ADVANCES IN SPECIAL NEEDS EDUCATION AND PRACTICES

Edited by
Ayo Osisanya
Adebayo F. Komolafe
Kelechi U. Lazarus
Abiodun T. Adewunmi

Advances in Special Needs Education and Practices

Edited by

Ayo Osisanya
Adebayo F. Komolafe
Kelechi U. Lazarus
Abiodun T. Adewunmi

JOHN ARCHERS

Published by
JOHN ARCHERS (PUBLISHERS) LTD.
First Floor Ebun Isola House 53 Gbadebo Str. Mokola
GPO Box 339, Dugbe, Ibadan
✆ o803 4476 916, 0701 085 1055
e-mail: archersbooksonline@gmail.com
johnarchers@yahoo.co.uk

www.johnarchers.com.ng

ISBN: 978–978–59958–2–4

Contents

CHAPTER SEVEN

Childhood Apraxia of Speech: Concept, Diagnosis and Intervention Techniques

Adenike Elizabeth Akanni

INTRODUCTION

CHILDHOOD Apraxia of Speech (CAS) is a motor speech disorder with difficulty in planning, coordinating, producing and sequencing speech sounds. It interferes with a child's ability to say sounds and to combine them into syllables, words, phrases and conversations. More specifically, American Speech-Language-Hearing Association (ASHA, 2007), defined Childhood apraxia of speech (CAS) as a neurological childhood (paediatric) speech sound disorder in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g., abnormal reflexes, abnormal tone). CAS is a disorder of speech motor in programming and planning with genetic, neurologic, or idiopathic causes (Terband, Maassen, van Lieshout, Nijland, 2011). A child with CAS knows what to say, however, the brain struggles to correctly move the lips, jaw and tongue in order to speak clearly and be understood. Also, for normal speech production to occur, the brain requires an accurate, sequenced plan to coordinate the movement and sequence of muscles within the vocal tract. This implies that the development of motor planning for speech production in children with CAS is impaired, resulting in uncoordinated vocal tract muscle movements. Leading to multiple speech sound errors which can create a speech pattern that significantly impacts the child's ability to communicate verbally.

CAS is often described as a "motor planning disorder in the absence of motor weakness" (Velleman, 2003). Many children are able to hear words, and are able to understand what they mean, but cannot change the words heard into the fine-motor skill of combining consonants and vowels. The motor difficulties within CAS are not related to muscle tone but are related to the plan of (vocal tract) muscle movement, including sequencing and

transitioning of vocal tract movements (Velleman, 2003). CAS may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of known or unknown origin, or as an idiopathic neurogenic speech sound disorder. The core impairment in planning and/or programming spatiotemporal parameters of movement sequences results in errors in speech sound production and prosody. CAS is often identified in early childhood but symptoms can remain well into school age or even adulthood, and there may be lasting impacts on social, academic, and communicative success.

Historically, CAS as a speech sound disorder came to be over sixty years ago, when Morley 1954 provided a seminar paper documenting a series of speech characteristics in children that resembled the speech production disorder of adults with acquired apraxia of speech. Early terms for the disorder have included, developmental apraxia of speech, developmental articulatory dyspraxia, congenital articulatory apraxia and developmental verbal apraxia (Bauman-Waengler, 2012). The term dyspraxia refers to an impaired praxis (the ability to plan for voluntary motor movement) and does not accurately reflect the severity of the disorder; therefore, apraxia serves as a more appropriate term to assist in the labeling of the disorder (Velleman, 2003). Also, the use of developmental is controversial because it denotes a disorder that will improve without speech and language therapy, thus, a need for a more accurate term. The current term for the disorder, Childhood Apraxia of Speech, removes the "developmental" label because CAS differs from a developmental delay, and arises from abnormal physiological function in which the brain has difficulty motor planning for speech (McCarty, 2013). CAS is also mistaken or confused with other related disorder such as ataxia which is a lack of coordination of movements; aphasia, an inability to produce and/or comprehend language; or abulia, the lack of desire to carry out an action. It is also not the same as developmental delays in speech, in which a child follows the typical path of speech development but does so more slowly than is typical.

