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A Narrative Review of the Intervention Techniques for Childhood Apraxia of Speech

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Childhood Apraxia of Speech (CAS) is a speech disorder that affects development of the motor planning skills needed for the production of speech. According to prevalence data, CAS affects approximately two children per 1,000 (Bauman-Waengler, 2012, p.366). 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. The development of motor planning for speech production is impaired in children with CAS, resulting in uncoordinated vocal tract muscle movements. This can lead 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, p. 2). Therefore, 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, p. 3).

Historically, CAS has been termed developmental apraxia of speech and developmental verbal dyspraxia (Teverovsky, Bickel, & Feldman, 2009, p. 95). Early terms for the disorder have included developmental articulatory dyspraxia, congenital articulatory apraxia and developmental verbal apraxia (Bauman-Waengler, 2012, p. 365). 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, p. 2). The use of the term developmental is also controversial because it denotes a disorder that will improve without speech-language therapy and is therefore hard to cover through insurance (Velleman, 2003, p. 4). Insurance companies have often denied covering all speech or language therapy that has been termed developmental (McCarty, 2013). Although CAS has been termed a developmental disorder, the nature of the disorder is also neurological (McCarty, 2013). 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). The prognosis of CAS is emblematic of the time in which CAS is diagnosed and the intensity of the intervention (Velleman, 2003, p. 8).

CAS is a complex speech disorder affected by many factors. Although CAS is a speech disorder that affects the motor planning skills for speech and the coordination of vocal tract muscle movements, the disorder does occur concurrently with phonological difficulties (Velleman, 2003, p. 2). There are many different symptoms that can occur with the disorder; however, there are no specific phonological characteristics that must be present in the diagnosis (Bauman-Waengler, 2012, p.368). The technical report for CAS produced by the American Speech-Language-Hearing Association lists the following segmental and suprasegmental characteristics of the disorder: "inconsistent errors on consonants and vowels in repeated productions of syllables or words, lengthened and disrupted coarticulatory transitions between sounds and syllables, and inappropriate prosody" (ASHA, 2007). Other characteristics that have been associated with the disorder include errors during the production of complex speech sounds, unusual errors that are not typical with other speech sound disorders, addition of speech sounds, omission of speech sounds, voicing errors, vowel errors, diphthong errors, sequencing difficulties, nasality difficulties, and groping behavior (Bauman-Waengler, 2012, p. 366). As mentioned previously, CAS can also occur with phonological and linguistic difficulties. Some phonological and linguistic characteristics that have been associated with CAS include "difficulty identifying rhymes and syllables" (Bauman-Waengler, 2012, p. 368). Aside from these symptoms, studies have revealed other possible characteristics that include academic difficulties and oral motor difficulties (Teverovsky et al., 2009, p. 95). Additionally, research has not yet identified an etiology for this disorder. The combination of factors makes the diagnosis of CAS difficult.

It is important to note that CAS is different than acquired apraxia of speech (AOS), a speech disorder resulting from neurological damage, including stroke or traumatic brain injury (Wambaugh, Nessler, Cameron, & Mauszycki, 2013, p. 84). Although both CAS and acquired apraxia of speech (AOS) are characterized by speech errors that stem from impaired motor programming rather than muscle weakness, there are important differences. (Bauman-Waengler, 2012, p. 395). An underlying difference between CAS and AOS is the etiology of the disorder. The etiology of AOS is damage to the central nervous system (Bauman-Waengler, 2012, p. 395). 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, p. 395). For a child

with CAS, there is no known cause or etiology for the disorder and a paucity of information makes the disorder difficult to diagnose. 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 AOS occurs with aphasia (Bauman-Waengler, 2012, 396).

