions; few substitutions) will likely demonstrate relatively few error processes, while a child whose speech is severely or profoundly impaired will demonstrate extensive misarticulations (i.e., high occurrence of omissions and substitutions; extremely limited phonemic and phonotactic repertoires). However, Shriberg and Kwiatkowski (1982) outlined a comprehensive procedure for the assessment of severity, beginning with obtaining a continuous speech sample on which to perform a quantitative evaluation of severity of involvement.

Development of Percentage of Consonants Correct (PCC). The Percentage of Consonants Correct (PCC) metric is a quantitative severity measure developed by Shriberg and Kwiatkowski (1982) and designed to assess the severity of involvement in individuals with speech sound disorders. The metric considers only the production of consonants, which are judged as correct or incorrect based on the PCC sampling rules. When calculating the PCC metric, the clinician determines the percentage of correctly articulated consonant sounds present out of all consonant sounds attempted during a five- to ten-minute conversational speech sample. See Appendix B of Shriberg and Kwiatkowski's 1982 study "Phonological Disorders III: A

Procedure for Assessing Severity of Involvement" for detailed calculation instructions. According to Shriberg and Kwiatkowski (1982), this percentage correlates to a corresponding severity level indicating the severity of the speech sound disorder. Individuals with a PCC greater than 85% receive a rating of mild, those with a score from 65-85% receive a rating of mild-moderate, scores of 50-64% receive a rating of moderate-severe, and individuals with PCC scores below 50% are classified as severe. In addition, an extensive set of norms developed by Austin and Shriberg (1997) allow the individual's performance to be compared to a normative sample of the same age, gender, and speech classification. For example, a 4-year-old boy with a mean PCC of 65% for all consonant sounds would be classified as speech delayed. PCC has been validated for use with preschool and elementary school children whose articulation errors consist primarily of deletions and substitutions and is not intended for use in adolescents and adults whose articulation errors consist primarily of distortions (Kent, Miolo, & Bloedel, 1994).

Shriberg and Kwiatkowski (1982) designed the PCC metric to account for a large portion of the variance in severity ratings. Prior to the development of the PCC metric, speech-language pathologists relied on estimates of the intelligible words in spontaneous speech for clinical intelligibility assessments (Shriberg & Kwiatkowski, 1982). However, this tally of the number of sound errors was inadequate because "the same pattern of errors becomes more intelligible as a listener becomes familiar with the pattern and other speaker, listener, context, message, and media characteristics interact significantly with communicative effectiveness" (Shriberg & Kwiatkowski, 1982, p. 257).

Two stimulus tapes were constructed, each including ten 20-second practice samples and 32 one-minute samples from children with developmental speech sound disorders. Fifty-two speech-language pathologists and 120 student volunteers were instructed to rate the severity of

involvement of 32 children with speech delay, for whom age and gender information was provided (Shriberg & Kwiatkowski, 1982). After assigning practice ratings for each of the ten 20-second samples, the participants were instructed to listen to each of the 32 minute-long samples only once and provide a rating for severity of involvement and a rationale for each rating.

The authors recruited ten seniors from a methods course in communication disorders and four first-year graduate students to participate in an intelligibility task. The student volunteers listened to the 32 one-minute speech samples and provided a gloss for each child's utterances. The intelligibility data obtained from this listening task was averaged to obtain a percentage of intelligible words for each of the samples. Suprasegmental characteristics of each of the samples were rated by ten individuals currently completing a practicum experience at a diagnostic-treatment center for communication disorders. Participants rated the samples on pitch, loudness, quality, rate, stress, and phrasing. After participants listened to each sample two times, they assigned ratings of 0, 1, or 2 based on how infrequently (1) or frequently (2) these suprasegmental features deviated from normal (0). The first 15 samples were rated in a group session, while the participants were instructed to rate the remaining samples on their own, using the same equipment they would typically use in the clinic.

Reliability and validity of PCC. The overall goals of the study were to determine if the severity ratings obtained reflected the constructs of disability, intelligibility, and handicap, and to determine the adequacy of the PCC metric as a measure of severity. A reliability and item-level analysis was provided for all measures. The percentage of consonants correct for each of the 32 one-minute speech samples was calculated by an individual experienced in the transcription of children's speech (Shriberg & Kwiatkowski, 1982). Intrajudge reliability for the PCC metric was

assessed by asking the same judge to rescore all thirty stimulus tapes five weeks after the original score was assigned. A Pearson correlation coefficient of .97 was calculated between ratings. Interjudge reliability for the PCC metric was determined by having two communication disorders graduate students score five randomly selected samples, with 50 target consonants being scored by the criterion judge and the two reliability judges. The greatest disagreement between any of the judges was 15 percent, and the data obtained indicated that the instructional content for teaching clinicians how to calculate PCC developed by Shriberg and Kwiatkowski was operationally sufficient (1982).

The severity of involvement ratings were assessed for effect of order of presentation. The Pearson correlation coefficient of .96 indicated that the order in which the speech samples were presented did not affect the severity ratings. Intrajudge reliability was established by assessing severity ratings for the two children whose samples appeared twice on each stimulus tape. Upon inspection, 47.3% of judges assigned the same rating for each of the two listening occasions, while 39.7% assigned a score within one scale point on each listening. A comparison of the ratings assigned by the experienced clinicians and those assigned by the college volunteers yielded a Pearson correlation coefficient of .86, revealing that both experienced and inexperienced listeners assigned similar severity of involvement ratings. In their rationales for the assigned ratings, more than ten percent of the judges cited intelligibility, age, articulation, language, and suprasegmentals as factors that influenced the rating. Interjudge reliability was not formally assessed.

Interjudge reliability for suprasegmental ratings ranged from 40% to 100%, indicating that the majority of judges were in agreement. Intrajudge reliability was assessed in two ways. A judge's use of a score for each suprasegmental feature was compared to the mean and standard

deviation of the total group of judges; this revealed that certain judges had a tendency to overuse one or more of the three values (0, 1, or 2). Intrajudge reliability was also assessed by comparing each judge's rating on the second occurrence of each speech sample, yielding an average of 77% agreement in the use of 0, 1, or 2 on each occurrence (Shriberg & Kwiatkowski, 1982). Test-retest agreement was found to be highest at the extremes of the scale. The effect of order of presentation was assessed for suprasegmental ratings by comparing the mean ratings for the two children whose samples were repeated. An average mean difference of .187 indicates that the central tendency value did not move as judges progressed through the stimulus tapes (Shriberg & Kwiatkowski, 1982). Interjudge agreement data for both group ratings and individual ratings did not reveal observable differences in interjudge agreement.

Correlational findings regarding the six suprasegmental features revealed that the suprasegmentals are not highly intercorrelated with one another and may be viewed as independent aspects of the suprasegmental domain. Intelligibility ratings data were only moderately correlated with PCC, indicating that intelligibility reflects an interaction of several factors in addition to articulation proficiency (Shriberg & Kwiatkowski, 1982). Data also indicated that while a child's age and suprasegmental characteristics influence ratings of severity, the PCC index is the primary predictor of severity, with 90% of the children's severity ratings being accurately predicted by the PCC value alone (Shriberg & Kwiatkowski, 1982).

Extensions to the PCC metric. While the PCC metric is specifically designed to express the percentage of correctly articulated consonant sounds present in a conversational speech sample, it has also been applied to results of articulation tests or speech samples gathered in non-conversational contexts (Shriberg et al., 1997).

Shriberg and colleagues (1997) raised several concerns regarding the clinical research application of the PCC metric. One such concern is the requirement of a conversational speech sample to determine PCC, as well as the inefficiency of collecting conversational speech samples on some children. Another concern was that PCC may obscure important differences associated with certain types or subgroups of sounds. It is sometimes useful in clinical research to differentiate omission and substitution errors from distortion errors. To account for this, researchers have developed the Articulation Competence Index (ACI; Shriberg et al., 1997), Percentage of Consonants Correct-Adjusted (PCC-A; Shriberg et al., 1997), and Percentage of Consonants Correct-Revised (PCC-R; Shriberg et al., 1997). The ACI is designed to differentially weight distortion errors and is calculated by adding the PCC and the Relative Distortion Index and then dividing the sum by two. The Relative Distortion Index is the percentage of an individual's errors that are distortions. The PCC-A is calculated in the same way as PCC, although common clinical distortions as described by Shriberg in 1993 (i.e., labialized and velarized /l/; labialized, velarized, and derhotacized /r/, /ɝ/, and /ɚ/; and dentalized and lateralized /s/, /z/, /ʃ/, /ʒ/, /ʤ/, and /ʧ/) are scored as correct. When calculating the PCC-R, both common and uncommon clinical distortions (i.e., weak consonants, imprecise consonants and vowels, failure to maintain oral/nasal contrasts, and notable failure to maintain appropriate voicing) are scored as correct. Researchers also expressed concern that information provided by the PCC is limited to consonant production and thus have developed Percentage of Vowels/Diphthongs Correct (PVC; Shriberg et al., 1997) and Percentage of Vowels/Diphthongs Correct-Revised (PVC-R; Shriberg et al., 1997). Because none of the previous measures reflect all the phonemes of American English, the Percentage of Phonemes Correct (PPC; Shriberg et al., 1997) and Percentage of Phonemes Correct-Revised (PPC-R; Shriberg et al., 1997) were

developed. A final concern expressed by researchers was that PCC scores are not adjusted for age or gender differences in articulation abilities and lack a standard error of measurement.

Shriberg and Austin (1997) obtained 33 conversational speech samples from both children and adults. Two individuals with years of research experience in narrow phonetic transcription and one individual with only one year of experience independently transcribed the speech samples. The PEPAGREE program was used to calculate the transcribers' broad and narrow transcription agreement, using one transcriber's gloss as the standard against which the other two transcribers' transcriptions were compared. The mean number of words in each speech sample was 196.2 words with a standard deviation of 42.7 words. For consonants, broad transcription agreement averaged 92.7% across transcribers, while narrow transcription averaged only 80.6%. This suggests that broad transcription is reliable enough for clinical research purposes, while narrow transcription may not be reliable enough for some research and assessment purposes.

Three reliability concerns were addressed by Shriberg and his colleagues (1997). The researchers determined that disagreement in transcription reduces the reliability of speech measures, which in turn may reduce the validity of interpretations and recommendations. To address these concerns, the authors recommended the use of consensus transcription whenever possible to periodically calibrate an individual's transcription skills. Additionally, narrow transcription should be used to provide certain articulatory detail, such as distinguishing among different types of distortions as well as between distortions and substitutions. Finally, it is important to consider the standard error of measurement (SEM) when selecting a conversational speech measure.

Validity concerns were addressed by encouraging researchers to select a measure that meets the specific needs of the assessment. Consonants may be assessed by PCC, PCC-A, PCC-R, and ACI. A child's phonetic inventory can be determined through the use of the PCI. Vowels and diphthongs are assessed by the PVC and PVC-R. All the phonemes of American English can be assessed with PPC and PPC-R. Additionally, the selected measure should be appropriate for the age and speech status of the speaker. PCC is appropriate for children aged 3 to 6 who have speech delay and provides information on all three error types. The PCC-A is appropriate for speakers of all ages and is sensitive to all uncommon clinical distortion errors. The PCC-R is appropriate for comparisons between speakers of different ages or speech statuses. Shriberg and colleagues (1997) also recommended using subscale scores for increased sensitivity to different classes of developmental sounds, as well as using z scores or standard scores to account for differences in age and gender and when making reference comparisons.

