# Speech Assessment in Children With Childhood Apraxia of Speech

**Article** *in* Perspectives of the ASHA Special Interest Groups · August 2017

DOI: 10.1044/persp2.SIG2.47



**2 authors:**

Jenya Iuzzini-Seigel
Marquette University


Elizabeth Murray
The University of Sydney

*Perspectives of the ASHA Special Interest Groups*
SIG 2, Vol. 2(Part 2), 2017, Copyright © 2017 American Speech-Language-Hearing Association

# Speech Assessment in Children With Childhood Apraxia of Speech

*Jenya Iuzzini-Seigel*

Communication, Movement and Learning Lab, Department of Speech Pathology and Audiology, Marquette University
Milwaukee, WI

*Elizabeth Murray*

Faculty of Health Sciences, The University of Sydney
Lidcombe NSW, Australia

**Disclosures**
*Financial:* Jenya Iuzzini-Seigel has no relevant financial interests to disclose. Elizabeth Murray has no relevant financial interests to disclose.
*Nonfinancial:* Jenya Iuzzini-Seigel has no relevant nonfinancial interests to disclose. Elizabeth Murray has no relevant nonfinancial interests to disclose.

## Abstract

*This article uses the International Classification of Functioning (ICF) framework to outline the assessment needs of children with apraxia of speech. Specifically, the level of breakdown for children with apraxia of speech—that of motor planning and programming at the level of body functions—is delineated using operationally defined criteria for greater diagnostic transparency.*

## Speech Assessment in Children With Childhood Apraxia of Speech

There are numerous challenges to being a pediatric speech pathologist. One of the more daunting issues relates to the difficulty in making a confident differential diagnosis between childhood apraxia of speech (CAS) and other speech sound disorders (e.g., phonological disorder). This article reviews the literature and provides guidance on how to assess CAS. In addition, it uses the International Classification of Functioning (ICF) framework to describe how CAS affects body structure and function, as well as how it may impact activities and participation and how personal factors and a child's environment may affect their remediation.

## Issues in Assessment and Diagnosis of CAS

There are no overt physical markers of CAS. Although there are genetic (Centanni et al., 2015; Fisher, Vargha-Khadem, Watkins, Monaco, & Pembrey, 1998; Laffin et al., 2012; Lai et al., 2000) and neurological markers (Liégeois & Morgan, 2012) associated with CAS, these are not yet considered diagnostic. Consequently, perceptual assessment of core features by a speech-language pathologist (SLP) is considered the current gold standard in diagnosis (American Speech-Language-Hearing Association [ASHA], 2007; Iuzzini-Seigel, Hogan, & Green, 2017; Maas, Butalla, & Farinella, 2012; Murray, McCabe, Heard, & Ballard, 2015). The published diagnostic tests that exist tend to lack fundamental psychometric properties that allow for confident and replicable differential diagnosis alone (McCauley & Strand, 2008). Diagnostic feature lists are often used in the literature, although features are rarely operationally-defined making it difficult for other researchers and clinicians to apply the same diagnostic procedures (Murray et al., 2015).

The extant CAS research often has methodological issues that limit application to clinical practice. Because of the low prevalence of CAS, studies often include heterogeneous participant populations (e.g., children from a broad age range) in an effort to investigate a larger sample of children. This is problematic because symptoms of CAS are found to change to over time and following treatment (Lewis, Freebairn, Hansen, Iyengar, & Taylor, 2004; Maassen, 2002). That is, children with CAS who are preschool-aged and who have received very little or no treatment often evidence different symptoms from children who are older and have received years of treatment or who have developed compensatory strategies. For example, a preschool-aged child may present with a limited phonetic inventory, speech inconsistency, and difficulty sequencing speech sounds whereas an older child may present with greater prosodic or resonance disturbances and residual articulation errors.

A related issue is that children with CAS often have comorbid impairments and/or medical diagnoses (Iuzzini-Seigel, Delaney, & Kent, 2016). For instance, ~50% of children with CAS are reported to have fine and gross motor deficits (Gretz, 2013). Likewise, upwards of ~80% of children with CAS have comorbid language impairments (Iuzzini, 2012; Lewis et al., 2004; Shriberg, Aram, & Kwiatkowski, 1997). Reading and writing impairments are also common (Lewis et al., 2004), and cognitive issues may be present (Shriberg et al., 1997). A subset of children with CAS also have comorbid neurodevelopmental disorders (e.g., Bashina, Simahkova, Grachev, & Gorbachevskaya, 2002; Iuzzini-Seigel et al., 2016) such as seizure disorders, syndromes (e.g., Fragile X Syndrome, Rett Syndrome, Down Syndrome), and metabolic disorders (e.g., Galactosemia; Shriberg, Potter, & Strand, 2011). Finally, in addition to having motor symptoms consistent with a CAS diagnosis, children with CAS may also have comorbid dysarthria or phonological disorder making it hard to determine which speech symptoms relate to which diagnosis.

In 2007, ASHA reported that three primary features had gained consensus in the field for contributing to the differential diagnosis of CAS and other speech sound disorders: "(a) inconsistent errors on consonants and vowels in repeated productions of syllables or words, (b) lengthened and disrupted coarticulatory transitions between sounds and syllables, and (c) inappropriate prosody, especially in the realization of lexical or phrasal stress" (2007, p. 4). The information described in the technical report has since been incorporated into ASHA's Practice Portal (ASHA, 2017). Although these recommendations provide important direction for differential diagnosis, the ASHA committee does not provide specific guidelines for applying these features to make a differential diagnosis. For example, how does one measure inconsistent production, how much inconsistency is too much inconsistency, how often and in what context must inappropriate prosodic disturbances occur, and how should one assess coarticulatory impairments? Also, if these criteria represent the minimum needed to make a diagnosis, what other assessment is needed? Some researchers and clinicians have attempted to use these features to diagnose CAS (Maas et al., 2012; Murray et al., 2015), however actual application of these diagnostic features varies based on interpretation. Even now, many other researchers and clinicians continue to use a different or broader set of diagnostic criteria to differentially diagnose CAS although the features have similarities (e.g., Iuzzini-Seigel et al., 2017; Laffin et al., 2012).

Ultimately assessment and diagnosis of CAS is a work in progress with many research teams working towards refining diagnostic procedures. In the meantime, however, clinicians need to be confident in the features they are assessing in order to determine if a child has CAS and would benefit from motor-based therapy.