Research of CAS has examined genetic and neurological components of the disorder. Some research has shown CAS to be “highly heritable” and that some children with a diagnosis of CAS have family members who also have speech and language disorders (Lewis, Freebairn, Hansen, Taylor, Iyengar, & Shriberg, 2004, p. 158). Researchers have studied a family pedigree of many members with a speech sound disorder. The pedigree, referred to as the K.E. family, has been shown to have characteristics of CAS including sequencing difficulties (Lewis et al., 2004, p. 158). Genetic testing of the K.E. family showed a mutation known as the FOXP2 gene (Lewis et al., 2004, p. 158). Neuroimaging of the K.E. family revealed frontal lobe and caudate nucleus abnormalities, two structures critical to speech production (Lewis et al., 2004, p. 158). The research of the K.E. family has led to further family pedigree research for families with members who have CAS. Studies on subsequent families have supported the previous findings of the K.E. family for a familial aggregation of CAS and other speech sound disorders (Lewis et al., 2004, p. 168). However, these studies do not provide enough support to consider the family pedigree findings as a recognized etiology for the disorder (Lewis et al., 2004, p. 169).

Further research has examined the neurological components of CAS. Neuroimaging studies have been reported as normal for two thirds of cases (Liégeois & Morgan, 2012, p. 444). An MRI for one case of CAS reported incomplete myelination (the insulated layer that forms around the axon of a neuron) (Liégeois & Morgan, 2012, p. 444). However, Liégeois and Morgan (2012) noted that one case is not enough evidence to generalize this type of neurological basis for all cases of CAS (p. 444). Neuroimaging research conducted by Lewis (2008) incorporated functional magnetic resonance imaging technology for children with childhood apraxia of speech. During the neuroimaging procedure, participants were asked to participate in a nonword repetition speech task (Lewis, 2008). Results of the neuroimaging study revealed activation patterns in Broca’s area that are considered abnormal, including little activation and no activation (Lewis, 2008).

There is no standard intervention approach to treat CAS; different approaches are recommended (Bauman-Waengler, 2012, p.

369). Murray, McCabe and Ballard (2014) conducted a systematic review of CAS intervention studies from 1970 to 2012 (p. 2). The authors reviewed 42 articles and examined the efficacy of the intervention approaches that were analyzed while excluding other systematic reviews from their study (Murray et al., 2014, p.8). The Cochrane journal conducted a systematic review which examined previous intervention studies of CAS though January 2007 (Morgan & Vogel, 2009, p. 103). The Cochrane systematic review examined 31 articles, and after careful consideration, all 31 studies were excluded (p. 106). The Cochrane review only pursued CAS intervention studies that were randomized control trials and quasi-randomized studies and none of the studies met their criteria (p. 105).

Systematic reviews contain collected and analyzed data from other researchers and provide high level evidence (Haynes & Johnson, 2009, p. 311). Systematic reviews “aim to answer a specific question in a way that minimizes biases present in the primary research and biases within the review process itself” (Garrett & Thomas, 2006, p. 97). A systematic review of interventions informs speech-language pathologists of the current research and allows them to make decisions consistent with the guidelines of evidence-based practice (Garret & Thomas, 2006, p. 102). A combination of current scientific evidence, client or stakeholder’s preferences and the clinician’s expertise determines the best treatment option (Haynes & Johnson, 2009, p. 418). Systematic reviews are critical to “validate research because causality between treatment and positive patient outcomes cannot be established on the basis of a single investigation” (Haynes & Johnson, 2009, p. 309). There are two schools of thought in regard to the concept of systematic reviews. According to Baker and McLeod (2011), systematic reviews contain a “relatively small portion of available studies” focused on published randomized controlled trials (RCTs) (p. 103). However, according to Garrett and Thomas (2006), a systematic review is not restricted to only experimental studies, but may also include non-experimental studies and case studies when appropriate (p. 98). For the purpose of this study, we are going to adopt the Baker and McLeod (2011) definition.

A systematic review does not typically cover studies of all Levels of Evidence and therefore lacks the “breadth and quality of all of the published evidence” (Baker & McLeod, 2011, p. 103). This can be problematic for a speech-language pathologist (SLP) trying to decipher the evidence of a particular intervention strategy, or research different strategies for children with rare cases (Baker & McLeod, 2011, p. 103). According to Baker and McLeod, a narrative review is an essential “complement to systematic reviews” which covers a broader scope of the published intervention literature (p. 103). Narrative reviews provide comprehensive information to SLPs regarding the

available evidence of a wide range of intervention approaches (Baker & McLeod, 2011, p. 103).