Clinician agreement in severity assessment. A comparison of phonological severity measures was conducted by Garrett and Moran in 1992 to determine the extent of agreement among scores based on percentage of consonants correct, phonological deviancy score, and the perceptual judgments of listeners. Twenty speech samples were obtained from children between the ages of 5 and 9 that were currently receiving speech-language pathology services. The phonological impairments of the children selected to provide speech samples ranged in severity from mild to severe. Each child was administered the Assessment of Phonological Processes-Revised (APP-R) and was required to pass a pure-tone hearing screening. Additionally, connected speech samples consisting of 100-140 words were elicited through the use of sequence cards and subsequently glossed by the author.

The speech samples were phonetically transcribed and entered into two separate computer programs for analysis. The *Computer Analysis of Phonological Processes,* developed by Hodson in 1985, was used to assess responses to the APP-R and derive a phonological deviancy score for each sample. Spontaneous speech samples were analyzed by the *PROPH+* program, which was used to calculate the percentage of consonants correct for each sample. Responses to the APP-R were also submitted to the *PROPH+* program in order to allow for comparison between PCC and Phonological Deviancy Score (PDS) measures obtained from the same speech samples; this yielded a second measure of PCC.

Ten senior-level undergraduate students in elementary education and ten master's students in speech-language pathology provided perceptual severity ratings. The groups were chosen due to the fact that these individuals made frequent judgments of the severity for children with speech impairments (Garrett & Moran, 1992). Listeners were first exposed to six 10-15 second speech samples that represented the range of severity of phonological impairments that would be presented in the listening samples. Listeners were instructed to rate the severity of each child's phonological impairment on a scale from 1 (i.e., mild) to 7 (i.e., severe). Ratings from each of the two groups were averaged for each speech sample.

Reliability of transcription was assessed by comparing the author's transcription to that of a graduate student in speech-language pathology. The graduate student transcribed all of the APP-R responses along with 10% of each speech sample. A mean percentage of agreement of 92% was revealed between the two transcriptions. Interjudge reliability for each of the two listener groups was determined to be .92 for elementary education majors and .86 for speech-language pathology graduate students (Garrett & Moran, 1992). The five severity scores (i.e., PDS, PCC-words, PCC-speech, Elementary Education Listener Ratings, and SLP Grads Listener

Ratings) were rank-ordered and had a high level of agreement (W = .92) and high intercorrelation.

High correlations were observed between PCC and listener severity ratings, while a lower correlation was observed between PCC and PDS measures. Additionally, the higher severity ratings assigned by elementary education students compared to those assigned by speech-language pathology graduate students disagreed with earlier findings, which indicate that there is not a significant difference in severity ratings assigned by experienced listeners and those assigned by inexperienced listeners. The strong correlation between PCC, PDS, and listener severity ratings suggests that the two measures are accurate indicators of severity (Garrett & Moran, 1992). Additionally, high correlations observed between PDS, listener ratings, and PCC based on single words suggest that standardized single-word measures are valid and clinically useful for speech sound assessment.

Flipsen, Hammer, and Yost (2005) examined the variability among clinicians in subjective ratings of "severity of involvement in speech delay," as well as the effect of the child's age on the level of severity assigned by the raters (p. 298). The authors used seventeen conversational speech samples previously collected by Shriberg (1986) from a group of twelve boys and five girls diagnosed with a speech delay who ranged in age from 2;11 to 5;3. Testing and transcription were performed by a speech-language pathologist who had approximately 30 years of experience with child phonology. Narrow transcription was used and all non-English phonemes were excluded. The length of the speech samples varied from 50-97 words, PCC values ranged from 43.5% to 76.7%, and length ranged from 4 to 13.5 minutes based on the intelligibility and lexical knowledge of the child. Listeners in the study included ten speech language pathologists with a minimum of ten years of experience beyond the clinical fellowship,

in the hopes that their familiarity with the rating scales might reduce variance in the severity ratings.

Listeners were not given specific instructions on how to rate the speech samples but were instead asked to used their best clinical judgment to assign ratings for severity of involvement (Flipsen, et al., 2005). Three practice samples from similarly developing children were provided to the clinicians, who could listen to the samples as many times as they needed in order to become familiar with the task and the rating system. Once the listeners proceeded to the samples to be rated, they were instructed to listen to those samples only once and assign a full or midpoint rating. Each listener heard the samples in sound field in quiet offices, using the same sequence and the same type of equipment, which included Windows-based or Macintosh desktops and Bose, Harmon Kardon, or Boston Acoustics speakers. Half of the ten listeners were unaware of the ages of the children in the samples, while the other half were given the child's specific age and gender.

Sixty-eight segmental measures were analyzed through the PEPPER program, including PCC, PCC-A, PCC-R, Percentage Consonants in the Inventory (PCI; Shriberg et al., 1997a), Absolute Omission Index (AOI; Shriberg et al., 1997a), Absolute Substitution Index (ASI; Shriberg et al., 1997a), Absolute Distortion Index (ADI; Shriberg et al., 1997a), Relative Omission Index (ROI; Shriberg et al., 1997a), Relative Substitution Index (RSI; Shriberg et al., 1997a), and Relative Distortion Index (RDI; Shriberg et al., 1997a) and their associated subscales. Whole-word measures including Phonological Mean Length of Utterance (PMLU; Shriberg et al., 1997a), Proportion of Whole-Word Proximity (PWP; Shriberg et al., 1997a), Whole-Word Accuracy (WWA; Shriberg et al., 1997a), Proportion of Whole-Word Variance (PWV; Shriberg et al., 1997a), intelligibility, as well as those previously mentioned were

analyzed through PEPPER. Depending on the listener's use of broad or narrow transcription, interpretations of severity and ratings varied among clinicians. Reliability ranged from 74.1% to 89.3% for transcription and 81% to 98% for various severity rating measures. Variability of the ratings from the ten listeners was examined across all of the samples both informally and with intraclass correlations (Flipsen, et al., 2005). Two analyses were performed to determine the effect of a clinician's knowledge of a child's age on perception of severity. Ratings for clinicians who knew the children's ages were correlated with age and compared to age correlations given by those listeners who were blind to the age of the children. Additionally, the ratings of the two groups of clinicians were directly compared.

Among the ten listeners in the study, there was a great deal of variability in severity ratings across the seventeen speech samples, with ratings displaying more variability in the middle of the scale than at the ends. Additionally, the study revealed no systematic relationship between the severity ratings and the age of the children. An intraclass correlation analysis revealed fair to poor listener agreement (Flipsen, et al., 2005). In the absence of a gold standard for severity ratings in the field, the authors suggest the creation of a "tin standard" in the study with a group of highly experienced listeners that agreed with one another. While it did limit generalization of findings, it allowed researchers to evaluate alternative measures of severity in relation to each other, as well as to perceptual ratings of severity. Through intraclass correlation analysis, this tin standard was determined to possess fair agreement between listeners, a small improvement from the larger group of ten listeners. The variability in ratings between experienced listeners indicates that subjective, informal severity ratings can be problematic and point to the need for more objective measures.

Severity measures focusing specifically on error frequencies were found to have a negative relationship with the severity ratings assigned to the samples. Additionally, rating measures dealing with omissions were found to have a significant positive relationship with the severity ratings assigned to the samples, suggesting that omissions contributed a great deal to listener perception of severity (Flipsen, et al., 2005). Correlations between relative error type measures (ROI) were more complex, with some types displaying negative relationships with severity ratings and some displaying positive relationships; this reveals that different types of errors were treated differently when determining severity ratings. When observing the use of PCC variations to determine severity of delay, PVC and PPC displayed a strong relationship with severity ratings, but PVC-R and PPC-R did not, indicating that clinicians focused more on uncommon distortion errors, as well as vowel errors and vowel distortions. There was no significant difference between the average ratings for those listeners who knew the children's ages and the average ratings for those listeners who were unaware of the children's ages, which indicates that knowledge of subject age does not influence severity ratings. Factors that the authors feel may have affected the listener's severity ratings include the use of conversational speech samples, the variations in sample length, intelligibility, variance in clinician focus during the sample, and the weight of different errors on clinicians' perceptions of severity. Overall, the study did not definitively identify which factors should serve as the basis for evaluating speech sound severity, resulting in a continued lack of consensus with regard to severity of involvement. This lack of consensus among professionals indicates a need for an objective measure to determine severity of involvement.

Previous Research Exploring SLPs' Assessment of Speech Sound Disorders

In light of ASHA's preferred practice patterns and the current lack of consensus among professionals regarding a definite procedure, SLPs' use of measures assessing severity of involvement, such as the PCC metric, is of particular interest; however, little research has been conducted on this subject. Two recent surveys of SLPs in both the United States and Australia explore speech sound assessment procedures commonly used by practicing clinicians.

Skahan, Watson, and Lof (2007) conducted a survey of 1,000 speech-language pathologists randomly selected from the ASHA membership database that examined the assessment practices used with children who have suspected speech sound disorders. Of the 333 respondents who identified themselves as serving the preschool- and school-age populations, a total of 309 respondents reported previous experience working with children with speech sound disorders.

Findings from this study indicated that the respondents used results of their assessments in order to determine eligibility for speech and language services, as well as to establish future therapy goals and procedures. Skahan and colleagues (2007) also found that when determining the assessment protocol used for a child with a speech sound disorder, time constraints were reported to be an impediment to the implementation of comprehensive speech sound assessments. Over half of the participants reported completing direct assessment activities in under 51 minutes, while only 27% of the participants reported devoting more than 60 minutes to these same activities. Interestingly, researchers observed that caseload size was not correlated with the amount of time spent performing assessment tasks; this may be due to the fact that clinicians may feel that they have little flexibility in their assessment procedures because all must follow the same state and federal guidelines when qualifying a child for special education

services. Skahan and colleagues discovered that while caseload size did not affect the time spent during assessment, the clinician's level of experience did have an effect on the amount of time spent on post-assessment activities. More experienced clinicians reported spending more time completing post-assessment analyses than those with fewer years of experience.

Findings from the survey reveal the assessment procedures most commonly used in determining the existence of a speech sound disorder. The most frequently used assessment procedures reported by the participants included conducting a hearing screening, administering a published measure yielding a standard score and percentile rank, estimating intelligibility, and determining stimulability. Over half of the respondents reported conducting an oral mechanism exam as part of their assessment protocol. Participants reported that estimation of intelligibility was an important component of the assessment protocol for a speech sound disorder because it frequently affects decisions about the need for intervention and determining the success of that intervention. However, research has suggested that many clinicians rely on impressionistic estimates of intelligibility rather than conducting a more objective measurement (Skahan et al., 2007; Gordon-Brannan & Hodson, 2000).