## Assessment and Diagnosis of CAS: Applying the ICF

Determining the underlying breakdown in CAS is crucial to making a differential diagnosis from other speech sound disorders (SSDs). Children with CAS have deficits in motor planning and programming (Shriberg, Lohmeier, Strand, & Jakielski, 2012; Terband & Maassen, 2010). Challenges in motor planning result in difficulties establishing general movement goals for each sound or syllable based on the spatial and temporal aspects of speech movements needed, putting these movements in sequential order and tailoring them for the specific speech environment. Motor programming challenges result in difficulty specifying which muscles need to contract and how much strength, force and range of movement is needed to execute speech (van der Merwe, 2009). Currently, we use specific speech features to detect symptoms associated with these underlying impairments (ASHA, 2007), while also confirming/excluding different comorbid diagnoses.

The following section works through the ICF framework for characterizing the impairments of body structure/function, limitations on activity, and restrictions on participation (World Health Organization, 2002). We also consider the personal and environmental factors that impact prognosis and management of individuals with CAS.

### Body Structure and Function

Body structures and function represent the underlying impairments of a disorder. "Body structures" refer to the anatomy (e.g., the mouth, teeth, lip, tongue, pharynx, and larynx), where "body functions" refer to the physiology of the body. Idiopathic CAS is associated with intact oral structures for speech and appropriate oral muscle tone (ASHA, 2007). Body structure deficits may be present if a child has a comorbid diagnosis such as cleft palate or dysarthria (Murray et al., 2015). Consequently, oral structures need to be assessed using an oral-motor assessment, such as the Oral and Motor Speech Protocol (Robbins & Klee, 1987). If structural impairments are noted, they should be addressed with appropriate referrals (e.g., ear nose, and throat surgeon) and clinical treatment.

The CAS diagnosis is associated with functional deficits rather than structural ones. As such, impaired motor planning and programming result in the speech features we associate with CAS, such as speech inconsistency, disturbed prosody, and lengthened or disrupted coarticulation (ASHA, 2007). To assess for CAS, we need to assess children's speech production on single word tests, such as the Goldman-Fristoe Test of Articulation (GFTA) or the Single Word Test of Polysyllables, as well as in repeated words and phrases, and connected speech. Polysyllable words and diadochokinesis tasks stress the motor system (Murray et al, 2015) and may elicit errors; however poor accuracy and inconsistency on polysyllable word production is also present in children with speech delay and phonological disorder (e.g., Iuzzini, 2012; Iuzzini-Seigel, Hogan, Guarino, & Green, 2015). Another useful task can be a dynamic motor speech exam where a child repeats words after the clinician and cueing such as simultaneous imitation and touch cues are used to determine what a child can do with support (Strand, McCauley, Weigand, Stoeckel, &Baas, 2013). Here we provide operational definitions (adapted from Iuzzini-Seigel et al., 2017) and brief reviews of speech features that are commonly associated with CAS (Shriberg, Potter, & Strand, 2011). It is important to note that no one feature alone is considered sufficient to diagnose CAS. Likewise, the features are not pathognomonic, meaning that they may also be observed in children without a CAS diagnosis. The features presented in the section below have been tested on school-aged children with CAS and speech delay and our data suggest that when a child exhibits five or more features out of 11 and evidences speech inconsistency, a CAS diagnosis is warranted (Centanni et al., 2015; Iuzzini-Seigel et al., 2017; Iuzzini-Seigel et al., 2015). A child was considered to produce a feature if they evidenced at least one occurrence of the feature during production of words on the GFTA-2. That is, if a child produced one vowel error on the GFTA-2, the child was said to evidence vowel errors. Likewise, if a child evidenced one stress error on the GFTA-2, the child was said to evidence stress errors. Even though a cutoff of five features was used to differentiate groups of children with speech disorders, Iuzzini-Seigel and colleagues (2015, 2017) found that school-aged children with CAS tended to produce an average of 8 features whereas children with speech delay displayed three features and typically developing children displayed only one feature on average.

This specific feature list has not yet been tested in toddlers and preschoolers, but similar lists of features have been discriminative (e.g., Murray et al., 2015). It is likely that younger children with CAS and speech delay would show a higher number of features as the speech system is still under considerable development. Empirical research that examines these features in preschool-aged children with CAS and speech delay is ongoing.

Clear and accurate speech requires the integrity of the motor speech subsystems. In children with idiopathic CAS who have no comorbidities, there is no *structural* impairment that affects the individual speech subsystems (i.e., phonatory, articulatory, resonatory, respiratory, prosodic; Kent & Kim, 2003). Children have the necessary anatomy to support phonation, articulation, respiration, resonance, and prosody; however, children with CAS still have difficulty with the motor planning and programming across these subsystems, often leading to inconsistent voicing and resonance due to timing errors, distorted articulation and substitutions, and impaired lexical stress. Below we operationally define and review the features that are commonly associated with CAS and identify the primary speech subsystems affected.

## *Operational Definitions and Brief Review of Features Commonly Associated With CAS*

### Vowel Error (Articulatory Subsystem)

> *A vowel production error in which the vowel is substituted for another vowel or in which the vowel is recognizable as a specific vowel but it is not produced accurately ([aka distorted] e.g., not a prototypical production, may sound like it's in between two vowels). It is not considered an error if the vowel is substituted with another phoneme that is consistent with an adult-like model (e.g., /hat dag/ /hat dɔg/).* (Iuzzini-Seigel et al., 2017, Supplemental Material 1)

Vowel errors are commonly associated with CAS (e.g., Davis, Jakielski, & Marquardt, 1998; Forrest, 2003; Iuzzini & Forrest, 2008; Iuzzini-Seigel et al., 2015; Lewis et al., 2004; Shriberg et al., 1997; Stackhouse, 1992; Williams, Ingham, & Rosenthal, 1981) and are frequently used to contribute to differential diagnosis of CAS and other speech sound disorders. In a recent study of inconsistent speech production among school-aged children with CAS and speech delay, Iuzzini-Seigel and colleagues (2017) found that 100% of participants with CAS (n = 20) evidenced at least one vowel error during production of words on the GFTA-2, whereas only 10% of children (1/10) with speech delay demonstrated this feature (i.e., evidenced one or more vowel errors during administration of the GFTA-2). Similarly, vowel errors were a differentiating symptom in Lewis et al.'s (2004) school-age follow-up of children with CAS, speech sound disorders, and combined speech and language disorders. When children were first assessed at preschool-age, 100% of children with CAS evidenced vowel errors compared with 8% of children with isolated speech sound disorder, and combined speech and language disorder. At school-age, 90% of children with CAS still made vowel errors, where only 8% of children with speech sound disorders and 0% of children with combined speech and language disorders evidenced this feature.