The purpose of this study is to provide a narrative review of the current peer-reviewed literature of a variety of suggested CAS intervention studies. The current published peer-reviewed literature will be examined from 2009 to the present. The review will examine intervention approaches from all Levels of Evidence (i.e. systematic reviews and meta-analyses) of the most state-of-the-art research. A narrative review containing studies and research designs from all Levels of Evidence can reflect the quality of the available evidence for specific intervention approaches for CAS and is currently unavailable to clinicians at this time. This narrative review seeks to determine the extent and strength of the evidence for current intervention approaches for CAS, as well as the need for future research. All Levels of Evidence will be included in this study to provide comprehensive coverage of the current intervention studies of children with CAS (Baker & McLeod, 2011, p. 104). Systematic reviews and meta-analyses will be included because both types of studies are ranked as high-level evidence and provide rigorous information of available studies. Case studies will also be included in this narrative review as they provide information pertaining to the intervention approaches used for rare and unique clinical cases (Baker & McLeod, 2011, p. 103). This broad review attempts to provide SLPs and researchers with an extensive scope of the available intervention literature.

Levels of Evidence apply specific criteria to clinical studies and research, and assess the quality and credibility of the study (ASHA, 2004). Table 1 outlines Levels of Evidence and its ranking according to the American Speech-Language-Hearing Association's (ASHA) guidelines. The chart is organized from evidence with the highest level of credibility to the least credible (ASHA, 2004). High-level credibility includes meta-analyses, and lowest level credibility includes expert committee reports, consensus and clinical experience (ASHA, 2004). Levels of Evidence are important for clinical decision making that adheres to evidence-based practice guidelines (ASHA, 2004). Table 2 provides the research designs of intervention studies for childhood apraxia of speech published from 2009 to the present (Baker & McLeod, 2011, p. 104).

Method

The following databases were used to search for peer-reviewed published studies: Medline, PsychInfo, Pubmed, Educational Resources Information Center (ERIC), Health Source Nursing Academic Edition, PsychARTICLES, Psychology and Behavioral Sciences Collection, and the American Speech, Language and Hearing (ASHA) online journals (Baker & McLeod,

2011, p. 105). The published intervention studies, 2009 to the present, were searched in order to analyze the most current interventions being implemented for childhood apraxia of speech. Key words and terms searched included combination-of childhood apraxia of speech, developmental apraxia of speech, speech sound disorder, articulation, and phonological with treatment, intervention and therapy (Baker & McLeod, 2011, p. 105). A wide range of search terms including historical terminology (i.e. developmental apraxia of speech) were used to find all possible relevant studies. The search was conducted by hand and yielded 579 results. After duplicates were eliminated, the search yielded a total of 493 results. To narrow the search down to relevant studies, specific criteria were applied (Baker & McLeod, 2011, p. 105). Intervention studies were selected using specific inclusionary criteria. The search was confined to studies of interventions with children identified with a diagnosis of CAS. Studies written in English or translated into English were selected and international studies were considered. Studies which included children with cleft palate, hearing loss, Down syndrome, and stuttering disorders were excluded (Baker & McLeod, 2011, p. 105). Studies that did not meet the specific criteria were excluded. The search was accomplished by hand by searching through the titles and abstracts for each of the studies (Baker & McLeod, 2011, p. 105). The search was narrowed down to 13 studies relevant to the purposes of this narrative review.

Table 1 Levels of Evidence

Level of Evidence	Research Design
Ia	Well-designed meta-analysis of >1 randomized control trial (RCT)
Ib	Well-designed RCT
IIa	Well-designed control study without randomization
IIb	Well-designed quasi-experimental study (including single-subject designs)
III	Well-designed nonexperimental studies
IV	Expert committee report, consensus conference, clinical experience of respected authorities

*Levels of Evidence rankings according to ASHA's 2004 technical report for evidence-based practice in communication disorders (Baker & McLeod, 2011, p. 104).