The most commonly used published assessments were the *Goldman-Fristoe Test of Articulation (GFTA)* and the *Khan-Lewis Phonological Analysis (KLPA)*. Skahan and colleagues (2007) speculate that the *GFTA*'s validity, reliability, versatility, and efficiency contribute to its continued use, although the information obtained from these measures may be too limited to determine appropriate goals for intervention. Respondents indicated that they only "sometimes" assess phonemic awareness skills, an important component due to the risk of children with speech sound disorders developing inadequate metaphonological skills.

Collection of a continuous speech sample is an essential component of a speech sound assessment, as it allows the clinician to adequately analyze the child's speech sound system. The type of speech sample obtained varies across clients and is dictated by the age of the child and severity of involvement exhibited in the child's speech. The speech-language pathologists that participated in the survey indicated that they administered and analyzed single-word tests more frequently than they elicited continuous speech samples. Upon completion of those measures, the most frequently used speech sound analysis procedure was the determination of the child's phonetic inventory and use of phonological processes. Two potentially valuable procedures that were not used often by survey participants include contextual testing to determine phonetic context effects and analysis of syllable and word shapes (Skahan et al., 2007). While single-word measures of articulation provide information about the child's production of phonemes in all word positions, they provide neither typical nor optimal measures of speech production. Analysis of a continuous speech sample is necessary for accurate determination of intelligibility and quantitative measure of severity (Morrison & Shriberg, 1992).

While collection of a continuous speech sample is ideal for speech sound assessment, the researchers contend that the severity of a child's speech sound disorder may affect the specific assessment procedures used. For example, a child with a more severe speech sound disorder would likely require more thorough assessment and analysis than a child whose impairments are less severe. However, analyzing collected speech samples from children with severe impairments may be more difficult and time-consuming (Skahan et al., 2007). The characteristics of the child and time available for assessment dictate the type of procedures a clinician may use, which may contribute to the variability in current assessment practices.

A more recent survey conducted by Australian researchers also examined assessment and analysis of speech sound disorders in children, as well as target selection, intervention, and service delivery practices for this population. McLeod and Baker (2014) surveyed 231 Australian SLPs that attended seminars conducted by the authors. Results of the study indicated that clinicians regularly conducted parent interviews, obtained child case histories, administered single-word assessments to determine sounds in error, determined stimulability of sounds in error, determined phonological processes, estimated intelligibility, and determined phonetic inventory. The practices less frequently undertaken included conducting hearing screenings, performing contextual testing to determine phonetic context effects, and administering single-word tests to determine the child's percentile rank and standard score. Commonly used analysis procedures among the Australian respondents included phonological process analysis as well as an analysis of substitutions, omissions, distortions, and additions; those that were less frequently used included independent and relational analysis, psycholinguistic analysis, nonlinear analysis, and computer analysis. While Australian SLPs were more likely to administer single-word assessments and determine stimulability than their American colleagues, the authors found that they were less likely to conduct hearing screenings, estimate intelligibility, examine oral motor skills using non-speech tasks, and observe children in the classroom environment. While the researchers included conversational speech sampling for the assessment of speech sound disorders, they did not inquire about the use of a quantitative measure for assessing severity of involvement.

The preceding surveys examining common speech sound assessment practices among American and Australian SLPs indicate that a measure of severity of involvement is not commonly used among practicing clinicians, despite the existence of such measures. Because

determination of severity of involvement is an area in which there is little consensus among professionals (Flipsen, Hammer, & Yost, 2005), the specific assessment procedures currently used by SLPs in the United States, particularly their knowledge and competence of the PCC metric, is of particular interest.

Chapter 3

Justification

Children with speech sound disorders constitute over half of the caseloads of school-based speech-language pathologists. The prevalence of speech sound disorders in children between the ages of five and seven ranges from 2% to 25% (Law et al., 2000). The large percentage of children with speech sound disorders indicates a need for knowledgeable clinicians who are competent in the assessment and treatment of this population.

The American Speech-Language Hearing Association has delineated preferred practice patterns regarding assessment of speech sound disorders, which includes, among other formal and informal assessments, a measure of severity of involvement. Despite its inclusion in ASHA's comprehensive assessment practices, recent studies investigating the assessment practices of current speech-language pathologists revealed that the majority of respondents used neither qualitative nor quantitative severity measures, although quantitative measures such as Percentage of Consonants Correct (PCC) exist (Skahan et al., 2007; McLeod & Baker, 2014). PCC yields the percentage of correctly articulated consonant sounds present out of all consonant sounds attempted from a five-to ten-minute conversational speech sample. While PCC was determined to be a valid and reliable measure that closely aligns with listener perceptions of severity, the use of the PCC metric will no doubt be influenced by SLPs' knowledge and competence using the procedure (Shriberg & Kwiatkowski, 1982; ASHA, n.d.).

The aim of the current study is to investigate speech-language pathologists' knowledge and competence regarding the use of PCC when assessing severity of involvement of a child's speech sound disorder. Questions will address SLPs' education and training in the evaluation of child and adolescent speech sound disorders and their familiarity with current research in this

area, providing insight into whether adequate knowledge about PCC exists in both recent graduates and those who graduated prior to 2005 following the publication of ASHA's Preferred Practice Patterns document in 2004. The skill of SLPs in calculating PCC is of particular interest, as is their ability to choose appropriate therapy targets based on the result of the assessment. Specifically, the current study hopes to answer the following questions:

1) How much academic and clinical training in assessment and diagnosis of speech sound disorders have SLPs received?
2) Does the level of educational and clinical training in the assessment of speech sound disorders differ between recent graduates and those who graduated prior to the publication of ASHA's Preferred Practice Patterns in 2004?
3) What formal and informal speech sound assessment methods are being used by practicing SLPs?
4) How accurate are practicing SLPs in their determination of Percentage of Consonants Correct? Do recent graduates differ from pre-2005 graduates in their ability to calculate PCC and their confidence in doing so?
5) Is there a relationship between SLPs' level of confidence and their competence in calculating PCC?

Chapter 4

Methods

Participants

A total of 62 respondents completed the survey. To meet inclusion criteria, respondents held American Speech-Language-Hearing Association (ASHA) certification or were clinical fellows with experience working with children. If inclusion criteria were not met, they were taken to the end of the survey and their responses were not used for analysis.

Materials

To answer the questions of the study, the investigators created a web-based, 33-item survey via Qualtrics software (See Appendix A) to address questions in five main areas: 1) general demographic information; 2) educational background; 3) service delivery; 4) knowledge regarding Percentage of Consonants Correct (PCC); and 5) competence and confidence in calculating PCC. Following is a description of each area.

Part I questions were designed to acquire information about speech-language pathologists' general professional background and years of experience, and the age range of current caseload. *Part II* questions addressed the participants' educational background with regard to the nature and assessment of speech sound disorders. Pre-professional clinical experience in assessment of children with speech sound disorders was also explored in addition to questions querying professional continuing education courses related to speech sound disorders. *Part III* questions addressed speech-language pathologists' service delivery methods and current caseload characteristics. Questions also investigated SLPs' familiarity with formal and informal assessment practices, as well as the frequency with which each measure is used in their professional practice. *Part IV* questions addressed participants' familiarity with the rules

used to calculate PCC. Participants were asked to answer a set of true/false questions based on Shriberg & Kwiatkowski's (1982) rules for calculating PCC. *Part V* questions addressed participants' ability to accurately calculate PCC. Participants were instructed to calculate PCC for four speech samples of increasing complexity; they were then asked to determine the presence of a speech delay and assign an appropriate severity rating. In addition to their competence with the measure, participants were asked to indicate their confidence in their ability to calculate PCC.

Procedure

Prior to the distribution of the survey, the authors piloted an initial draft of the questionnaire. The authors contacted university faculty members from nine states who indicated a clinical or research interest in the area of articulation and phonology. A group of six articulation and phonology faculty members provided feedback about the content and general format of the survey, which was then modified accordingly.

Participants in the current study were obtained via three methods. Initially, the coordinators for three of ASHA's Special Interest Groups were contacted regarding the project. The selected groups were the Language Learning and Education Special Interest Group (SIG 1), Craniofacial and Velopharyngeal Disorders Special Interest Group (SIG 5), and School-Based Issues Special Interest Group (SIG 16). These special interest divisions were selected due to their focus on service provision to school-aged individuals and the resulting probability that many of their members may be working with individuals with speech sound disorders. An introductory email, containing an information letter with a weblink to the online survey, was sent to the coordinators of these divisions and then posted on the respective listservs.

Following the initial recruitment attempts, a search of the ASHA membership directory through the ASHA community was conducted to find potential participants who (a) hold ASHA certification in speech-language pathology; (b) listed their current place of work as a school or other location where the predominant population is pediatric; and (c) were employed in one of 9 states: Alabama, Colorado, Florida, Illinois, Louisiana, Massachusetts, Missouri, New York, and Washington. This selection process was designed to ensure equal geographic representation, by selecting one state from each geographic division of the United States as defined by the U.S. Census (2010). As participants who fit these criteria were found, the researchers e-mailed the same information letter that was posted on the listserv to every fifth individual as listed in the membership directory. A total of 100 e-mails were sent to speech-language pathologists in each state.

Finally, a message containing a brief description of the survey and its purpose was posted on the ASHA Facebook page. The message also contained an embedded link to direct interested individuals to the survey. When potential participants clicked on the embedded link, they were directed to an alternate version of the survey in which the first question was the information letter; participants were instructed to indicate their consent by selecting either "yes" or "no."

The survey was administered using the online survey tool Qualtrics, which is a secure Internet-based software program used for online survey development. The participants were asked to provide consent to participate by clicking on a link provided in the introductory e-mail. All data was collected anonymously. A total of 900 emails were sent via the ASHA membership directory, and a total of 130 individuals initiated the survey. Responses were then filtered for survey completion, resulting in a total of 62 responses. A total of 10 participants (16.1%) were recruited via the ASHA membership directory, yielding a response rate of 1.1% for that

recruitment method. While response rates could not be calculated for other recruitment methods, 10 (16.1%) individuals were recruited via the ASHA Community Discussion Board; 1 (1.6%) individual was recruited via the ASHA Facebook page; 5 (8.1%) participants were contacted via Special Interest Group 5, Craniofacial and Velopharyngeal Disorders; 31 (50.0%) participants were recruited via ASHA Special Interest Group 16, School-Based Issues; and 5 (8.1%) indicated “other.”

Chapter 5

Results

Data Analysis

Survey responses were filtered for completion and analyzed in Excel. To determine a mean response for each item, the responses for all individuals who responded were averaged. In cases where some participants chose not to respond to a question, the averages were calculated using the number of respondents who responded to that item, as opposed to the number who completed the survey.

General Background Information

A total of 62 participants completed the survey and met inclusion criteria. The majority of respondents indicated that their highest degree received was a master's degree (90.3%; *n* = 56), while 9.6% (*n* = 6) earned a doctorate degree. A total of 32 respondents (51.6%) graduated prior to 2005, while 30 respondents (48.4%) graduated in 2005 or later.