### Consonant Distortion (Articulatory Subsystem)

"*A consonant production error in which a speech sound is recognizable as a specific consonant but is not produced accurately (e.g., an /s/ that is produced with lateralization or dentalization)*" (Iuzzini-Seigel et al., 2017, Supplemental Material 1). Distortions are thought to reflect a motoric basis in that the articulatory precision of the speech sound is impaired, even though knowledge of the phonological category is demonstrated (e.g., Preston, Hull, & Edwards, 2013). Consonant distortions are commonly reported among children with CAS (e.g., Davis et al., 1998; Rosenbek & Wertz, 1972; Shriberg et al., 1997); however, in comparison to vowel errors, which are fairly pathognomonic for children with CAS compared to those with speech delay or phonological disorder, consonant distortions are prevalent among individuals with a range of disorder types. In their school-aged follow-up of children with various speech and language disorders, Lewis et al. (2004) found that 50% of children with isolated speech sound disorders and 33% of those with combined speech and language disorders evidenced consonant distortions (distortions were not quantified for children with CAS). Distortions are among the most frequently reported type of speech error observed in older children and adults, and are even present among young typically developing children (Shriberg, 1993). Likewise, distortions are common among individuals with structural anomalies including cleft palates (e.g., Bzoch, 1965) and dental malocclusions (e.g., open bite; Leavy, Cisneros, & LeBlanc, 2016). Although consonant distortions are prevalent among children with CAS, they do not specifically affect this population, suggesting that their contribution to differential diagnosis may be limited.

### Stress Errors (Prosodic Subsystem)

> *An error in which appropriate stress is not produced correctly at the lexical (i.e., word) or sentence levels. For example: desERT (wS, verb) and DESert (Sw, noun) have different stress patterns. It is considered an error if the stress is inappropriately equalized across syllables, or is shifted onto the wrong syllable.* (Iuzzini-Seigel et al., 2017)

Stress errors can only be identified in contexts that contain contrastive syllable stress. Therefore, words or sentences with two or more syllables containing contrastive stress should be used to assess this feature. In English, strong syllables are conveyed with longer vowel duration, increased pitch, and increased loudness relative to weak syllables. Children with CAS tend to produce weak syllables with *increased* stress such that weak and strong syllable targets may sound as if they have equal stress. Early studies found that inappropriate *sentential* stress was observed in 52% of children with CAS compared to 10% of those with speech delay, showing that although this feature had poor sensitivity to identify children with CAS, it had high specificity (90%) in that 90% of children with speech delay evidenced appropriate stress. Consequently, this research provided a potential marker to differentiate the groups (Shriberg et al., 1997). A follow-up study (Velleman and Shriberg, 1999) on a subset of these participants did not find significant differences between children with CAS and speech delay for lexical (word) stress, suggesting that assessment of stress at the sentential level may be more informative that at the lexical level. In contrast, studies by Skinder-Meredith, Strand, and colleagues (Skinder, Connaghan, Strand, & Betz, 2000; Skinder, Strand, & Mignerey, 1999) reported differences in stress between children with CAS and speech delay, particularly in lexical stress of bisyllabic and multisyllabic real and nonsense words. Likewise, Shriberg et al. (2003) found that the Lexical Stress Ratio differentiated children with CAS and speech delay on production of trochaic (strong-weak), iambic (weak-strong), and spondee (strong-strong) stress patterns, although some children with CAS displayed increased stress while others displayed decreased stress. Shriberg and colleagues went on to use "inappropriate stress" as one of three or four primary markers of CAS as they found it discriminated CAS from speech delay and dysarthria. Here, "inappropriate stress" was calculated perceptually for 24 utterances produced during connected speech and then coded to create a ratio of the number of utterances produced with inappropriate stress relative to the total number of utterances. This is similar to Murray et al.'s (2015) lexical stress matches—however, this is a lexical stress measure calculated on 50 three, four, and five syllable words produced in the Single Word Test of Polysyllables (Gozzard, Baker, & McCabe, 2004). This measure discriminated between children with CAS and those with non-CAS speech disorders with 80% accuracy and contributed to a set of four measures that differentiated the groups with 91% accuracy. Another promising development in assessment of stress is the Pairwise Variability Index (Ballard, Robin, McCabe, & McDonald, 2010; Low, Grabe, & Nolan, 2000) an acoustic measure and algorithm that can be calculated for duration, fundamental frequency, and pitch across adjacent vowels in a word or sentence. A positive number is given for Sw stress and a negative number given for wS stress, with results close to 0 showing equalization across syllables. These methods need to be used in relation to typical development and studies using the Pairwise Variability Index have shown lexical stress development continues past 11 years of age (Arciuli & Ballard, 2017; Ballard, Djaja, Arciuli, James, & van Doorn, 2012).

### Syllable Segregation (Prosodic Subsytem)

> *Brief or lengthy pause between sounds, syllables, or words, such that they are segregated from one another and lacking appropriately smooth transitions (ASHA, 2007; Shriberg et al., 2003). Speech may also be described as having a choppy or staccato-like quality.* (Murray et al., 2015; Shriberg et al., 2003)

Syllable segregation may result from equalization of stress, duration, intensity, and pitch across syllables; specifically, prosodic features of stressed-weak and weak-stressed syllables may not vary appropriately (Ballard et al., 2010). Iuzzini-Seigel et al. (2017) found that 15/20 school-aged participants with CAS evidenced syllable segregation at least one time during responses on the GFTA-*2* (Goldman & Fristoe, 2000), where only 3/10 participants with speech delay evidenced this feature. Murray and colleagues (2015) investigated the ASHA CAS features (2007) in 47 preschool-aged children with CAS or other speech disorders (e.g., submucosal cleft, phonological disorder, and dysarthria). Results showed that syllable segregation was moderately sensitive and specific in differentiating children with CAS from those with a different speech sound disorder, leading Murray et al. (2015) to suggest that syllable segregation has strong potential as a core feature of CAS.

### Groping (Articulatory Subsystem)

> *Groping may refer to prevocalic (silent) articulatory searching prior to onset of phonation, possibly in an effort to improve the accuracy of the production (i.e., articulatory groping). Groping may also refer to extraneous oral movements during nonspeech oral motor tasks (i.e., nonspeech oral motor groping), such as during an oral mechanism exam (e.g., Murray et al., 2015)*. Iuzzini-Seigel et al., 2017, Supplemental Material 1)

Articulatory groping has been commonly associated with CAS, however, not all children with CAS evidence this feature. In Lewis et al.'s (2004) longitudinal study of 39 children with CAS, speech disorder, and combined speech and language disorder, findings showed that 5/9 participants with CAS evidenced groping in a conversational sample when they were preschool-aged; data on groping were not reported for participants at their school-age follow-up, or for the other groups at any time point. In a recent study of speech inconsistency in school-aged children with CAS and speech delay, only 1/20 children with CAS displayed articulatory groping during responses on the GFTA-2 (Iuzzini-Seigel et al., 2017) and none of the children with speech delay evidenced this feature. It is possible that more children would evidence this feature in more complex speech tasks (e.g. a polysyllable word test). Murray et al. (2015) found that articulatory groping accurately identified 54% of preschool-aged participants with CAS, and nonspeech oral motor groping identified 29% participants with CAS compared to participants with non-CAS SSDs. Overall within-speech groping would be consistent with a CAS diagnosis, whereas nonspeech groping could be due to a nonspeech oral apraxia (Murray et al., 2015). As with many other features of CAS, groping may be evidenced by a subset of children in this population, but should not be considered mandatory to receive a CAS diagnosis.