In addition, CAS and Acquired apraxia of speech, hence, (AOS) are different co-related condition. AOS, is a speech disorder resulting from neurological damage, including stroke or traumatic brain injury (Wambaugh,

Nessler, Cameron and Mauszycki, 2013). Although both CAS and acquired apraxia of speech (AOS) are characterised by speech errors that stem from impaired motor programming rather than muscle weakness, there are important differences. (Bauman-Waengler, 2012). An underlying difference between CAS and AOS is the etiology of the disorder. The etiology of AOS is damage to the central nervous system. AOS may result from injury to the frontal lobe including Broca's area, the supplemental motor cortex, the basal ganglia and other cortical regions as well (Bauman-Waengler, 2012). For CAS, there is no known cause or etiology, imaging and other studies have not been able to find evidence of brain damage or differences in the brain structure of children with CAS. However, children with CAS often have family members who have a history of a communication disorder or a learning disability. This observation and recent research findings suggest that genetic factors may play a role in the disorder. Another difference between AOS and CAS is the impact that CAS has on phonological and linguistic development (ASHA, 2007). CAS is a motor speech disorder that can co-occur with phonological impairments, where AOS is typically free of phonological or linguistic impairments unless it occurs with aphasia (Bauman-Waengler, 2012).

CHARACTERISTICS OF CHILDHOOD APRAXIA OF SPEECH

Children with CAS have significant speech impairments due to inability to control placement and timing of lip, tongue and vocal movements which vary depending on the age and severity of the condition.

One manifestation of CAS is significant breakdown in the precision of speech as words become increasingly complex (e.g. increased number of phonemes and syllables). Children with CAS also experience inconsistent productions of the same words, difficulty in sequencing speech sounds together to form fluent words and sentences and impairments of the melody (i.e. prosody) of speech (Murray *et al*, 2012). In addition to the core features of CAS, children may also have co-occurring impairments affecting non-speech oral motor function, language, phonemic awareness/meta-linguistics and literacy (ASHA, 2007). Younger children typically present with more severe forms of the disorder, with improvement noted over time for both idiopathic CAS (Davis 2005; Jacks 2006) and individuals with CAS associated

with genetic syndromes (Morgan, 2017; Morgan, 2018). Other features include:

(i) Limited or little babbling as an infant (void of many consonants).
(ii) First words may not appear at all, pointing and "grunting" may be all that is heard.
(iii) The child is able to open and close mouth, lick lips, protrude, retract and lateralise tongue while eating, but may not be able to when directed to do so.
(iv) First word approximations occurring beyond the age of 18 months, without developing into understandable simple vocabulary words by age 2.
(v) Continuous grunting and pointing beyond age 2.
(vi) Lack of a significant consonant repertoire: child may only use /b, m, p, t, d, h/.
(vii) All phonemes (consonants and vowels) may be imitated well in isolation, but attempts to combine phonemes are unsuccessful.
(viii) Difficulty moving smoothly from one sound, syllable or word to another.
(ix) Groping movements with the jaw, lips or tongue to make the correct movement for speech sounds.
(x) Using the wrong stress in a word, such as pronouncing "banana" as "BUH-nanuh" instead of "buh-NAN-uh".
(xi) Using equal emphasis on all syllables, such as saying "BUH-NAN-UH".
(xii) Separation of syllables, such as putting a pause or gap between syllables.
(xiii) Inconsistency, such as making different errors when trying to say the same word a second time.
(xiv) Difficulty imitating simple words – Inconsistent voicing errors, such as saying "down" instead of "town," or "zoo" instead of "Sue".
(xv) Vowel distortions or replacements occur which are not due to oral motor weakness.
(xvi) The ability to blurt out clear whole words, phrases or sentences may occur though there is difficulty imitating these same words

"on command" or upon imitation.

(xvii) Difficulty in maintaining clarity with extended word length or complexity.

(xviii) Verbal perseveration: getting "stuck" on a previously uttered word, or bringing oral motor elements from a previous word into the next word uttered.

(xix) Oral groping may occur when attempting oral motor movements or consonant/vowel production.

(xx) Echolalic utterances (the automatic repetition of words, phrases, or sentences often without comprehension) might be perfectly articulated but novel attempts at words or combinations might be more effortful.