With regard to the location in which the respondents are practicing and professionally licensed, 61 (98.4%) indicated that they are licensed in the United States, while one individual (1.6%) reported holding licensure in Canada. Participants represented the demographic regions of the Northeast, South, Midwest, and West (See Table 1). The largest percentage of respondents reported that they currently practice and hold professional licensure in the South (*n* = 21; 35.6%), followed by the West (*n* = 17; 28.8%), Northeast (*n* = 11; 18.6%), and Midwest (*n* = 10; 16.9%).

Years of professional experience ranged from less than a year (3.2%; *n* = 2) to 16 or more years (48.4%; *n* = 30), while 11 (17.7%) reported 1-5 years of experience, 16 (25.8%) reported 6-10 years of experience, and 3 (4.8%) reported 11-15 years of experience. Regarding the clinic

Table 1. States in Which Participants were Currently Practicing.

Area of Residence	***n* (%)**
South	
Alabama	5 (8.5)
Arkansas	1 (1.7)
Florida	1 (1.7)
Louisiana	2 (3.4)
North Carolina	2 (3.4)
South Carolina	1 (1.7)
Tennessee	2 (3.4)
Texas	7 (11.9)
Midwest	
Illinois	4 (6.8)
Michigan	1 (1.7)
Minnesota	1 (1.7)
North Dakota	2 (3.4)
Ohio	2 (3.4)
Northeast	
Massachusetts	8 (13.6)
New York	2 (3.4)
Rhode Island	1 (1.7)
West	
Arizona	1 (1.7)
California	6 (10.2)
Colorado	4 (6.8)
Nevada	2 (3.4)
Oregon	1 (1.7)
Washington	3 (5.1)

Note. *n* = number of respondents; % = percentage of respondents

population served, all respondents indicated that they work with children for either clinical or research purposes. Respondents were then asked to select all age groups of children that they served. The age group most commonly served by participants are children between the ages of 6;0 to 10;11 (87.1%; *n* = 54), followed by children aged 3;1 to 5;11 (85.5%; *n* = 53), those between the ages of 11;0 to 14;11 (62.9%; *n* = 39), children 15;0 to 21;0 (33.9%; *n* = 21), and finally children from birth to 3;0 years of age (32.3%; *n* = 20).

Educational Background with Regard to Assessment of Speech Sound Disorders

Following questions on general background, participants were queried as to the amount of time dedicated to the assessment of speech sound disorders during their graduate studies. When asked how many courses in their graduate studies addressed speech sound assessment as a component of the course, the largest percentage (46.8%; *n* = 29) reported that two courses addressed speech sound disorder assessment, while 32.3% (*n* = 20) indicated one course, and 17.7% (*n* = 11) indicated three courses. Although 3.2% of respondents (*n* = 2) indicated that they had no graduate coursework addressing the assessment of speech sound disorders, it is possible that these individuals had an undergraduate course that addressed speech sound assessment as a component of the course. Of these courses, the number of contact hours of instruction devoted to speech sound assessment ranged from 1-3 hours (22.4%; *n* = 13) to 9 or more hours (27.6%; *n* = 16), with 15 respondents (25.8%) reporting 4-6 hours and 14 (24.1%) reporting 7-9 hours of instruction. When asked about continuing education, 83.9% of respondents (*n* = 52) indicated that they had obtained credits related to speech sound disorders since receiving their highest degree. Additionally, 57.7% (*n* = 30) reported that they annually seek out continuing education credits related to speech sound disorders.

Participants were then presented with a Likert-type scale and asked to rate their past exposure to various speech sound assessment measures. Participants were asked to rate how familiar they became with 18 formal and informal assessment measures during their undergraduate and graduate training programs. Responses are in Table 2.

Table 2. SLPs' exposure to speech sound assessment procedures during educational training.

	Never exposed		Reviewed		Practiced administering		Administered		I do not recall	
	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
GFTA	0.0	0	8.1	5	16.1	10	75.8	47	0.0	*0*
KLPA	9.7	6	32.3	20	9.7	6	30.6	19	17.7	11
DEAP	56.9	33	12.1	7	1.7	1	3.4	2	25.9	15
HAPP	13.6	8	30.5	18	10.2	6	23.7	14	22.0	13
PAT	16.9	10	27.1	16	8.5	5	28.8	17	18.6	11
SPAT-D	39.7	23	15.5	9	3.4	2	12.1	7	29.3	17
Arizona	22.0	13	22.0	13	8.5	5	27.1	16	20.3	12
Phonetic transcription	6.7	4	13.3	8	21.7	13	51.7	31	6.7	4
Phonetic inventory	4.9	3	16.4	10	26.2	16	45.9	28	6.6	4
PCC	18.9	11	20.7	12	15.5	9	20.7	12	24.1	14
SSL	17.2	10	18.9	11	17.2	10	22.4	13	24.1	14
Phonotactic analysis	25.4	15	22.0	13	15.3	9	8.5	5	28.8	17
Phonological MLU	22.4	13	10.3	6	29.3	17	18.9	11	18.9	11
CAAP	27.6	16	27.6	16	8.6	5	8.6	5	27.6	16
BBTOP	31.7	19	26.7	16	8.3	5	3.3	2	30.0	18
McDonald Deep	34.5	20	31.0	18	6.9	4	10.3	6	17.2	10
Severity rating	11.5	7	21.3	13	8.2	5	42.6	26	16.4	10
Intelligibility rating	3.4	2	15.3	9	16.9	10	52.5	31	11.9	7

Note: *n* = number of respondents per degree of familiarity; % = percentage of respondents; GFTA = Goldman Fristoe Test of Articulation; KLPA = Khan Lewis Phonological Analysis; DEAP = Diagnostic Evaluation of Articulation and Phonology; HAPP = Hodson Analysis of Phonological Patterns; PAT = Picture Articulation Test; SPAT-D = Structured Photographic Articulation Test; PCC = Percentage of Consonants Correct; SSL = Syllable Structure Level; MLU = Mean Length of Utterance; CAAP = Clinical Assessment of Articulation and Phonology; BBTOP = Bankson-Bernthal Test of Phonology; McDonald = McDonald Deep Test of Articulation

Of the formal assessment measures, respondents indicated that they were most familiar with the *Goldman-Fristoe Test of Articulation* and the *Khan-Lewis Phonological Analysis*; the informal assessments with which participants were most familiar included intelligibility ratings, phonetic transcription, phonetic inventories, and severity ratings.

With regard to the level of exposure participants had to Percentage of Consonants Correct (PCC), the majority of respondents had at least some exposure during graduate study (56.9%; n = 33). Slightly over one-third of the participants responding that they had experience calculating PCC either through practice in a course or with a client (36.2%; n = 21); however, 18.9% reported they did not have exposure to PCC in graduate study, and 24.1% of respondents did not recall their exposure to the PCC metric.

A chi-square analysis was conducted in SPSS to evaluate whether recent graduates received more or less exposure to PCC during undergraduate and graduate coursework. The two variables were (a) year of graduation, with two levels (recent and pre-2005) that were collapsed from the initial four in the survey (prior to 1985, 1985-1994, 1995-2004, and 2005-present), and (b) degree of exposure to PCC, with three levels (no exposure, course review, and practice administration) collapsed from the initial five (no exposure, course review, administration in a course, administration with a client, and unknown exposure). Table 3 displays the sample size and proportions associated with each of these levels.

Table 3. Exposure to PCC in recent (2005-present) vs. prior graduates (before 2005).

	Recent		Prior	
	%	*n*	%	*n*
No exposure	14.8	4	41.2	7
Course review	29.6	8	23.5	4
Practice administration	55.6	15	35.3	6

Note: n = number of respondents per level of exposure; % = percentage of respondents

Because of its' robustness to small sample sizes, 2x3 Fisher's exact tests were used to determine significance as >20% of the cells had expected counts of less than 5 (i.e., the suggested minimum for Pearson chi-square analyses). Year of graduation was not found to be significantly related to degree of exposure to PCC (Fisher's exact test, $p = .167$).

Respondents who indicated they had exposure to PCC in undergraduate or graduate school were then queried as to the amount of time devoted to the measure. Of the 33 respondents who answered this question, responses ranged from no classes to more than one month. The largest percentage of respondents (45.5%; $n = 15$) indicated one class, while 24.2% ($n = 8$) indicated more than one week, 15.2% ($n = 5$) indicated more than one month, 9.1% ($n = 3$) indicated one month, and 6.1% ($n = 2$) reported that PCC was not discussed at all. Respondents were also presented with a Likert-type scale designed to determine whether they felt they could have benefitted from additional coursework devoted to speech sound assessment. In response to this question, 14 participants (22.6%) indicated that they strongly agreed, 18 (29.0%) agreed with the statement, 17 (27.4%) neither agreed nor disagreed, 11 participants (17.7%) disagreed, and 2 (3.2%) strongly disagreed with the statement.

Respondents were then asked a series of questions to determine the level of clinical experience received during their graduate training programs with regard to the assessment of speech sound disorders. When asked how many children with speech sound disorders they had the opportunity to assess during their practicum in the university clinic, the largest number of respondents (44.3%; 27) indicated 5 or more while 26.2% ($n = 16$) indicated 3-4 children, 21.3% ($n = 13$) indicated 1-2 children, and 3.3% ($n = 2$) indicated they did not have the opportunity to assess any children with speech sound disorders at the university clinic. An additional 4.9% ($n = 3$) indicated that they did not have a practicum experience in the university clinic. When asked if

they had the opportunity to use PCC in the university clinic to assess the severity of a child's speech sound disorder, the majority (80.3%; *n* = 49) indicated that they did not.

Respondents were also queried as to the number of children with speech sound disorders they had the opportunity to assess during their off-campus practicum. The majority of respondents indicated they assessed 5 or more children with speech sound disorders (60.7%; *n* = 37), while 14 participants (22.9%) assessed 3-4 children, 5 (8.2%) reported that they assessed 1-2 children, and 4 respondents (6.6%) reported that they did not assess any children with speech sound disorders. One participant (1.6%) indicated that they did not have an off-campus clinical practicum. Of those respondents who did have an off-campus practicum experience, only 18.0% (*n* = 11) reported having the opportunity to use PCC to assess the severity of a child's speech sound disorder.

Participants were then presented a Likert-type scale designed to determine whether they believed they could have benefitted from additional clinical experience related to assessing children with speech sound disorders. When asked to describe the degree to which they agreed with the previous statement, 16.1% of individuals (*n* = 10) strongly agreed, 40.3% (*n* = 25) agreed, 24.2% (*n* = 15) neither agreed nor disagreed, 16.1% (*n* = 10) disagreed, and 3.2% (*n* = 2) strongly disagreed. The majority (56.4%; *n* = 35), therefore, either agreed or strongly agreed that they would have benefitted from additional clinical experience assessing speech sound disorders in children.