### Intrusive Schwa (e.g., in clusters; Articulatory Subsystem)

"*A schwa is added in between consonants. For example, it may be inserted in between the consonants in a cluster (e.g., /blu/ becomes /bəlu/)"* (Iuzzini-Seigel et al., 2017, Supplemental Material 1). Schwa insertion (also known as epenthesis) has been frequently reported among children with CAS (e.g., Ballard et al., 2010; Nijland, Maassen, Hulstijn & Peters, 2004; Shriberg et al., 2011), but is also a feature is observed among children with speech delay. Iuzzini-Seigel et al. (2017) reported that 15/20 school-aged children with CAS and 3/10 school-aged children with speech delay evidenced schwa insertion during administration of a standardized articulation test. Murray et al. (2015) also found intrusive schwa evidenced by children with non-CAS speech disorders, however children with CAS made more intrusive schwa errors. Therefore, schwa insertion is not pathognomonic to CAS and has been the subject of investigation in typical speakers of Dutch (Warner, Jongman, Cutler, & Mucke, 2001), and French (Milne, 2013) who may use schwa insertion to simplify cluster production or to increase emphasis of a word (Milne, 2013). Explanations for schwa insertion usage in children with CAS have not been empirically examined, although cluster simplification is a possible cause as is an effort to facilitate coarticulation.

**Voicing Error (Articulatory Subsystem)**

"*A sound is produced as its voicing cognate (e.g., a /p/ that is produced as a /b/). In addition, this could also describe productions that appear to be between voicing categories (i.e., blurring of voicing boundaries)"* (Iuzzini-Seigel et al., 2017, Supplemental Material 1). In typically developing children, the voicing contrast usually develops between the ages of 1;3–3;11 (Macken & Barton, 1980). Before they have stability of this contrast, children may produce one primary voicing category for voiced and voiceless targets—typically, they will produce voiced productions for voiced and voiceless targets, such that the target word "pig" may sound like "big" instead. Longitudinal research of the voicing contrast in typically developing children has revealed three phases that children often progress through on their way to adult-like voicing categories: (a) single voicing category where all productions are in the voiced range, (b) two voicing categories where one is in the voiced range and the other has excessively long voice onset times, and (c) two voicing categories that are often in the adult-like voice onset ranges (Macken & Barton, 1980).

Children with CAS tend to show protracted development of the voicing contrast such that even 5-year-olds with CAS may produce most voiced and voiceless targets in the voiced range (Iuzzini, 2012). There is copious evidence of voicing errors in the extant literature on children with CAS. In Yoss and Darley's (1974) research on children with CAS and other speech sound disorders, they found that the CAS group produced at least twice as many voicing errors as their non-CAS speech disordered group. In their longitudinal study of children with CAS, Lewis et al. (2004) found that 9/10 preschool-aged children with CAS evidenced voicing errors at the time of diagnosis and 40% of these participants continued to evidence this feature during their school-aged follow-up. Iuzzini-Seigel and colleagues (2017) found that 17/20 school-aged children with CAS evidenced voicing errors. In contrast, only 4/10 children with speech delay and none of the typically developing controls evidenced this feature. Murray et al. (2015) found that voicing errors did not discriminate between CAS and non-CAS groups due to voicing errors also being present in other disorders. While voicing errors are not pathognomonic for CAS, research shows that they are highly prevalent in this population and occur at a higher frequency than children with a non-CAS speech disorder. This is reasonable from a motor planning and programming perspective, as the timing requirements of voicing across sounds means it is easier to plan and program all voiced sounds compared to alternating between voiced and voiceless sounds.

**Slow Rate (Articulatory & Prosodic Subsystems)**

*Speech rate is atypically slow* (Iuzzini-Seigel et al., 2017). Slow production of syllables, whole words, or phrases in children with CAS may occur so that children with CAS have a greater opportunity to make use of auditory feedback to improve the precision of their speech production (Iuzzini-Seigel et al., 2015; Rosenthal, 1994; Terband & Maassen, 2010). This slowing of speech rate may facilitate speech improvements similar to the way that individuals who stutter may evidence greater fluency when using slower speech (Van Riper, 1982). Iuzzini-Seigel et al. (2017) found that 10/20 school-aged participants with CAS evidenced slow speech during productions on a standardized articulation test, compared with 2/10 children with speech delay. Murray et al. (2015) assessed articulation rate in 60 seconds of connected speech, measured as syllables per second, in children with CAS and non-CAS speech disorders. The procedure of how to assess articulation rate can be found in Logan, Byrd, Mazzocchi, & Gillam (2011) article. Results showed that speech rate was only 18% accurate in predicting expert diagnosis. Slow rate is also a feature that is commonly associated with dysarthria (Shriberg & McSweeny, 2002) and consequently, the presence of this feature cannot be considered a clear indicator of CAS.

**Increased Difficulty With Multisyllabic Words (Articulatory & Prosodic Subsystems)**

*A disproportionately increased number of errors as the number of syllables increases, as compared to number of errors on words with fewer syllables* (Iuzzini-Seigel et al., 2017). This feature is commonly associated with CAS but can be difficult to assess objectively without careful consideration. In their investigation of differential diagnosis of preschoolers with CAS and other non-CAS speech disorders, Murray and colleagues (2015) used a magnitude of change score to quantitatively determine if a child evidenced increased difficulty on longer words relative to shorter words. This score was calculated as:

$$\text{Magnitude of change score: } \frac{\text{\# phonemes correct on 12 monosyllables}}{\text{\# phonemes correct on 12 polysyllabic words}}$$

If a child evidenced a score of >1, he/she was considered to have increased difficulty on multisyllabic words. Monosyllabic target words were selected from items on the Diagnostic Evaluation of Articulation and Phonology (DEAP) Inconsistency subtest (Dodd, Hua, Crosbie, Holm, & Ozanne, 2006) and polysyllabic words were selected from stimuli on *Single Word Test of Polysyllables* (Gozzard et al. 2004, 2008). Results showed that this measure was not effective in differentiating children with and without CAS, as both groups made greater errors on polysyllable words. This finding is in contrast to other studies that show that children with CAS evidence poorer performance on multisyllabic words compared to children with a non-CAS speech sound disorder, however here the groups were not matched for speech severity (e.g., Lewis et al., 2004). If one is interested in ascertaining whether multisyllabic word production is particularly challenging compared with monosyllabic word production, it is essential to compare the number of errors in relation to the length of the word. That is, one would expect a child to make more errors on a word of three or more syllables compared with a word of one or two syllables because there are more phonemic opportunities to produce an error. The research on this feature is equivocal and therefore, it is unknown if this feature should make a useful contribution to differential diagnosis of CAS; however, this information may be useful in planning of treatment and probe targets. It is plausible the greater errors on polysyllable words could be due to different underlying impairments making it less discriminative.