CAS symptoms are found to change over time and following treatment (Lewis, Freebairn, Hansen, Iyengar, and Taylor, 2004). This implies, children with CAS who are preschool-aged and who have received very little or no treatment often manifest 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, and Kent, 2016). For instance, 50 percent of children with CAS are reported to have fine and gross motor deficits (Gretz, 2013). Likewise, 80 percent of children with CAS have comorbid language impairments (Iuzzini, 2012). Also, reading and writing impairments are common (Lewis *et al*, 2004). A subset of children with CAS have comorbid neurodevelopmental disorders (Iuzzini-Seigel *et al*, 2016) such as seizure disorders, syndromes (for example, Fragile X Syndrome, Rett Syndrome, Down Syndrome), and metabolic disorders (for example, Galactosemia; Shriberg, Potter, and Strand, 2011). 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.

PREVALENCE OF CAS

CAS is a rare condition, so there are no epidemiological data on its prevalence, although it occurs infrequently in comparison with other forms of developmental speech disorder such as articulation disorder and phonological disorder, which occur in around 3.5 percent of preschool children (Eadie, 2015). CAS is found in 3.4 percent to 4.3 percent of the children referred to clinics for speech disorder management (Delaney, 2004), and is more prevalent within particular medical subgroups, particularly in certain genetic syndromes (Fedorenko, 2016; Mei, 2017).

DIAGNOSIS OF CAS

Childhood Apraxia of Speech (CAS) is diagnosed by a speech language pathologist (SLP) also known as speech and language therapist. The following three segmental and suprasegmental speech characteristics as proposed by ASHA CAS Technical Report must be met before CAS can be diagnosed:

(1) Inconsistent error production on both consonants and vowels across repeated productions of syllables or words;
(2) Lengthened and impaired coarticulatory transitions between sounds and syllables; and
(3) Inappropriate prosody (ASHA, 2007).

In addition, many researchers also use the Mayo's 10 checklist which requires children to have at least 4/10 of the features listed across three speech tasks (Shriberg *et al*, 2011). Clinically, moderate profound CAS in young children (aged 3 7) can also be diagnosed using the DEMSS assessment tool (Strand *et al*, 2019). For a diagnosis of CAS to be accurate, children need to have a clear intent to communicate regardless of age or severity.

The CAS diagnosis is associated with functional deficits rather than structural ones; therefore, a comprehensive oral musculature structural and functional evaluation is needed to establish or rule out comorbid conditions. Oral-motor assessment, such as the Oral and Motor Speech Protocol, oral examination such as pursing lips, blowing, licking lips, elevating the tongue, and general mouth examination are done. A complete exam also includes surveillance of the patient eating and talking.

Furthermore, assessment is done on speech production on single words,

test 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, so there is need to measure the inconsistency such as DEAP, SRT or repeated productions from the single word test used. However, poor accuracy and inconsistency on polysyllable word production is also present in children with speech delay and phonological disorder (Iuzzini, 2012; Iuzzini, Seigel, Hogan, Guarino and Green, 2015). Another useful task can be a dynamic motor speech exam where a child repeats words after the speech therapist and cueing such as simultaneous imitation and touch cues are used to determine what a child can do with support (Strand, McCauley, Weigand, Stoeckel, and Baas, 2013).

A differential diagnosis of CAS is frequently not possible for children under the age of 2 years old. Even when children are between 2–3 years, a clear diagnosis cannot always occur, because at this age, they may not still be capable to focus on, or cooperate with testing procedures (Wangchuck, 2015).

EFFECT OF CAS

Children with speech impairments can evidence a breadth of limitations across the lifespan, including long-term limitations to education and employment (McLeod, Harrison and McAllister, 2010). Due to the functional challenges experienced by children with speech impairments – and CAS specifically – many limitations are anticipated. The speech of these children is often unintelligible and the disability can persist throughout the lifespan, despite normal intelligence and comprehension of language (Lewis, Freebairn, Hansen, Iyengar, Taylor, 2004). 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; McNeill, Gillon and Dodd, 2009). Phonological impairment is also highly comorbid as the speech system is developing. Children with CAS may also 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.

A child with CAS may have difficulty communicating wants and needs, interacting socially, singing, engaging in conversations, 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. 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, compounding communicative limitations to social interaction.

INTERVENTION TECHNIQUES

CAS, has no cure but with suitable, and intensive involvement in speech therapy, children with the disorder can improve considerably. The treatment of CAS due to its characteristics and associated risk factors must be long term maintenance of learned skills and generalisation of treatment across other co-occurring conditions. CAS requires speech therapy which varies with individual needs, hence, the type of therapy will depend on:

(1) the child's symptoms
(2) age
(3) the severity of the condition, and
(4) any other health or existing developmental problems.