Service Delivery

Respondents were asked a series of questions exploring their service delivery methods and current caseload characteristics. When asked what percentage of their current caseload is comprised of children, the majority of respondents (91.9%; *n* = 57) reported that children

comprised 91-100% of their caseload, while 4.8% of respondents (*n* = 3) reported a caseload of 81-90% children, 1.6% of participants (*n* = 1) reported 61-70%, and 1.6% of respondents (*n* = 1) reported a caseload comprised of 0-10% children. Participants were then queried as to what percentage of the children on their caseloads were receiving treatment for speech sound disorders (See Table 4).While reported percentages varied, over half of the respondents (53.2%; *n* = 33) indicated that at least 41% of their caseloads were receiving treatment for speech sound disorders.

Table 4. Percentage of caseload receiving treatment for speech sound disorders.

	%	*n*
0-10%	16.1	10
11-20%	8.1	5
21-30%	11.3	7
31-40%	11.3	7
41-50%	12.9	8
51-60%	9.7	6
61-70%	11.3	7
71-80%	11.3	7
81-90%	1.6	1
91-100%	6.5	4

Note: N = 62; *n* = number of respondents; % = percentage of respondents

Participants were then presented with a Likert-type scale designed to describe the frequency with which they use certain formal and informal speech sound assessment procedures; respondents were asked to indicate frequency by choosing "Always," "Sometimes," "Rarely," or "Never." The most commonly used formal and informal assessments included the *Goldman-Fristoe Test of Articulation*, phonetic transcription, phonetic inventory, severity ratings, and intelligibility ratings. A full description of participants' responses is provided in Table 5.

Table 5. Frequency with which SLPs use speech sound assessment measures.

	Always		Sometimes		Rarely		Never	
	%	*n*	%	*n*	%	*n*	%	*n*
GFTA	54.8	34	33.9	21	3.2	2	8.1	5
KLPA	3.3	2	29.5	18	18.0	11	49.2	30
DEAP	0.0	0	3.3	2	4.9	3	91.8	56
HAPP	4.9	3	14.8	9	19.7	12	60.7	37
PAT	0.0	0	16.1	10	12.9	8	70.9	44
SPAT-D	1.6	1	8.2	5	8.2	5	81.9	50
Arizona	6.6	4	6.6	4	9.8	6	77.0	47
Phonetic transcription	50.0	30	20.0	12	6.7	4	23.3	14
Phonetic inventory	40.3	25	38.7	24	4.8	3	16.1	10
PCC	8.1	5	20.9	13	14.5	9	56.5	35
SSL	14.5	9	33.9	21	12.9	8	38.7	24
Phonotactic analysis	8.1	5	24.2	15	3.2	2	64.5	40
Phonological MLU	8.1	5	25.8	16	4.8	3	61.3	38
CAAP	3.3	2	18.0	11	8.2	5	70.5	43
BBTOP	0.0	0	3.3	2	1.6	1	95.1	58
McDonald Deep	0.0	0	1.6	1	9.8	6	88.5	54
Severity rating	51.6	32	27.4	17	8.1	5	12.9	8
Intelligibility rating	66.1	41	24.2	15	4.8	3	4.8	3

Note: n = number of respondents per category; % = percentage of respondents; GFTA = Goldman Fristoe Test of Articulation; KLPA = Khan Lewis Phonological Analysis; DEAP = Diagnostic Evaluation of Articulation and Phonology; HAPP = Hodson Analysis of Phonological Patterns; PAT = Picture Articulation Test; SPAT-D = Structured Photographic Articulation Test; PCC = Percentage of Consonants Correct; SSL = Syllable Structure Level; MLU = Mean Length of Utterance; CAAP = Clinical Assessment of Articulation and Phonology; BBTOP = Bankson-Bernthal Test of Phonology; McDonald = McDonald Deep Test of Articulation

Knowledge of PCC Rules

Participants were asked a series of true/false questions designed to determine their knowledge of the rules used to calculate PCC. It should be noted that two queried rules (i.e.,

Target consonants in all repetitions of a syllable are scored, Target consonants in words that are partially or completely unintelligible should be scored) were listed twice and therefore were omitted from data analysis. Overall, participants demonstrated strengths and weaknesses in their knowledge of the rules of PCC Calculation (see Table 6). The largest percentage of respondents demonstrated understanding that deletions, substitutions, and distortions would be scored as incorrect, while the minority of respondents demonstrated understanding of rules, such as adding a consonant before a vowel, deletion of stressed and unstressed /ɝ/ and /ɚ/, and deletion of initial /h/ and final /n/ for /ŋ/ substitution.

Table 6. SLPs' knowledge of the rules governing PCC.

	Correct	Incorrect
	n (%)	*n* (%)
*Consonants in the third or successive repetitions of adjacent words should be scored only if articulation changes (e.g. /kʌp, kʌp, kʌp/ versus /kʌp, tʌp, kʌp/).	25 (60.9)	16 (39.0)
*Deletion of a target consonant is scored as incorrect.	37 (90.2)	4 (9.8)
*Substitution of another sound for a target consonant is scored as incorrect.	38 (92.7)	3 (7.3)
Addition of a consonant before a vowel (e.g., /hæt/ for "at") is scored as incorrect.	13 (31.7)	28 (68.3)
*Partial voicing of initial target consonants is scored as incorrect.	26 (63.4)	15 (36.6)
*Distortions of a target consonant are scored as incorrect.	36 (87.8)	5 (12.2)
*Addition of a sound to a correct or incorrect target consonant (e.g., /kɑrks/ for "cars") is scored as incorrect.	29 (70.7)	12 (29.3)
Deletion of stressed and unstressed /ɝ/ and /ɚ/ is scored as incorrect.	14 (34.1)	27 (65.9)
*Deletion of initial /h/ and final /n/ for /ŋ/ substitution is scored as incorrect only when they occur in stressed syllables.	15 (36.6)	26 (63.4)
*Deletion of post-vocalic /r/ is scored as incorrect.	28 (68.3)	13 (31.7)
Allophones are scored as incorrect (e.g., /bʌɾɚ/ for /bʌtɚ/).	23 (56.1)	18 (43.9)

Note. * = True answers are marked with an asterisk; *n* = number of participants; % = percentage of participants

A chi-square analysis was conducted to evaluate whether recent graduates received more exposure to PCC during undergraduate and graduate coursework. The two variables were (a) year of graduation, with two levels (recent and pre-2005) that were collapsed from the initial four in the survey (prior to 1985, 1985-1994, 1995-2004, and 2005-present), and (b) number of correct responses to questions, collapsed from a possible score zero to 13 to the following three categories (zero -5, 6-9, 10-13). See Table 7 for the *n* and percentages associated with these levels.

Table 7. Number of true/false questions answered correctly in recent vs. prior graduates.

	Recent		Prior	
	%	*n*	%	*n*
0-5 Correct	19.2	5	45.0	9
6-9 Correct	61.5	16	50.0	10
10-13 Correct	19.2	5	5.0	1

Note: n = number of respondents per category; % = percentage of respondents

Because of its' robustness to small sample sizes, a 2x3 Fisher's exact tests was used to determine significance as >20% of the cells had expected counts of less than 5. Year of graduation was not found to be significantly related to number knowledge of PCC rules (Fisher's exact test, p =.366).

Calculation of PCC

To determine their competence in using the PCC metric, participants were asked to calculate PCC for four speech samples of increasing complexity. Table 8 compares the abilities of recent graduates and their pre-2005 counterparts to correctly calculate PCC, both by exact percentage and within the correct range of severity.

Table 8. SLPs' accuracy in PCC calculation: Recent graduates vs. prior graduates

	Accurate Percentage				Within Severity Range			
	Recent Graduates		Prior Graduates		Recent Graduates		Prior Graduates	
	%	*n*	%	*n*	%	*n*	%	*n*
Word level	39.1	9	29.4	5	73.9	17	47.1	8
Phrase level	39.1	9	23.5	4	52.2	12	35.3	6
Sentence level	16.7	4	5.9	1	79.2	19	41.2	7
Multi-sentence sample	9.1	2	12.5	2	40.9	9	31.3	5

Note: n = number of respondents per category; % = percentage of respondents

Of the 62 individuals who completed the survey, 41 participants from both graduate groups elected to respond to questions in this section. When asked to calculate the PCC for a single word, 34.1% of participants (*n* = 14) provided an accurate percentage; however, 60.9% (*n* = 25) calculated a PCC that was within the appropriate severity range as proposed in Shriberg & Kwiatkowski (1982). A chi-square analysis was conducted to evaluate whether recent graduates were more or less accurate when calculating PCC. The two variables were (a) year of graduation and (b) accurate PCC calculation. No significant difference was found at the word level between recent graduates and prior graduates in the accuracy of PCC calculation, Pearson χ^2 (1, N = 40) = .406, p = .739, Cramer's V = .101. Additionally, no significant difference was found between groups of graduates in regard to their ability to calculate a PCC within the appropriate severity range, Pearson χ^2 (1, N=40) = 3.01, p = .107, Cramer's V= .274.

When asked to calculate the PCC for a phrase, 31.7% of participants (*n* = 13) provided an accurate percentage, while 41.5% (*n* = 17) calculated a PCC that was within the appropriate severity range. A chi-square analysis was conducted to evaluate whether recent graduates were

more accurate when calculating PCC at the phrase level. The two variables were (a) year of graduation and (b) accurate PCC calculation. No significant difference was found at the phrase level between recent graduates and prior graduates in PCC accuracy, Pearson χ^2 (1, N=40) = 1.09, p = .333, Cramer's V = .165; there was also no significant difference in the ability of the two groups to calculate PCC within an appropriate severity range, Pearson χ^2 (1, N=40) = 1.13, p = .345, Cramer's V = .168.

When asked to calculate the PCC at the sentence level, 12.2% of participants (n = 5) provided an accurate percentage, while 63.4% (n = 26) calculated a PCC that was within the appropriate severity range. A chi-square analysis was conducted to evaluate whether recent graduates were more accurate when calculating PCC at the sentence level. The two variables were (a) year of graduation and (b) accurate PCC calculation. No significant difference was found at the sentence level between groups of graduates with regard to accuracy of PCC calculations, Fishers exact test = .382. However, recent graduates were shown to be more likely to calculate a PCC within the appropriate range of severity, Pearson χ^2 (1, N=41) = 6.19, p = .021, Cramer's V = .168.

When asked to calculate the PCC for a three-sentence speech sample produced by a four-year-old female speaker of Standard American English (SAE), 9.8% of participants (n = 4) provided an accurate percentage, while 34.1% (n = 14) calculated a PCC that was within the appropriate severity range. A chi-square analysis was conducted to evaluate whether recent graduates were more accurate when calculating PCC in the multi-sentence sample. The two variables were (a) year of graduation and (b) accurate PCC calculation. No significant difference was found between groups of graduates with regard to PCC accuracy, Fishers exact test = 1.00 or

their ability to calculation of a PCC within the appropriate severity range, Pearson χ^2 (1, N=38) = .371, p = .735, Cramer's V = .099.