Table 2 Levels of Evidence and Research Designs across the Intervention Studies for Childhood Apraxia of Speech Published From 2009 through 2014

Level of Evidence	Research Design	Number (%) studies
Ia	Meta-analysis	0
Ib	Randomized control trial	1 (7.7%)
IIa	Control study without randomization including Systematic & Narrative Reviews	2 (15.4%)
IIb	Quasi experimental study (including single-subject designs and multiple baseline designs)	8 (61.5%)
III	Case studies and correlational studies	2 (15.4%)
IV	Expert committee report, consensus conference, clinical experience of respected authorities	0

* Level of Evidence and research design across studies table was created following Baker & McLeod (2011) guidelines. Levels of Evidence provided are in accordance with ASHA's 2004 technical report for evidence-based practice in communication disorders.

Specific information was extracted from the remaining studies using the guidelines implemented in a narrative review conducted by Baker & McLeod (2011). This information included the “reference, year of publication, intervention approach, research design, participant numbers and age, mode of service delivery, study duration, and Level of Evidence” (Baker & McLeod, 2011, p. 105). Information pertaining to the statistical significance of the studies and the reported treatment outcomes were also extracted. Levels of Evidence were applied to the published intervention studies using the American Speech-Language-Hearing Association (ASHA) guidelines (ASHA, 2004). Levels of Evidence are configured by the research design and the outcomes of the study. The research designs considered for the study include systematic reviews, randomized control trials (RCTs), non-randomized (quasi-experimental) controlled trials, case studies, single-

subject experiments, correlational designs and consensus findings.

Reliability

Interjudge reliability measures were conducted. The second author re-coded three articles that were randomly selected for Levels of Evidence data (Baker & McLeod, 2011, p. 106). Since the quantity of data was relatively small, statistical analysis of the re-coded data was not performed. Interjudge reliability measures resulted in 100 % agreement between both authors.

Results

The total search of online databases resulted in 493 results. Initially, 473 results were excluded because they were not relevant to the purpose of this narrative review. Further examination resulted in the exclusion of an additional seven studies. Reasons for exclusion varied, such as results that were not an intervention study, results were not specific to CAS, or results that did not meet the inclusionary and exclusionary criteria of the study. The online database search resulted in four studies that reported research related to the procedure of intervention approaches for CAS but were not specific to the intervention technique being used and as a result were excluded for this narrative review (Maas & Farinella, 2012; Maas, Butalla, & Farinella, 2012; Edeal & Gildersleeve-Neumann, 2011; Nordess, 2011).

The results of the online database search yielded 13 peer-reviewed intervention studies for CAS that met the inclusionary and exclusionary criteria of the current narrative review. The intervention studies consisted of the following research designs: systematic reviews, RCTs, quasi-experimental (single-subject designs), and case studies. The most frequently used research design was a single-subject design which included multiple baseline designs and AB designs. Single-subject designs accounted for 61.5 % of the intervention studies found. Subsequently, systematic reviews (15.4%) and case studies (15.4%) were the next type of research design frequently used. The results only consisted of one RCT (7.7%). Levels of Evidence were applied to each study according to the strength of the research design following the ASHA's 2004 technical report for evidence-based practice in communication disorders.

The treatment outcomes reported in the intervention studies varied across research designs. There was only RCT found in the database search and the study reported consistent outcomes (Dale & Hayden, 2013). For quasi-experimental research designs, five out of eight studies reported consistent outcomes (Ballard, Robin, & McCabe, 2010; Martikainen & Korpilahti, 2011; McCabe, Macdonald-D'Silva, van Rees, Ballard, & Arciuli, 2014; McNeill, Gillon, & Dodd, 2009; Preston, Brick, &

Landi, 2013). For case studies, one out of two studies reported consistent outcomes (McNeill, Gillon, & Dodd, 2009). Table 3 provides a chart of the results of the 13 peer-reviewed CAS intervention studies. Table 3 was configured following the guidelines of Baker & McLeod (2011). The chart provides the following information pertaining to the 13 studies: reference, intervention approach, research design, participant number and age, service delivery, study duration, consistent outcomes, statistical significance, and the Level of Evidence.