Typically, treatment involves one-on-one therapy with a speech and language pathologist (SLP), and the therapy should commence as soon as the disorder is identified. Speech therapy helps the brain form new connections to help make the movements for speech. Speech therapy will also focus on improving the language system in children with both speech and language deficits; pre-literacy and literacy skills may also be addressed in older children with CAS (Wangchuck, 2015). The following techniques are important in the therapy process:

(i) Treatment needs to be intense and highly individualised, with about 3-5 therapy sessions each week.
(ii) A maximum of 30 minutes per session is best for young children.
(iii) Non-speech oral motor therapy is not necessary or sufficient.
(iv) Phonemic and articulation approaches (teaching the child how to make sounds and combine sounds into syllables).
(v) Cueing approaches:
    (a) Visual cues (providing a hand cue that the child can see such as Cued Speech) .
    (b) Visual-tactile cues (e.g. turtle vowels by Strode and Chamberlain).
    (c) Physical cues (PROMPT) where the therapist touches the facial area where the sound is made.
(vi) A multi-sensory approach to therapy may be beneficial: using sign language, pictures, and Augmentative and Alternative Communication (AAC) to ensure that they can communicate and maintain their expressive language development.
(vii) Multimodal or Total Communication approaches i.e. using word in addition to signs or cues to use signs to teach speech and language.
(viii) Prosodic approaches (melodic intonation therapy) use singing and rhythm to help the child learn sound combinations.
(ix) Shaping approaches which deconstruct and construct words (e.g. the Kaufman Praxis Treatment Kit) break words down to the level of complexity that the child can say, moving the word immediately into functional expressive vocabulary use, and then building the word up through shaping procedures.

There is not one program used to treat CAS. Treatment will depend on the child's speech characteristics, age and ability level. In some cases, sign language or a talking device are used to help the child communicate until the child's speech is clear to others. Therapy also needs to be frequent, and there should be a home practice program. The child will need lots of practice making sounds, but this can be done as part of play, singing and daily activities. The basic difference is that CAS therapy focuses on length and complexity of sound combinations whereas traditional therapy focuses on

individual sounds in a sound by sound approach. CAS treatment progresses from teaching the child individual speech movements (a consonant vowel combination) to sequences of movements, from shorter to longer, less to more complex.

EVIDENCED BASED INTERVENTIONS FOR CAS

(1) Rapid Syllable Transition Treatment (ReST)

Rapid Syllable Transition Treatment (ReST) is a treatment for improving the motor planning and programming deficits that cause prosody and speech sound errors in CAS (McCabe, Murray, Thomas and Evans, 2017). It addresses sound consistency, rapid and fluent transitions between syllables and lexical stress (Murray, McCabe and Ballard, 2012). It consists of high intensity practice of randomly presented pseudo words, with varying phonetic structure and lexical stress. These enable the child to learn new motor plans and programmes without the interference of previously incorrectly learned plans, and programmes (Murray et al., 2012). The treatment employs motor-learning principles thought to facilitate long-term skill retention and generalisation (Maas, Robin, Austermann Hula, Freedman, Wulf, Ballard, and Schmidt, 2008; Schmidt and Lee, 2011), such as pre-practice and practice phases within each session, random presentation of stimuli, and a predominance of delayed low-frequency feedback about whether or not the item was correct (McCabe *et al*, 2017). The efficacy of ReST treatment has been established in randomised controlled trial (Murray, McCabe, and Ballard, 2015) as well as SCED studies (Ballard, Robin, McCabe, and McDonald, 2010; McCabe, Macdonald D'Silva, van Rees, Ballard, and Arciuli, 2014).

(2) Dynamic Temporal and Tactile Cueing (DTTC)

DTTC is a treatment method designed specifically for children with severe CAS. It is a motor-based approach, meaning; it is designed to improve the brain's ability to plan and programme movements for speech. It helps to improve the efficiency of neural processing for the development and refinement of movements. The incorporation of a number of principles of motor learning helps the child maintain accurate movement over time. It is an explicitly modified version of eight-step continuum treatment (Rosenbeck,

Lemme, Ahern, Harris and Wertz, 1973). The steps are as follows:

(i) Imitation: in its implantation, DTTC begins with direct, immediate imitation of natural speech.