Participants were then asked to determine the presence and severity of a speech sound disorder based on the PCC for a given sample whose PCC of 66.6% correlated to a mild-moderate severity rating as proposed by Shriberg & Kwiatkowski in 1982. After calculating the PCC for a three-sentence sample produced by a four-year-old female speaker of Standard American English (SAE), 65.0% of respondents (n = 26) correctly selected either mild or moderate, indicating the presence of a mild-moderate speech sound disorder. When asked to rate the severity of the child's speech sound disorder, a total of 25 respondents (96.2%) appropriately placed the child's speech sound disorder within Shriberg & Kwiatkowski's mild-moderate range, with 50.0% of respondents (n = 13) indicating a mild disorder, 46.2% (n = 12) indicating a moderate disorder, and 3.8% (n = 1) indicating a severe disorder. When asked what they based their severity rating on, 26.9% of respondents (n = 7) indicated that they based their judgment of severity on their PCC calculation, while 73.1% (n = 19) based their judgment of severity on clinical experience.

Confidence in Calculation of PCC

Finally, respondents were queried with regard to the degree of confidence in their ability to calculate PCC. Participants were asked to rate their degree of confidence using a five-point Likert-type scale. When asked to indicate the extent to which they agreed with the statement, "I am confident in my ability to calculate PCC," 29.3% (n = 12) of respondents strongly disagreed, 24.4% (n = 10) disagreed, 21.9% (n = 9) neither agreed nor disagreed, 21.9% (n = 9) agreed, and 2.4% (n =1) strongly agreed. A chi-square analysis was conducted to evaluate whether recent graduates were more or less confident with regard to calculation of PCC. The two variables were

(a) year of graduation and (b) reported confidence in the calculation of PCC. Confidence was collapsed into three levels (i.e., agree/strongly agree, neutral, and disagree/strongly disagree). No significant difference was found with regard to confidence between recent graduates and prior graduates in PCC accuracy, Pearson χ^2 (2, N=52) = .410, p = .815, Cramer's V = .089.

Relationship between confidence and competence. Correlation coefficients were calculated among reported confidence (collapsed into 3 levels as indicated above), competence calculating PCC at the sample level based on an exact percentage, and competence calculating PCC within the same severity level. Using the Bonferroni approach to control for Type 1 error across the 3 correlations, a p value of less than .016 (.05/3 = .016) was required for significance. Based on the results of correlation analysis, neither the ability to correctly determine PCC at the percentage level (r = .115, p = .472) or within the correct severity rating (r = .068, p = .674) were significantly related to confidence in calculation of PCC; however, the ability to calculate PCC correctly at the percentage level and the ability to ability to calculate PCC within the correct severity level reached a moderate level of significance (r = .457, p = .00).

Chapter 6

Discussion

The purpose of this study was to explore speech-language pathologists' (SLPs') knowledge and competence regarding Percentage of Consonants Correct (PCC), specifically those who serve pediatric populations. The findings of the study indicate that the majority of SLPs have limited knowledge with regard to the rules used to calculate PCC, and their resulting ability to accurately calculate PCC is somewhat low. As a quantitative measure of severity is advocated by ASHA (n.d.), these findings suggest that SLPs may benefit from increased clinical and academic training; however, the possibility exists that the development of a more efficient quantitative tool for determining speech sound severity may be required to sufficiently address the need indicated by the current findings.

Background

Respondents were asked a series of questions with regard to both their general background and their level of education relating to the assessment of speech sound disorders. With regard to the location in which participants are currently practicing and professionally licensed, the largest percentage of respondents indicated that they worked in the South, followed by the West, Northeast, and Midwest. The high response rate from the South may be the result of a regional bias, as respondents from the South may have been more likely to respond to a survey request from a southern university.

Educational Background with Regard to Assessment of Speech Sound Disorders

Approximately half of the participants received their highest degree prior to the publication of ASHA's current Preferred Practice Patterns in 2004, while the remainder of the participants graduated in the year 2005 or after. During their graduate training programs, 96.8%

of respondents indicated that they had at least one course in which the assessment of speech sound disorders was a component of the course. Throughout these courses, participants became most familiar with the *Goldman Fristoe Test of Articulation*, the *Khan-Lewis Phonological Analysis*, intelligibility ratings, phonetic transcription, phonetic inventories, and severity ratings. As the *GFTA* and the *KLPA* have been found to be the most commonly used assessment tools (Skahan et al., 2007), respondents' high familiarity with these measures may be reflective of this. The possibility exists that the instruments which clinicians become the most familiar with in graduate training will become used the most clinically. Equally possible, as Skahan and colleagues (2007) speculated about its' clinical popularity, the *GFTA*'s and *KLPA*'s validity, reliability, versatility, and efficiency contribute to their high frequency of exposure in the graduate curriculum. Also, knowing that clinicians are most likely to use this test throughout their careers, it is logical that the large majority of programs would give students exposure to this often-used assessment.

Exposure to PCC. While slightly over half of survey respondents discussed PCC as a component of their graduate coursework, only slightly more than 1/3 of participants had experience calculating PCC either through practice in a course or with a client. The majority of participants also reported limited experience related to using PCC as a speech sound assessment practice in their clinical practicum, with only around 20% having experience using PCC to assess speech sound severity. It is surprising that clinicians do not receive more exposure to PCC in their undergraduate and graduate training programs, as objective measures of severity of involvement like PCC are specifically mentioned in ASHA's online Practice Portal for articulation and phonology. It is also interesting that although their exposure to PCC was limited, participants recognized the importance of the measure as slightly over half of the participants

believed that they could have benefitted from additional academic and clinical training in the assessment of speech sound disorders in children.

Data related to exposure to PCC was further examined to determine whether a relationship existed between a participants' graduation date and their level of exposure to PCC. Findings indicated that there was no significant relationship between recent graduates and those who graduated prior to 2005 in their level of academic or clinical exposure to PCC. It was expected that recent graduates would have greater exposure to PCC in their graduate training in light of ASHA's recommendation of objective, ecologically valid speech sound severity measures like PCC in both their Preferred Practice Patterns and their online Practice Portal. However, as PCC was developed by Shriberg and Kwiatkowski in 1982, its emergence as a novel assessment of speech sound severity may have resulted in its' use in graduate preparation even prior to the publication of the ASHA's Preferred Practice Patterns.

Service Delivery

All respondents indicated that they currently serve children for either clinical or research purposes, and the majority serve children with speech sound disorders. This finding is not surprising, as recent data from ASHA (2014) indicates that approximately 93% of school-based SLPs report that they serve students with articulation/phonology delays or disorders. Of those who routinely serve children with speech sound disorders, the majority relied on standardized measurements to determine their clients' speech sound abilities. This finding supports previous research by Skahan and colleagues (2007) as well as McLeod and Baker (2014), who found that SLPs commonly used published single-word measures for speech sound assessment, such as the *Goldman-Fristoe Test of Articulation (GFTA)* and the *Khan-Lewis Phonological Analysis (KLPA)*. It is to be expected that practicing clinicians would use the speech sound assessment

measures with which they became most familiar during their graduate training programs as the findings of the current investigation indicate.

The current study also found that the most commonly used informal speech sound assessment measures were broad and narrow phonetic transcription, phonetic inventory, severity ratings, and intelligibility ratings. Skahan and colleagues (2007) presented similar findings, with participants indicating that they commonly collect speech samples with which they calculate the child's phonetic inventory and estimate intelligibility. Similarly, a survey of Australian SLPs conducted by McLeod and Baker in 2014 revealed that respondents frequently determined the phonetic inventory and estimated the intelligibility of children with speech sound disorders on their caseloads. As respondents indicated gaining the most exposure to phonetic transcription, phonetic inventory, severity ratings, and intelligibility ratings during graduate school, it is not surprising that these four measures are the most commonly used informal assessment procedures in clinicians' speech sound assessment practice. It is also possible that phonetic transcription, phonetic inventory, and severity ratings may all be derived from standardized assessments such as the *GFTA.*

With regard to PCC, the majority of participants in the current study indicated that they rarely or never use PCC as a speech sound assessment measure. Although advocated in ASHA's online Practice Portal, reasons exist which may account for its' lack of use, such as time constraints, as well potential reasons found in the current investigation (e.g., decreased academic and clinical exposure, competence and confidence related to PCC). If the majority of SLPs have not had significant exposure and training in PCC and are not competent or confident in their abilities, it stands to reason they would not frequently use the measure. In addition, the lack of use of PCC is not surprising given that speech sound severity measures such as PCC were

omitted from previous studies of speech sound assessment practices (McLeod & Baker, 2014; Skahan et al., 2007). The omission of an objective measure of speech sound severity such as PCC from the service delivery of practicing SLPs may be reflective of the lack of consensus regarding the use of speech sound severity measures among practicing SLPs, which may also contribute to clinicians' limited use of the measure.

Knowledge of PCC Rules

Participants in the current study demonstrated inconsistent knowledge with regard to the rules used to calculate PCC. While typically more than half of respondents demonstrated an understanding of the rules regarding how to distinguish correct from incorrect utterances, respondents were most familiar with the commonly discussed and encountered errors of substitutions, distortions, and omissions (Preston & Edwards, 2010; Smit, 1993a). They demonstrated greater difficulty with more complex and perhaps less encountered errors such as consonant epenthesis; when presented, participants demonstrated a tendency to incorrectly label them as errors. The inconsistent knowledge of the rules for calculating PCC was not surprising given that the majority of participants indicated limited exposure to PCC during their undergraduate and graduate training programs, as well as limited opportunities to use PCC to assess speech sound severity during their clinical practicum experiences. Further, responses were examined to determine whether participants' year of graduation was related to their knowledge of the rules governing the use of PCC. Results indicated that there was no significant relationship between knowledge of PCC rules in recent graduates and those who graduated prior to 2005. This is also somewhat expected given that the current investigation indicated that neither group of participants reported more academic or clinical exposure to PCC than the other.

Competence and Confidence in Calculation of PCC

Of the 62 individuals who completed the survey, only 41 participants elected to respond to questions requiring the application of PCC to samples of varying length. The authors believe that the lack of academic/clinical exposure and general lack of practical use of this measure may have negatively affected the response rate for questions in this section. Results of the study suggested that as the length of the speech sample increased, participants' ability to calculate an accurate PCC decreased. When asked to calculate the PCC for a single word, slightly over one-third of respondents provided an accurate percentage, as opposed to the one-tenth of respondents who provided an accurate PCC for a three-sentence speech sample. As spontaneous speech samples are typically well beyond one-word utterances, this is of concern; however, results were more promising when analyzed based on the participant's ability to calculate a PCC within the appropriate severity range as proposed in Shriberg & Kwiatkowski (1982). These findings indicated that a larger percentage of respondents were able to identify the correct severity level of a child based on PCC calculation in instances where the calculation was not exact. Even through this lens, however at least one-third of clinicians were not able to do so correctly at the word, phrase or sentence level. Factors involved in this may be lack of academic or clinical exposure, decreased knowledge of the rules, or simply that they do not frequently use the measure so have not retained the skills necessary to accurately calculate PCC.