### Resonance or Nasality Disturbance (Articulatory & Resonatory Subsystems)

*Resonance sounds either hyponasal, in which there is not enough airflow out of nose such that the child sound "stuffy" or hypernasal in which there is too much airflow out of nose for non-nasal phonemes such as plosives* (e.g., ASHA, 2007; Iuzzini-Seigel, 2017). In their study of school-aged children with CAS and speech delay, Iuzzini-Seigel et al. (2017) found that 10/20 participants with CAS evidenced a resonance disturbance compared to only 1/10 children with speech delay who displayed this feature. Shriberg and colleagues (1997, 2010) found that 6/14 children with suspected CAS evidenced a resonance disturbance and that this disturbance varied among the affected children. Two of the children evidenced increased pharyngeal resonance where other children were identified as having nasal or denasal resonance. Because children with CAS may have difficulty with timing and coordination of velopharyngeal closure, most children with CAS may evidence variable resonance, sounding hyponasal on some words or phrases and hypernasal on others (ASHA, 2007). This variable resonance was a major distortion error in the CAS group in the Murray et al. (2015) study. It should also be noted that while resonance disturbance can affect children who have a sole diagnosis of CAS, it can also be observed in children who have comorbid dysarthria (e.g., Turner et al., 2013) or velopharyngeal incompetence. Resonance is often assessed perceptually and these ratings can be unreliable (Bradford, Brooks, & Shelton, 1964). Although many of the instrumental measures used to assess resonance (e.g., nasometry, videonasendoscopy, etc.) can be complicated, expensive and inaccessible to clinicians, recent innovations (e.g., Bunton, Hoit, & Gallagher, 2011) make evaluation of velopharyngeal function more simple, inexpensive, and possible for clinicians to perform. If a persistent resonance disturbance is suspected, a client should be referred to an Ear, Nose and Throat specialist for videonasendoscopy to rule out any craniofacial anomalies such as a cleft or velopharyngeal insufficiency.

### Difficulty Achieving Initial Articulatory Configurations or Transitionary Movement Gestures (Articulatory Subsystem)

"*Initiation of utterance or initial speech sound may be difficult for child to produce and may sound lengthened or uncoordinated. Also, child may evidence lengthened or disrupted coarticulatory gestures or movement transitions from one sound to the next*" (Iuzzini-Seigel et al., 2017, Supplemental Material 1). ASHA (2007) recommends that "lengthened and disrupted coarticulatory transitions between sounds and syllables" (p. 2) should contribute to the differential diagnosis of CAS. Iuzzini-Seigel et al. (2017) found that 16/20 school-aged participants with CAS evidenced difficulty initiating or transitioning between sounds during whole-word productions on GFTA-2; in contrast, only 2/10 participants with speech delay evidenced this feature. Likewise, previous acoustics research provides further evidence of this feature among children with CAS relative to typically developing speakers. For example, Nijland and colleagues (2002) found a higher rate of idiosyncratic coarticulation patterns among children with CAS compared with typically developing peers. Nijland et al. (2002) suggest that these idiosyncratic patterns are observed because children with CAS use unique motor patterns to help them manage their speech impairments.

**Speech Sound Inconsistency (Articulatory Subsystem)**

*Variable production of a phoneme (i.e., phonemic inconsistency), word or phrase (i.e., token-to-token inconsistency) across multiple opportunities* (Iuzzini-Seigel et al., 2017). Previous research on preschool-aged children shows that phonemic inconsistency—inconsistency of speech sounds across multiple opportunities within and across word position—differentiates children with suspected CAS and phonological disorder (Iuzzini, 2012; Iuzzini & Forrest, 2010). Likewise, children with high phonemic inconsistency, based on an inconsistency severity percentage of 18% or higher on production of sounds-in-words on the *GFTA-2,* (Goldman & Fristoe, 2000), also evidenced vowel and voicing errors based on acoustic analyses (Iuzzini, 2012). These findings are important because they show convergence of features that are more prevalent among children with CAS relative to those with non-CAS speech sound disorders (e.g., speech delay, phonological disorder). Phonemic inconsistency can be calculated on responses from a custom word list or based on responses from an articulation test (e.g., GFTA) making additional use of data that are already being collected.

Token-to-token inconsistency is analyzed on multiple productions of words or phrases. The DEAP (Dodd et al., 2006) assesses inconsistency on repeated production of 25 words. The word list is produced three times in a naming task and then production across the three trials is compared. If there is at least one difference across the three trials that is not an error that could be typically developing, the word is considered inconsistent. The number of words that are produced inconsistently is divided by the total number of words produced and a token-to-token inconsistency score is calculated. If the score is 40% or higher, then trials are rescored and items that contain alternations between developmental errors and accurate productions are removed. At that point, scores of 40% or higher are considered "inconsistent". Our previous work that investigated inconsistent performance on the DEAP in preschool-aged children with CAS and phonological disorder showed that token-to-token inconsistency assessment was less effective than phonemic inconsistency in differentiating between these groups (Iuzzini, 2012). In fact, there were even some typically developing talkers who evidenced high levels of token-to-token inconsistency suggesting that *phonemic inconsistency* may be more effective in differentiating groups at this young age. This is consistent with research by Murray et al. (2015), which showed that token-to-token inconsistency on the DEAP was less discriminative in differentiating between preschool-aged talkers with CAS and non-CAS speech disorders compared to other measures. One possible explanation is that phonemic inconsistency assessment provides a more fine-grained analysis compared with token-to-token analysis, and may therefore be more effective in differentiating between these groups at a young age.