(ii) Simultaneous production with prolonged vowels: Once the child cannot imitate, the therapist makes the task easier and more supported by introducing simultaneous production. The sound is produced at normal volume, very slowly, with touch/gesture cues. The utterance is slowed by sustaining the vowel e.g. 'sea' is produced as 'si:::::::::: and not as sssssssssea, 'me as mi:::::::::: and not mmmmmme. This allows the child to imitate while allowing the clinician run a 'visual check' of jaw and lip postures.

(iii) Reduction of vowel length: The rate of stimuli production is increased (i.e. vowel, length is reduced) to sound more natural.

(iv) Graduate increase of rate to normal: Practice continues at this level to the point where the child synchronises effortlessly with the therapist at normal rate, with normal movement gestures and without silent posturing.

(v) Reduction of therapist's vocal loudness, eventually mining: Using delicate timing, the therapist is then in a position to reduce volume eventually reaching a point of miming or mouthing as the child says it aloud.

(vi) Direct imitation: The SLP ensures that the child is comfortable with moving to this harder level in which the child watches the adult's face while an auditory model is provided. The child attempts to repeat the model and if successful, it will be repeated several times.

(vii) Introduction of a one or two second S-R delay (least support): once the child can imitate the therapist model with normal rate, vary and appropriate the articulatory gestures, a new requirement is introduced. A one to two second delay before the child imitates, so that the child produces a very slightly delayed response.

(viii) Spontaneous production: finally, the therapist elicits the spontaneous utterances, for example by asking the child questions.

The key to implementation is the therapist's informed observations of, and sensitivity to, what the child is giving by way of responses. The skill and flexibility involved in continually fine-tuning the hierarchy of stimuli and the amount of support provided to the child to enable him or her imitate spontaneously is critical, especially with the CAS population. Auditory (including prosodic), visual and tactile cues and level of demand on the child are continually modulated in each practice trial according to the child's responses.

(3) Nuffield Dyspraxia Programme – Third Edition (NDP-3)

The Nuffield Dyspraxia Programme – third edition (NDP-3) aims to improve children's speech production by developing their motor planning and programming (Williams and Stephens, 2004). It is based on a psycholinguistic framework and teaches skills in a hierarchical manner, beginning with isolated phonemes and phoneme sequences and then moving to simple words and lastly to sentences, with success required at foundation levels before progressing to more complex tasks (Williams and Stephens, 2004). Three goals are selected for each child, with at least one targeting new phonotactic structures and at least one targeting sounds (Murray et al., 2012). Each goal is targeted for a short block within each session, with immediate detailed feedback provided on each attempt of each word.

(4) Biofeedback

Biofeedback treatments use instrumental means to provide feedback on aspects of physiological functioning (Preston, Brick, and Landi, 2013). Biofeedback techniques such as electropalatography (EPG) and ultrasound provide feedback on the position and movement of the articulators, particularly the tongue, during speech. EPG registers contact between the tongue and areas of the palate via a custom-designed dental plate with inbuilt electrodes, whereas ultrasound uses reflected sound waves via a transducer held below the chin to determine the position of the tongue.

It has been hypothesised that the feedback provided by biofeedback systems compensate for the poor feed-forward mechanism in children with CAS by providing 'knowledge of an individual's performance that can be used to update, modify, and stabilise motor plans for speech' (Preston et

al., 2013). Most biofeedback treatments target sound production, but there are many ways the treatments are structured to achieve broad goals. In some treatments, biofeedback is used for an entire treatment session (Carter and Edwards, 2004), in others, only part of a session (e.g. Preston *et al*, 2013). The stimuli, feedback type and schedule vary between the treatments using biofeedback. For example, Preston, Maas, Whittle, Leece, and McCabe (2016) used biofeedback via ultrasound in approximately half of each treatment session to target the production of two sound sequences per child (e.g. VC, /ir/; CC, /fl/) in linguistic structures up to sentences. In contrast, Carter and Edwards (2004) used biofeedback via EPG for the whole of every session in a treatment block, targeting all the child's errored consonants (up to 16 error patterns) with up to half the block spent practising the position for the consonant silently.