The current investigation also sought to determine whether respondents' graduation date was related to their ability to calculate PCC. No significant relationship was found between participants' year of graduation and their ability to accurately calculate PCC at the word, phrase, or sentence level or in a multi-sentence sample. These findings were not surprising given the limited knowledge of the rules for calculating PCC demonstrated by both recent graduates and

those who graduated prior to 2005. No significant relationship was found between year of graduation and participants' ability to calculate a PCC within the appropriate severity range at the word level, phrase level, or in a multi-sentence sample; however, recent graduates were significantly more likely than their pre-2005 counterparts to calculate a PCC within the appropriate severity range at the sentence level. It is possible that the more recent exposure to PCC academically and/or clinically accounts for this; however, why this difference occurs at the sentence level as opposed to levels of lesser and greater complexity remains to be seen.

After providing a judgment of speech sound severity, almost three quarters of participants indicated that their judgment of severity was based on clinical experience rather than determination of PCC. These findings were somewhat expected in light of participants' lack of academic and clinical experience using PCC, as well as their frequent omission of the measure from their speech sound assessment service delivery. Not surprisingly, over half of the participants in the current study indicated that they were not confident in their ability to calculate PCC; additionally, there was no significant relationship between confidence in recent graduates and those who graduated prior to 2005. The authors believe this could be a result of the shared lack of exposure to PCC experienced by both groups during their undergraduate and graduate training. Additionally, the lack of confidence felt by participants may have negatively impacted their likeliness to respond to the questions requiring them to calculate the PCC for a given sample. What was surprising, however, was that there was no significant relationship between participants' confidence and competence in calculating PCC. One's ability to correctly calculate PCC does not, therefore, directly relate to ability.

Limitations and Future Directions

The primary limitation of the current investigation is the low response rate. Of the 900 individuals invited to participate in the survey via email, 10 completed the survey through this recruitment method, yielding a 1.1% response rate. The low response rate indicates that this sample may not fully represent the general population. Despite the low response rate, however, participants represented all four geographic regions of the United States.

Another factor that could limit the current investigation's generalization is the possibility that only SLPs interested in speech sound assessment and PCC may have responded to the survey. If an SLP has a particular interest in this subject they may regularly seek out additional information on the topic and be more aware than an SLP who does not have a particular interest in the subject. In fact, more than half of the participants in the current study indicated that they seek out continuing education credits related to speech sound disorders annually. Therefore, the possibility exists that clinicians are not as knowledgeable about the PCC measure as indicated by the results of this survey.

There is currently a lack of consensus among practicing clinicians regarding the best methods of determining speech sound severity in children (Flipsen, Hammer, & Yost, 2005). Because PCC is a well-validated measure that closely aligns with listener perceptions of severity, it is surprising that the tool is rarely used in current speech sound assessment practices (McLeod & Baker, 2014; Skahan et al., 2007). It would be of interest to examine the reasons behind clinicians' limited use of the measure to assess speech sound severity, such as time constraints, level of difficulty, lack of confidence, lack of academic and clinical training, etc.

Also surprising is that clinicians who graduated following the publication of ASHA's Preferred Practice Patterns and who had access to ASHA's online Practice Portal, which

specifically mention PCC as a recommended measure of speech sound severity, indicated limited academic and clinical exposure to PCC in their undergraduate and graduate training. It is surprising that despite ASHA's recommendation of its use due to its validity and similarity to listener perceptions of severity, training programs do not more extensively advocate its use (2004; Shriberg & Kwiatkowski, 1982). It would be of interest to examine the reasons behind the lack of emphasis placed on PCC in speech-language pathology training programs.

Another unexpected finding from this study is the lack of a relationship between participants' confidence and competence in calculating PCC; these results suggest that clinicians' self-efficacy in regard to PCC has little effect on their ability to accurately calculate the measure. To examine the relationship between self-efficacy and performance with regard to PCC calculation, it may be of interest to conduct further examination of SLPs' competence in PCC calculation with the inclusion of a self-efficacy measure.

Clinical Implications

The current investigation offers a novel perspective on the assessment of severity of involvement in children with speech sound disorders. To the authors' knowledge, this study is the first to examine speech-language pathologists' competence in calculating PCC. This was accomplished by asking participants to calculate the PCC for speech samples increasing in complexity from the word level to a three-sentence sample. Additionally, to ensure that participants' phonetic transcription skills did not affect their calculation of PCC, each phonetically transcribed speech sample was accompanied by both an orthographic and phonetic gloss. Further, this study was the first to examine speech-language pathologists' confidence in their ability to calculate PCC.

The results of this study are consistent with recent findings (McLeod & Baker, 2014; Skahan et al., 2007) regarding current speech sound assessment practices. Participants in the current study frequently relied on standardized assessments such as the *GFTA* and *KLPA*, as well as phonetic transcription, phonetic inventory, severity ratings, and intelligibility ratings. However, quantitative severity measures, particularly PCC, are rarely used despite being well-validated and closely aligned with listener perceptions of severity. Additionally, participants reported limited academic and clinical exposure to PCC, inconsistent knowledge of PCC rules, and a lack of confidence using the measure; therefore, it appears that some pediatric speech-language pathologists could benefit from additional instruction with regard to PCC rules and clinical experience calculating PCC.

Although additional clinical and academic exposure to PCC may increase SLPs' level of familiarity and competence with the measure, it does not necessarily follow that this increased knowledge will result in SLPs' more frequent use of the measure in their speech sound assessment practices. Calculating PCC can be a time-consuming task, and although increased experience and practice with the measure may increase the speed with which an individual can complete this assessment, some clinicians may not consider the use of PCC a feasible task given the limited assessment time available to many clinicians. Although PCC is a valid method for objectively quantifying severity of involvement, the time and skill involved in using the measure may render it more appropriate for research rather than frequent clinical use. Despite its faults, clinicians' omission of PCC and other objective severity measures is concerning in light of ASHA's recommendation of their use during comprehensive speech sound assessments (n.d.; 2004). In light of ASHA's recommendations, the findings of the current study suggest that a need exists among SLPs. Yet to be determined is whether this need can be sufficiently addressed

by increased exposure to PCC during academic and clinical training in the area of speech sound assessment or if there is a need for a more expedient process by which to objectively quantify severity.

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Appendix A

Knowledge and Competence Regarding Percentage of Consonants Correct: A National Survey of SLPs

We appreciate your participation. How did you hear about the survey?
- ❍ Email via ASHA Community Profile Page
- ❍ ASHA Community Discussion Board
- ❍ ASHA Facebook Page
- ❍ ASHA Special Interest Group 5, Craniofacial and Velopharyngeal Disorders
- ❍ ASHA Special Interest Group 16, School-Based Issues
- ❍ Other _____

Highest degree received:
- ❍ Bachelor's degree
- ❍ Master's degree
- ❍ Doctorate degree

Date highest degree received:
- ❍ Prior to 1985
- ❍ 1985-1994
- ❍ 1995-2004
- ❍ 2005-Present

Years of professional experience, beginning with your Clinical Fellowship Year:
- ❍ < 1 year
- ❍ 1-5 years
- ❍ 6-10 years
- ❍ 11-15 years
- ❍ 16+ years

I have obtained continuing education credits related to speech sound disorders since receiving my highest degree:
- ❍ Yes
- ❍ No

Do you seek out continuing education credits related to speech sound disorders annually?
- ❍ Yes
- ❍ No

Are you currently practicing and professionally licensed in the United States?
- ❍ Yes
- ❍ No

In what state are you currently practicing and professionally licensed?

- ❍ Alabama
- ❍ Alaska
- ❍ Arizona
- ❍ Arkansas
- ❍ California
- ❍ Colorado
- ❍ Connecticut
- ❍ Delaware
- ❍ District of Columbia
- ❍ Florida
- ❍ Georgia
- ❍ Guam
- ❍ Hawaii
- ❍ Idaho
- ❍ Illinois
- ❍ Indiana
- ❍ Iowa
- ❍ Kansas
- ❍ Kentucky
- ❍ Louisiana
- ❍ Maine
- ❍ Maryland
- ❍ Massachusetts
- ❍ Michigan
- ❍ Minnesota
- ❍ Mississippi
- ❍ Missouri
- ❍ Montana
- ❍ Nebraska
- ❍ Nevada
- ❍ New Hampshire
- ❍ New Jersey
- ❍ New Mexico
- ❍ New York
- ❍ North Carolina
- ❍ North Dakota
- ❍ Ohio
- ❍ Oklahoma
- ❍ Oregon
- ❍ Pennsylvania
- ❍ Puerto Rico
- ❍ Rhode Island
- ❍ South Carolina
- ❍ South Dakota
- ❍ Tennessee

- ❍ Texas
- ❍ U.S. Virgin Islands
- ❍ Utah
- ❍ Vermont
- ❍ Virginia
- ❍ Washington
- ❍ West Virginia
- ❍ Wisconsin
- ❍ Wyoming

Are you currently practicing and professionally licensed in a country other than the United States? If yes, please indicate what country in the text box below.

- ❍ Yes. _____
- ❍ No

What is the age range of the children with whom you work (for clinical or research purposes)? Select all that apply.

- ❑ Birth-3;0
- ❑ 3;1-5;11
- ❑ 6;0-10;11
- ❑ 11;0-14;11
- ❑ 15;0-21;0
- ❑ I do not work with children.

How many courses in your graduate studies addressed the assessment of speech sound disorders as a component of the course?

- ❍ 0
- ❍ 1
- ❍ 2
- ❍ 3+

Across these courses, approximately how many contact hours of instruction were devoted to the assessment of speech sound disorders?

- ❍ 1-3 hours
- ❍ 4-6 hours
- ❍ 7-9 hours
- ❍ 9+ hours
- ❍ No time was spent discussing assessment of speech sound disorders.

During your undergraduate and graduate experience, how familiar did you become with the following assessment procedures?

	I have never been exposed to this assessment.	I reviewed the assessment as a component of a course in undergraduate	I practiced administering this assessment as a component	I have administered this assessment to a client while	I do not recall my exposure to this

		or graduate school.	of a course in undergraduate or graduate school.	in undergraduate or graduate school.	assessment procedure
Goldman-Fristoe Test of Articulation, Second Edition (GFTA-2)	❍	❍	❍	❍	❍
Khan-Lewis Phonological Analysis, Second Edition (KLPA-2)	❍	❍	❍	❍	❍
Diagnostic Evaluation of Articulation and Phonology (DEAP)	❍	❍	❍	❍	❍
Hodson Assessment of Phonological Patterns, Third Edition (HAPP-3)	❍	❍	❍	❍	❍
Photo Articulation Test, Third Edition (PAT-3)	❍	❍	❍	❍	❍
Structured Photographic Articulation Test II Featuring Dudsberry (SPAT-D II)	❍	❍	❍	❍	❍
Arizona Articulation	❍	❍	❍	❍	❍

Proficiency Scale, Third Edition (Arizona 3)					
Clinical Assessment of Articulation and Phonology (CAAP)	❍	❍	❍	❍	❍
Bankson-Bernthal Test of Phonology (BBTOP)	❍	❍	❍	❍	❍
McDonald Deep Test of Articulation	❍	❍	❍	❍	❍
Broad and/or narrow phonetic transcription	❍	❍	❍	❍	❍
Phonetic inventory	❍	❍	❍	❍	❍
Severity rating	❍	❍	❍	❍	❍
Percentage of Consonants Correct (PCC)	❍	❍	❍	❍	❍
Syllable structure level	❍	❍	❍	❍	❍
Phonotactic analysis	❍	❍	❍	❍	❍
Phonological MLU	❍	❍	❍	❍	❍
Intelligibility rating	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍
None	❍	❍	❍	❍	❍

Approximately how much time was spent discussing Percentage of Consonants Correct (PCC) during your undergraduate and graduate coursework?