Recent work on school-aged children with CAS and speech delay showed that token-to-token inconsistent production of the simple phrase "buy Bobby a puppy" was sensitive and specific in differentiating between children in these groups (Iuzzini-Seigel, Hogan, & Green, 2017). Children were asked to say the phrase five times and were considered inconsistent if they produced any differences across productions. Children with speech delay and age-matched typically developing peers were highly consistent in producing this phrase whereas children with CAS evidenced inconsistent production. Why might this phrase be so effective in differentiating between school-aged children with CAS and speech delay? One possibility is that the phrase samples different vowels and the voicing contrast, which tend to be areas of particular challenge for children with CAS but simple for children with speech delay. Another interesting finding from this study, is that token-to-token inconsistency calculated on challenging multisyllabic words (e.g., alligator) was not effective in differentiating between talkers with CAS and speech delay. In fact, even typically developing school-aged children evidenced difficulty producing these challenging words consistently. The main take away when using inconsistency to contribute to a differential diagnosis of CAS and speech delay, is that the age of the child, the type of stimuli and method of analysis are all important factors and may impact results.

## Cognitive-Linguistic Functions

In addition to impaired motor planning and programming, children with CAS can also have comorbid impairments in language production, reading, spelling, and writing (Iuzzini, 2012; Lewis et al., 2004; McNeill, Gillon, & Dodd, 2009; Shriberg et al., 1997). Phonological impairment is also highly comorbid as the speech system is developing. Children with CAS also may experience fine and gross motor deficits (Gretz, 2013), as well as social and emotional challenges, which may be secondary to or independent from communication impairments. All children with CAS would benefit from language, phonological awareness and reading and writing assessments according to their age, to determine if they need assistance in these areas. Referrals to other professionals may also be warranted.

## Limitations on Activity and Restrictions to Participation

Children with speech impairments can evidence a breadth of limitations across the lifespan including long-term limitations to education and employment (Felsenfeld, Broen, & McGue, 1992, 1994; Felsenfeld, McGue, & Broen, 1995; McCormack, McLeod, Harrison, & McAllister, 2010). Due to the functional challenges experienced by children with speech impairments—and CAS specifically—many limitations are anticipated. A child with CAS may have difficulty communicating wants and needs, interacting socially and in an academic setting, singing, engaging in conversation with medical professionals or other formal conversational partners, and may also demonstrate challenges communicating their emotions. Depending on a child's level of severity, limitations in accessing the curriculum may also be observed. For instance, if a child has low speech intelligibility, teachers may have difficulty assessing comprehension of material, expressive language abilities and oral reading abilities. A child who has low intelligibility and needs clarification from a teacher may not be able to successfully ask questions using oral communication. An assessment of the child's participation is therefore warranted.

For some children with CAS, an alternative augmentative communication (AAC) may be effective in increasing their communicative output and decreasing limitations to activities. A child's severity will impact the need for special accommodations. Therefore, assessment of a child's communicative competence (e.g., the pragmatic functions they can express) would also be valuable with a view to selecting verbal treatments or augmentative systems.

Depending on a child's comorbid impairments, limitations to physical activities may also be present. Fine and gross motor deficits may impact writing, drawing, playing of musical instruments, mobility, self-feeding and self-care, and may limit participation in physical and athletic activities. Because of these physical limitations, communicative limitations to social interaction may be compounded. Adaptive techniques and equipment may support inclusion for children with physical limitations, led by occupational or physical therapists.

## Environmental Factors

Environmental factors may positively or negatively impact function, activities, and participation (McCormack et al., 2010). Such factors can include technology and services that are available to facilitate a child's communication. For example, does a child have an AAC device for use both at school and at home, and are caregivers, classroom aids, SLPs and teachers all trained so that the device provides maximum communicative benefit? Other environmental factors include the level of support and facilitative relationships that are in place for the child. Are caregivers, teachers, and SLPs all knowledgeable about CAS and working together to achieve maximal gains? What are the general attitudes that the child is confronted with? Are adults and peers supportive, or is the child facing criticism or bullying? The child's environment can vary broadly in terms of supportive communication partners, access to alternative assistive communication technology, and access to appropriate and sufficient therapeutic services with an expert provider. All of these factors can facilitate or limit a child's potential.

## Personal Factors

Pertinent personal factors can include presence of other comorbidities such as cognitive-linguistic and motor impairments. Likewise, the age of differential diagnosis, a family's access to therapeutic resources, as well as a child's cooperation in therapy and motivation to improve may also impact progress. As one considers personal factors across the lifespan, an individual's level of education, chosen profession, and individual psychological assets can also make a significant difference in one's ability to remediate and cope with residual deficits.

## Conclusions

Many researchers are working on the differential diagnosis of CAS compared to other SSDs. Clinicians are often confident in determining impaired versus non-impaired speech, however discriminating between the different SSDs is more difficult. This article used the ICF framework to outline the assessment needs of children with CAS. Specifically, the level of breakdown for children with CAS—that of motor planning and programming at the level of body functions—was delineated using Iuzzini-Seigel et al.'s (2017) criteria for greater diagnostic transparency. Children with CAS—if correctly identified and treated—can likely improve their functional verbal communication and accurate diagnosis is the first step in this journey.

## References

American Speech-Language-Hearing Association. (2007). *Childhood apraxia of speech* [Technical Report]. Available from www.asha.org/policy

American Speech-Language-Hearing Association. (2017). *Childhood apraxia of speech* (Practice Portal). Retrieved from http://www.asha.org/Practice-Portal/Clinical-Topics/Childhood-Apraxia-of-Speech/

Arciuli, J. & Ballard, K. J. (2017). Still not adult-like: Lexical stress contrastivity in word productions of eight- to eleven-year-olds. *Journal of Child Language*. 1–15. https://doi.org/10.1017/S0305000916000489

Ballard, K. J., Djaja, D., Arciuli, J., James, D. G., & van Doorn, J. L. (2012). Developmental trajectory for production of prosody: Analysis of lexical stress contrastivity in children aged 3 to 7 years and adults. *Journal of Speech, Language, and Hearing Research, 55,* 1822–1835.

Ballard, K. J., Robin, D. A., McCabe, P., & McDonald, J. (2010). A treatment for dysprosody in childhood apraxia of speech. *Journal of Speech, Language, and Hearing Research, 53*(5), 1227–1245.

Bashina, V. M., Simashkova, N. V., Grachev, V. V., & Gorbachevskaya, N. L. (2002). Speech and motor disturbances in Rett syndrome. *Neuroscience and Behavioral Physiology, 32,* 323–327.

Bradford, L., Brooks, A., & Shelton, R. (1964). Clinical judgments of hypernasality in cleft palate children. *Cleft Palate Journal, 6,* 329–335.