(5) Combined Approaches

There are several reports of combined treatments for CAS. It is not immediately clear why individual researchers used combined treatments. It may be that the nature of CAS, with deficits in several areas, is thought to benefit from combined treatments given that most treatments aim to treat only one facet of the impairment. Indeed, combined treatments are not dissimilar to routine clinical practice for many speech impairments, where clinicians report using eclectic treatments (Glogowska, Roulstone, Enderby and Peters, 2000; Joffe and Pring, 2008; McLeod and Baker, 2014). For example, Stimulability with modified Core Vocabulary, Melodic Intonation Therapy and Touch Cue Method, Nuffield Dyspraxia Programme, Melodic Intonation Therapy and Multisensory Cues.

CONCLUSION

CAS is a low-incidence disorder, with prevalence estimated at one child per 1,000 (Shriberg *et al.* 2019). However, the presence of these disorder has a significant burden of psychosocial, educational, economic and communication deficits which remains across the lifespan with resultant restrictions on participation and daily life of affected children, particularly those with comorbid diagnoses. In recent years, substantial progress has been made in improving speech pathology treatment for CAS but there

remains many older children, adolescents and adults who have severe limitations to all aspects of their lives due to ineffective and/or insufficient treatment. This write-up therefore provides a procedure to support the identification, differential diagnosis and intervention techniques of CAS. This will help Speech therapist and other professionals gain confidence and expertise diagnosing CAS thereby increasing the quality of care of children with these challenging diagnoses.

REFERENCES

American Speech, Language, and Hearing Association (2015). Childhood Apraxia of Speech. www.asha.org/public/speech/disorders/ChildhoodApraxia

American Speech-Language-Hearing Association (2007). Childhood apraxia of speech (Report No. TR2007-00278). Rockville, MD: Author. Retrieved from http://www.asha.org/policy

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

Bauman-Waengler, J.A. (20212). *Articulatory and Phonological Impairments*. New York, NY: Pearson Higher Education.

Carter, P. P. and Edwards, S. S. (2004). EPG therapy for children with long-standing speech disorders: predictions and outcomes. *Clinical Linguistics and Phonetics*, 18(6–8), 359-372.

Davis, B. L., Jacks, A. and Marquardt, T. P. (2005). Vowel Patterns in Developmental Apraxia of Speech: Three Longitudinal Case Studies. *Clinical Linguistics and Phonetics* 19(4): 49-74 doi: 10.1080/02699200410001695367.

Delawey, A.L. and Kent, R.D. (2004). Developmental Profiles of Children Diagnosed with Apraxia of Speech. Poster Session Presented at the Annual Convention of the American- Speech-Language-Hearing Association, Philadelphia.

Eadie, P., Morgan, A., Ukoumunne, O.C., Ttofari Eecen, K., Wake, M. and Reilly, S. (2015). Speech Sound Disorder at 4 years. Prevalence Comorbidities, and Predictors in a Community Cohort of Children. *Developmental Medicine and Child Neurology*.

Fodorenko, E., Morgan, A., Murray, E., Cardinaux, A., Mei, C., Tager-Flusberg, H. *et al.* A highly penetrant form of childhood apraxia of speech due to deletion of 16p11.2 *European Journal of Human Genetics*.

Gillon, G.T. and Moriarty, B.C. (2007). Childhood apraxia of speech: children at risk for persistent reading and spelling disorder. *Seminar in Speech and Language*, 28(1):48–57.

Glogowska, M., Roulstone, S., Enderby, P., and Peters, T. J. (2000). Randomised

controlled trial of community based speech and language therapy in preschool children. *British Medical Journal*, 321(7266), 923.

Gretz, S. (2013). 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-Seigel, J., Delaney, A., and 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. P., Rong, P. and Green, J. R. (2015). Longitudinal development of speech motor control: Motor and linguistic factors. *Journal of Motor Learning and Development*, 3(1), 53-68.

Jacks, A. and Marquardt, T. P. (2006). Consonant and Syllable Structure Patterns in Childhood Apraxia of Speech: Developmental change in three children. *Journal Communication Disorder,* 39(6)424-41.

Joffe, V. and Pring, T. (2008). Children with phonological problems: A survey of clinical practice. *International Journal of Language and Communication Disorders,* 43(2), 154-164. https://doi.org/10.1080/13682820701660259

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

Lewis, B. A., Freebairn, L.A., Hansen, A., Gerry Taylor, H., Iyengar, S. and Shriberg, L. D. (2004). Family pedigrees of children with suspected childhood apraxia of speech. *Journal of Communication Disorders*, 37, 157-175.

Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J. and Schmidt, R. A. (2008). Principles of motor learning in treatment of motor speech disorders. *American Journal of Speech-Language Pathology*, 17(3), 277-298.

Mei, C., Fedorenko, E., Amor, D.J., Boys, A., Hoeflin, C. and Carew, P. (2017). Speech and language phenotype in 16p11.2 deletion. *European Journal of Human Genetics.*

McCabe, P., Murray, E., Thomas, D. C., and Evans, P. (2017). Clinician manual for Rapid Syllable Transition Treatment (ReST). Retrieved from http://sydney.edu.au/healthsciences/rest-media/rest-clinician-manual.pdf

McCabe, P., Macdonald-D'Silva, A. G., van Rees, L. J., Ballard, K. J. and Arciuli, J. (2014). Orthographically sensitive treatment for dysprosody in children with childhood apraxia of speech using ReST intervention. *Developmental Neurorehabilitation* 17(2), 137-146. https://doi.org/10.3109/17518423.2014.906002

McLeod, S. and Baker, E. (2017). Children's speech: An evidence-based approach to

assessment and intervention: Boston, MA: Pearson Education.

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

Morgan, A. T., Murray, E. and Liégeois, F. J. (2018). Interventions for childhood apraxia of speech. *Cochrane Database of Systematic Reviews*, (5).

Morley M., Court D. and Miller H. (1954). Developmental dysarthria. *British Medical Journal* doi:10-1136/brj.1.4852.8. PMID: 13106450, PMCID: PMC2093079.

Murray, E., McCabe, P. and Ballard, K. J. (2012). A comparison of two treatments for childhood apraxia of speech: methods and treatment protocol for a parallel group randomised control trial. BMC Pediatrics, 12, 1–9. https://doi.org/10.1186/1471-2431-12-112.

_____(2015). A randomized control trial for children with Childhood Apraxia of Speech comparing Rapid Syllable Transition treatment and the Nuffield Dyspraxia Programme – Third edition. *Journal of Speech, Language and Hearing Research*, 58, 669–686. https://doi.org/10.1044/2015_JSHLR-S-13-017

Murray, E., Iuzzini-Seigel, J., Maas, E., Terband, H. and Ballard, K. J. (2021). Differential diagnosis of childhood apraxia of speech compared to other speech sound disorders: A systematic review. *American Journal of Speech-Language Pathology* 30(1), 279-300. https://doi.org/10.1044/2020_AJSLP-20-00063

Murray, E., McCabe, P., Heard, R. and 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.

Preston, J. L., Brick, N. and Landi, N. (2013). Ultrasound biofeedback treatment for persisting childhood apraxia of speech. *American Journal of Speech-Language Pathology*, 22(4), 627-643.

Preston, J. L., Maas, E., Whittle, J., Leece, M. C. and McCabe, P. (2016). Limited acquisition and generalisation of rhotics with ultrasound visual feedback in childhood apraxia. *Clinical Linguistics and Phonetics*, 30(3-5), 363-381.

Schmidt, R. A. and Lee, T. (2011). Motor control and learning, a behavioral emphasis (5th ed.). Champaign, IL: Human Kinetics.

Shriberg, L. D., Potter, N. L. and 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.

Strand, E. A. and McCauley, R. J. (2019). Dynamic Evaluation of Motor Speech Skill (DEMSS) manual. Brookes. https://doi. org/10.1016/j.jcomdis.2014.06.008

Strand, E. A., McCauley, R. J., Weigand, S. D., Stoeckel, R. E. and 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., van Lieshout, P. and Nijland, L. (2011). Stability and

composition of functional synergies for speech movements in children with developmental speech disorders. *Journal of Communication Disorders,* 44(1): 59-74.

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

Wambaugh, J.L., Nessler, C., Cameron, R. and Mauszycki, S.C. (May 2012). "Acquired apraxia of speech: the effects of repeated practice and rate/rhythm control treatments on sound production accuracy". Am J Speech Lang Pathol 21 (2): S5–27. doi:10.1044/1058- 0360(2011/11-0102). PMID 22230177

Williams, P. and Stephens, H. (2004). Nuffield Centre Dyspraxia Programme: Third Edition. Windsor, England: The Miracle Factory.

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