- ❑ One class
- ❑ One week
- ❑ One month
- ❑ More than one month
- ❑ It was not discussed.

I feel that I could have benefited from additional coursework addressing the assessment of speech sound disorders:

- ❍ Strongly Agree
- ❍ Agree
- ❍ Neither Agree nor Disagree
- ❍ Disagree
- ❍ Strongly Disagree

During my graduate training program, I had the opportunity to assess ____ children with speech sound disorders in the university clinic:

- ❍ 0
- ❍ 1-2
- ❍ 3-4
- ❍ 5+
- ❍ I did not have a graduate clinical practicum in a university clinic.

During my practicum in the university clinic, I had the opportunity to use PCC to assess the severity of a child's speech sound disorder.

- ❍ Yes
- ❍ No

During my graduate training program, I had the opportunity to assess ____ children with speech sound disorders in an off-campus clinical practicum.

- ❍ 0
- ❍ 1-2
- ❍ 3-4
- ❍ 5+
- ❍ I did not have an off-campus graduate clinical practicum.

During my off-campus clinical practicum, I had the opportunity to use PCC to assess the severity of a child's speech sound disorder.

- ❍ Yes
- ❍ No

I feel that I could have benefited from additional clinical experience in assessing children with speech sound disorders.

- ❍ Strongly Agree
- ❍ Agree
- ❍ Neither Agree nor Disagree
- ❍ Disagree
- ❍ Strongly Disagree

What percentage of your caseload is comprised of children?

- ❍ 0-10%
- ❍ 11-20%
- ❍ 21-30%
- ❍ 31-40%
- ❍ 41-50%
- ❍ 51-60%
- ❍ 61-70%
- ❍ 71-80%
- ❍ 81-90%
- ❍ 91-100%

Of these children, approximately what percentage are receiving treatment for speech sound disorders?

- ❍ 0-10%
- ❍ 11-20%
- ❍ 21-30%
- ❍ 31-40%
- ❍ 41-50%
- ❍ 51-60%
- ❍ 61-70%
- ❍ 71-80%
- ❍ 81-90%
- ❍ 91-100%

Please indicate the frequency with which you use the following formal and informal measures when assessing children with speech sound disorders:

	Always	Sometimes	Rarely	Never
Goldman-Fristoe Test of Articulation, Second Edition (GFTA-2)	❍	❍	❍	❍
Khan-Lewis Phonological Analysis, Second Edition (KLPA-2)	❍	❍	❍	❍
Diagnostic Evaluation of Articulation and Phonology (DEAP)	❍	❍	❍	❍
Hodson Assessment of Phonological Patterns, Third Edition (HAPP-3)	❍	❍	❍	❍
Photo Articulation Test, Third Edition (PAT-3)	❍	❍	❍	❍
Structured Photographic Articulation Test II Featuring Dudsberry (SPAT-D II)	❍	❍	❍	❍
Arizona Articulation Proficiency Scale, Third Edition (Arizona 3)	❍	❍	❍	❍
Clinical Assessment of Articulation and	❍	❍	❍	❍

Phonology (CAAP)				
Bankson-Bernthal Test of Phonology (BBTOP)	❍	❍	❍	❍
McDonald Deep Test of Articulation	❍	❍	❍	❍
Broad and/or narrow phonetic transcription	❍	❍	❍	❍
Phonetic inventory	❍	❍	❍	❍
Severity rating	❍	❍	❍	❍
Percentage of Consonants Correct (PCC)	❍	❍	❍	❍
Syllable structure level	❍	❍	❍	❍
Phonotactic analysis	❍	❍	❍	❍
Phonological MLU	❍	❍	❍	❍
Intelligibility rating	❍	❍	❍	❍

Please answer the following true/false questions with regard to the calculation of PCC.

	True	False
Target consonants in all repetitions of a syllable are scored (e.g., ba-baby)	❍	❍
Target consonants in words that are partially or completely unintelligible should be scored	❍	❍
Target consonants in all repetitions of a syllable are scored (e.g., ba-baby)	❍	❍
Target consonants in words that are partially or completely unintelligible should be scored.	❍	❍
Consonants in the third or successive repetitions of adjacent words should be scored only if articulation changes (e.g. /kʌp, kʌp, kʌp/ versus /kʌp, tʌp, kʌp/).	❍	❍
Deletion of a target consonant is scored as incorrect.	❍	❍
Substitution of another sound for a target consonant is scored as incorrect.	❍	❍
Addition of a consonant before a vowel (e.g., /hæt/ for "at") is scored as incorrect.	❍	❍
Partial voicing of initial target consonants is scored as incorrect.	❍	❍
Distortions of a target consonant are scored as incorrect.	❍	❍
Addition of a sound to a correct or incorrect target consonant (e.g., /kɑrks/ for "cars") is scored as incorrect.	❍	❍

Deletion of stressed and unstressed /ɝ/ and /ə˞/ is scored as incorrect.	❍	❍
Deletion of initial /h/ and final /n/ for /ŋ/ substitution is scored as incorrect only when they occur in stressed syllables.	❍	❍
Deletion of post-vocalic /r/ is scored as incorrect.	❍	❍
Allophones are scored as incorrect (e.g., /bʌɾə˞/ for /bʌtə˞/).	❍	❍

Please calculate the PCC for the following word produced by a child speaker of Standard American English:
Orthographic gloss: scarecrows
Phonetic gloss: /skɛrkroz/
Child's production: /stɛtwoz/

Please calculate the PCC for the following phrase produced by a child speaker of Standard American English:
Orthographic gloss: the sna-snake in the grass
Phonetic gloss: /ðə sneɪ-sneɪk ɪn ðə græs/
Child's production: /də sneɪ-sneɪt ɪn də dwæs/

Please calculate the PCC for the following sentence produced by a child speaker of Standard American English:
Orthographic gloss: The boy is ru-running around.
Phonetic gloss: /ðə bɔɪ ɪz rʌ-rʌnɪŋ əɾɑʊnd/
Child's production: /də bɔɪ ɪs wʌ-wʌnɪn əwɑʊn/

Please calculate the PCC for the following speech sample obtained from a 4;0 year old female speaker of Standard American English:
Orthographic gloss: I saw a snake at the zoo today. He was long and fat and brown. He li-likes to eat little animals.
Phonetic gloss: /ɑɪ sɔ ə sneɪk æt ðə zu tədeɪ. hi wʌz lɔŋ ænd fæt ænd bɾɑʊn. hi lɑɪ-lɑɪks tu it lɪtəl ænəməlz./
Child's production: /hɑɪ sɔ ə sneɪt æt də su tədeɪ. hi wʌs wɔn ænd fæt ænd bwɑʊn. hi wɑɪ-wɑɪts tu it wɪɾəl æməls./

Based on the PCC above, would this child be considered to have a Speech Delay (SD)?
- ❍ Yes
- ❍ No

How severe is the above child's speech sound disorder?
- ❍ Mild
- ❍ Moderate
- ❍ Severe
- ❍ Profound

On what did you base your judgment of severity?
- ❍ Percentage of Consonants Correct (PCC)
- ❍ Clinical experience

Please indicate the extent to which you agree with the following statement: I am confident in my ability to calculate PCC.
- ❍ Strongly Agree
- ❍ Agree
- ❍ Neither Agree nor Disagree
- ❍ Disagree
- ❍ Strongly Disagree

Appendix B

(NOTE: DO NOT AGREE TO PARTICIPATE UNLESS IRB APPROVAL INFORMATION HAS BEEN ADDED TO THIS DOCUMENT.)

INFORMATION CONSENT
for a Research Study entitled
"Knowledge and Competence Regarding Percentage of Consonants Correct: A National Survey of Speech-Language Pathologists"

You are invited to participate in a research study to learn about practicing speech-language pathologists' knowledge and competence regarding the calculation of Percentage of Consonants Correct (PCC) in the assessment of children with speech sound disorders. This study is being conducted by Emily W. Dale, Master's student in Communication Disorders at Auburn University, and Dr. Allison M. Plumb, associate professor in the Auburn University Department of Communication Disorders. You were selected as a possible participant because you are currently working as an ASHA certified speech-language pathologist or a Clinical Fellow in a pediatric setting.

What will be involved if you participate? If you decide to participate in this research study, you will be asked to complete an online survey form. Your total time commitment will be approximately 20 minutes.

Are there any risks or discomforts? The risk associated with participating in this study is the ever-present risk of breach of confidentiality with surveys. To minimize these risks, we will keep all responses completely anonymous with no identifying information whatsoever being collected and use all reasonable and customary security measures. The data will be stored behind a secure firewall and all security updates are applied in a timely fashion.

Are there any benefits to yourself or others? There is no direct benefit to you for participating in this study, but it is hoped that the results of this study will help to provide needed information on the current assessment practices used by speech-language pathologists with children with speech sound disorders, particularly their use of Percentage of Consonants Correct (PCC). This information will aid in developing an understanding of speech-language pathologists' knowledge and skill regarding the use of the PCC metric.

Will you receive compensation for participating? There is no compensation for completing this survey; however, your participation would be greatly appreciated.

Are there any costs? There are no costs associated with this survey, except for the few minutes of your time that it takes to complete the survey.

If you change your mind about participating, you can withdraw at any time by closing your browser window. Your participation is completely voluntary. Once you have submitted

anonymous data, it cannot be withdrawn due to it being unidentifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University or the Department of Communication Disorders.

Any data obtained in connection with this study will remain anonymous. We will protect your privacy and the data you provide by NOT asking for any identifiable information. Information collected through your participation may be presented at state or national conferences and may be published in a professional journal.

If you have questions about this study, please contact Dr. Allison Plumb at amp0016@auburn.edu.

If you have any questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334) 844-5966 or email at IRBadmin@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION ABOVE, PLEASE DECIDE IF YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. IF YOU DECIDE TO PARTICIPATE, INDICATE THAT YOU AGREE TO DO SO BY COPYING AND PASTING THE FOLLOWING LINK TO ACCESS THE SURVEY.

I AGREE TO PARTICIPATE:
http://auburncla.az1.qualtrics.com/SE/?SID=SV_40LrZvnvGVv4LNr

YOU MAY PRINT A COPY OF THIS LETTER TO KEEP.

Emily W. Dale, Master's Student	10/6/15
Emily W. Dale, Master's Student	Date

Allison M. Plumb, Ph.D., CCC-SLP	10/6/15
Allison M. Plumb, Ph.D., CCC-SLP	Date

The Auburn University Institutional Review Board has approved this document for use from September 24, 2015 to September 23, 2018. Protocol #15-391 EX 1509.