Bunton, K., Hoit, J. D., & Gallagher, K. (2011). A simple technique for determining velopharyngeal status during speech production. *Seminars in Speech and Language, 32*(1), 69–80.

Bzoch, K. R. (1965). Articulation proficiency and error patterns of preschool cleft palate and normal children. *The Cleft Palate Journal, 2,* 340–349.

Centanni, T. M., Sanmann, J. N., Green, J. R., Iuzzini-Seigel, J., Bartlett, C., Sanger, W. G., & Hogan, T. P. (2015). The role of candidate-gene CNTNAP2 in childhood apraxia of speech and specific language impairment. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics, 168*(7), 536–543.

Davis, B. L., Jakielski, K. J., & Marquardt, T. P. (1998). Developmental apraxia of speech: Determiners of differential diagnosis. *Clinical Linguistics & Phonetics, 12*(1), 25–45.

Dodd, B., Hua, Z., Crosbie, S., Holm, A., & Ozanne, A. (2006). *Diagnostic evaluation of articulation and phonology*. San Antonio, TX: Pearson.

Felsenfeld, S., Broen, P. A., & McGue, M. (1992). A 28-year follow-up of adults with a history of moderate phonological disorder: linguistic and personality results. *Journal of Speech and Hearing Research, 35*(5), 1114–1125.

Felsenfeld, S., Broen, P. A., & McGue, M. (1994). A 28-year follow-up of adults with a history of moderate phonological disorder: Educational and occupational results. *Journal of Speech and Hearing Research, 37*(6), 1341–1353.

Felsenfeld, S., McGue, M., & Broen, P. A. (1995). Familial aggregation of phonological disorders: results from a 28-year follow-up. *Journal of Speech and Hearing Research, 38*(5), 1091–1107.

Fisher, S. E., Vargha-Khadem, F., Watkins, K. E., Monaco, A. P., & Pembrey, M. E. (1998). Localisation of a gene implicated in a severe speech and language disorder. *Nature Genetics, 18,* 168–170.

Forrest, K. (2003). Diagnostic criteria of developmental apraxia of speech used by clinical speech language pathologists. *American Journal of Speech-Language Pathology, 12*(3), 376–380.

Goldman, R., & Fristoe, M. (2000). *Goldman-Fristoe test of articulation,* 2nd Edition. Circle Pines, MN: Pearson.

Gozzard, H., Baker, E., & McCabe, P. (2004). *Single word test of polysyllables*: Unpublished work.

Gozzard, H., Baker, E., & McCabe, P. (2008). Requests for clarification and children's speech responses: Changing "pasghetti" to "spaghetti." *Child Language Teaching and Therapy, 24,* 249–263.

Gretz, S. (2013, February). *Current trends in CAS from the "street"*. Panel presentation at the Childhood Apraxia of Speech Research Symposium, Atlanta, GA.

Iuzzini, J. (2012). *Inconsistency of speech in children with childhood apraxia of speech, phonological disorders, and typical speech.* Unpublished Doctoral Dissertation, Indiana University, Bloomington, IN.

Iuzzini, J., & Forrest, K. (2008, March). *Acoustic vowel area in phonologically disordered, CAS, and normal speech.* Poster presented at the Conference for Motor Speech, Monterey, CA.

Iuzzini, J., & Forrest, K. (2010). Evaluation of a combined treatment approach for Childhood Apraxia of Speech. *Clinical Linguistics & Phonetics, 24*(4–5), 335–345.

Iuzzini-Seigel, J., Delaney, A., & Kent, R. (November, 2016). *Analysis of communication and motor abilities in 213 children with childhood apraxia of speech.* Poster presentation at the annual convention of the American Speech, Language, and Hearing Association, Philadelphia, PA.

Iuzzini-Seigel, J., Hogan, T., & Green, J. (2017). Speech inconsistency in children with childhood apraxia of speech, language impairment and speech delay: Depends on the stimuli. *Journal of Speech Language and Hearing Research.*

Iuzzini-Seigel, J., Hogan, T. P., Guarino, A., & Green, J. R. (2015). Reliance on auditory feedback in children with childhood apraxia of speech. *Journal of Communication Disorders, 54,* 32–42.

Kent, R. D., & Kim, Y. J. (2003). Toward an acoustic typology of motor speech disorders. *Clinical Linguistics & Phonetics, 17*(6), 427–445.

Laffin, J. J. S., Raca, G., Jackson, C. A., Strand, E. A., Jakielski, K. J., & Shriberg, L. D. (2012). Novel candidate genes and regions for childhood apraxia of speech identified by array comparative genomic hybridization. *Genetics in Medicine: Official Journal of the American College of Medical Genetics, 14*(11), 928–936.

Lai, C. S. L., Fisher, S. E., Hurst, J. A., Levy, E. R., Hodgson, S., Fox, M., Monaco, A. P. (2000). The SPCH1 region on human 7q31: Genomic characterization of the critical interval and localization of translocations associated with speech and language disorder. *American Journal of Human Genetics, 67,* 357–368.

Leavy, K. M., Cisneros, G. J., & LeBlanc, E. M. (2016). Malocclusion and its relationship to speech sound production: Redefining the effect of malocclusal traits on sound production. *American Journal of Orthodontics and Dentofacial Orthopedics, 150*(1), 116–123.

Lewis, B. A., Freebairn, L. A., Hansen, A. J., Iyengar, S. K., & Taylor, H. G. (2004). School-age follow up of children with childhood apraxia of speech. *Language, Speech, and Hearing Services in Schools, 35*(2), 122–140.

Liégeois, F. J., & Morgan, A. T. (2012). Neural bases of childhood speech disorders: lateralization and plasticity for speech functions during development. *Neuroscience & Biobehavioral Reviews, 36*(1), 439–458.

Logan, K. J., Byrd, C. T., Mazzocchi, E. M., & Gillam, R. B. (2011). Speaking rate characteristics of elementary-school-aged children who do and do not stutter. *Journal of Communication Disorders, 44*(1), 130–147.

Low, E. L., Grabe, E., & Nolan, F. (2000). Quantitative characterizations of speech rhythm: Syllable-timing in Singapore English. *Language and Speech, 43,* 377–401.

Maas, E., Butalla, C. E., & Farinella, K. A. (2012). Feedback frequency in treatment for childhood apraxia of speech. *American Journal of Speech-Language Pathology, 21,* 239–257.

Maassen, B. (2002). Issues contrasting adult acquired versus developmental apraxia of speech. *Semin Speech Lang, 17;23*;(4), 257–266.

Macken, M. & Barton, D. (1980). The acquisition of the voicing contrast in English: A study of voice-onset time in word-initial stop consonants. *Journal of Child Language, 7*(1), 41–74.

McCormack, J., McLeod, S., McAllister, L. & Harrison, L. J. (2010). My speech problem, your listening problem, and my frustration: The experience of living with childhood speech impairment. *Language, Speech, and Hearing Services in Schools, 41*(4), 379–392.

McCauley, R. J., & Strand, E. A. (2008). A review of standardized tests of nonverbal oral and speech motor performance in children. *American Journal of Speech-Language Pathology, 17*(1), 81–91.

McNeill, B. C., Gillon, G. T., & Dodd, B. (2009). Phonological awareness and early reading development in childhood apraxia of speech (CAS). *International Journal of Language & Communication Disorders, 44*(2), 175–192.

Milne, P. M. (2013). The relationship between schwa insertion and consonant cluster simplification in French: An analysis of covariance. *University of Pennsylvania Working Papers in Linguistics, 19*(1), 121–128.

Murray, E., McCabe, P., Heard, R., & Ballard, K. J. (2015). Differential diagnosis of children with suspected childhood apraxia of speech. *Journal of Speech, Language, and Hearing Research, 58*(1), 43–60.

Nijland, L., Maassen, B., Hulstijn, W., & Peters, H. (2004). Speech motor coordination in Dutch-speaking children with DAS studied using EMMA. *Journal of Multilingual Communication Disorders, 2*(1), 50.

Nijland, L., Maassen, B., Meulen, S. V. D., Gabreëls, F., Kraaimaat, F. W., & Schreuder, R. (2002). Coarticulation patterns in children with developmental apraxia of speech. *Clinical Linguistics & Phonetics, 16*(6), 461–483.

Preston, J. L., Hull, M., & Edwards, M. L. (2013). Preschool speech error patterns predict articulation and phonological awareness outcomes in children with histories of speech sound disorders. *American Journal of Speech-Language Pathology, 22*(2), 173–184.

Robbins, J., & Klee, T. (1987). Clinical assessment of oropharyngeal motor development in young children. *Journal of Speech and Hearing Disorders, 52,* 271–277.

Rosenbek, J. C., & Wertz, R. T. (1972). A review of fifty cases of developmental apraxia of speech. *Language, Speech, and Hearing Services in Schools, 3,* 23–33.

Rosenthal, J. B. (1994). Rate control therapy for developmental apraxia of speech. *Clinics in Communication Disorders, 4*(3), 190–200.

Shriberg, L. D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech, Language, and Hearing Research, 36*(1), 105–140.

Shriberg, L. D., Aram, D. M., & Kwiatkowski, J. (1997). Developmental apraxia of speech II. Toward a diagnostic Marker. *Journal of Speech, Language, and Hearing Research, 40*(2), 286–312.

Shriberg, L. D., Campbell, T. F., Karlsson, H. B., Brown, R. L., McSweeny, J. L., & Nadler, C. J. (2003). A diagnostic marker for childhood apraxia of speech: the lexical stress ratio. *Clinical Linguistics and Phonetics, 17*(7), 549–574.

Shriberg, L. D., Jakielski, J. J., & Strand, E. A. (2010, November). *Diagnostic markers of childhood apraxia of speech.* Presentation at the American Speech-Language-Hearing Association Convention, Philadelphia, PA.

Shriberg, L. D., Lohmeier, H. L., Strand, E. A., & Jakielski, K. J. (2012). Encoding, memory, and transcoding deficits in childhood apraxia of speech. *Clinical Linguistics & Phonetics, 26*(5), 445–482.

Shriberg, L. D., & McSweeny, J. L. (2002). Classification and misclassification of childhood apraxia of speech. *Phonology Project Technical Report, 11,* 1–27.

Shriberg, L. D., Potter, N. L., & Strand, E. A. (2011). Prevalence and phenotype of childhood apraxia of speech in youth with galactosemia. *Journal of Speech, Language, and Hearing Research, 54,* 487–519.

Skinder, A., Connaghan, K., Strand, E., & Betz, S. (2000). Acoustic correlates of perceived lexical stress errors in children with developmental apraxia of speech. *Journal of Medical Speech-Language Pathology, 4,* 279–284.

Skinder, A., Strand, E. A., & Mignerey, M. (1999). Perceptual and acoustic analysis of lexical and sentential stress in children with developmental apraxia of speech. *Journal of Medical Speech Language Pathology, 7*(2), 133–144.

Stackhouse, J. (1992). Developmental verbal dyspraxia I: A review and critique. *International Journal of Language & Communication Disorders, 27*(1), 19–34.

Strand, E. A., McCauley, R. J., Weigand, S. D., Stoeckel, R. E., & Baas, B. S. (2013). A motor speech assessment for children with severe speech disorders: Reliability and validity evidence. *Journal of Speech, Language and Hearing Research, 56*(2), 505–520.

Terband, H., & Maassen, B. (2010). Speech motor development in childhood apraxia of speech: generating testable hypotheses by neurocomputational modeling. *Folia Phoniatrica et Logopaedica, 62*(3), 134–142.

Turner, S. J., Hildebrand, M. S., Block, S., Damiano, J., Fahey, M., Reilly, S., . . . Morgan, A. T. (2013). Small intragenic deletion in FOXP2 associated with childhood apraxia of speech and dysarthria. *American Journal of Medical Genetics, 161A*(9), 2321–2326.

Van der Merwe, A. (2009). A theoretical framework for the characterization of pathological speech sensorimotor control. In M.R. McNeil (Ed.), *Clinical Management of Sensorimotor Speech Disorders* (2nd ed.). New York, NY: Thieme.

Van Riper, C. (1982). *The nature of stuttering*. Englewood Cliffs: Prentice-Hall.

Velleman, S. L., & Shriberg, L. D. (1999). Metrical analysis of the speech of children with suspected developmental apraxia of speech. *Journal of Speech, Language, and Hearing Research, 42*(6), 1444–1460.

Warner, N., Jongman, A., Cutler, A., & Mücke, D. (2001). The phonological status of Dutch epenthetic schwa. *Phonology, 18*(2), 387–420.

World Health Organization. (2002). *Towards a Common Language for Functioning, Disability and Health ICF*. Geneva, Switzerland: WHO.

Williams, R., Ingham, R. J., & Rosenthal, J. (1981). A further analysis for developmental apraxia of speech in children with defective articulation. *Journal of Speech and Hearing Research, 24,* 496–505.

Yoss, K. A., & Darley, F. L. (1974). Developmental apraxia of speech in children with defective articulation. *Journal of Speech, Language, and Hearing Research, 17*(3), 399–416.

*History:*
Received January 27, 2017
Revised April 10, 2017
Accepted May 02, 2017
https://doi.org/10.1044/persp2.SIG2.47