Discussion

The Level of Evidence reveals the strength of the research design. The research design of a case study is comprised of a lower ranking of evidence and does not provide as much support as other types of designs, e.g., single-subject designs and RCTs. The results of this narrative review reveal that CAS intervention studies are in a quasi-experimental research stage. The number of case studies is scarce and there are currently more quasi-experimental designs. Quasi-experimental designs portray stronger evidence than case studies because of their research designs and are therefore assigned a higher Level of Evidence. However, the designs of RCTs have more strength and high evidence compared to quasi-experimental designs and CAS intervention studies using an RCT design. This narrative review found only one published RCT in the last five years. Other narrative reviews and meta-analysis of speech and language disorders in children also report a lack of intervention studies with high-quality evidence and strong research designs (Baker & McLeod, 2011; Law, Garret, & Nye, 2004). In terms of strength, CAS intervention studies can greatly improve on the types of research designs currently implemented. Strong research designs like RCTs are connected to evidence that “yields a more credible, internally valid evidence base” (Baker & McLeod, 2011, p. 114). Although quasi-experimental studies like single-subject designs pose many benefits, RCTs are widely considered the “gold standard” design for intervention research (Byiers, Reichle & Symons, 2012, p. 398).

Single-subject designs (SSD's) for intervention studies in communication disorders serve many important purposes. The research design provides clinicians engaged in EBP with “helpful information about how and why an intervention might work” (Baker & McLeod, 2011, p. 114). SSD's can be beneficial for evaluating the effectiveness of interventions as well as comparing one intervention to another (Byiers et al, 2012, p. 412). SSD's are useful and “serve as a common framework for decision making” (Byiers et al, 2012, p. 412). However, a disadvantage of SSD's is that the results of the studies are difficult to generalize with larger populations (Paul & Cascella, 2007, p. 194). Additionally, quasi-experimental designs lack the quality of random assignment which is implemented in RCT studies.

Random assignment adds strength to the design of an RCT and does so by eliminating experimenter and participant bias (Haynes & Johnson, 2009, p. 323). The strength of RCTs and its high-level ranking can be attributed to the “double-blinding, randomization, and rigid experimental control in order to reduce any error in measurement of the dependent variable” (Haynes & Johnson, 2009, p. 326). Although SSD's serve a purpose in the field of communication sciences and disorders, they tend to lack the rigor of RCTs and do not provide the same strength of evidence. RCTs have a more rigorous research design and can provide clinicians with intervention studies that are highly credible. However, the results of this study reveal that SSD's are carried out more frequently than RCTs. RCTs may not be as popular as SSD's because RCTs are much more difficult to execute and complete, and are time intensive (Haynes & Johnson, 2009, p. 325).

Scientific evidence is a critical aspect of EBP. High-quality evidence serves many purposes in speech-language pathology. Evidence should be considered when choosing treatment plans because it helps ensure that the best outcomes for clients can be achieved (Paul & Cascella, 2007, p. 199). High-quality evidence not only helps serve the client, but also benefits the caregiver/stakeholder (Paul & Cascella, 2007, p. 199). High quality research can be provided to caregivers/stakeholders and the information regarding treatment options are available for them. Scientific evidence benefits the clinician by corroborating their decisions in therapy (Paul & Cascella, 2007, p. 199). High-quality research also adds credibility to the profession (Haynes & Johnson, 2009, p. 4). Current scientific research allows clinicians and researchers to stay up to date with current practices (Haynes & Johnson, 2009, p. 12). By improving research designs and researching current techniques, the profession finds ways to help improve client outcomes.

The strength of research designs should be considered when engaging in EBP. Scientific evidence is a large component of EBP in combination with client values and clinical expertise (Haynes & Johnson, 2009, p. 397). During clinical decision-making, clinicians should “identify the highest quality evidence directly related to the clinical question” (Haynes & Johnson, 2009, p. 402). EBP is a crucial and necessary component when deciding the treatment plan for a client (Haynes & Johnson, 2009, p. 417). Scientific evidence from research combined with the other components of EBP is important for achieving the best possible patient outcomes (Haynes & Johnson, 2009, p. 419). Speech-language pathologists must adopt the principles of EBP “to ensure that clients receive the best possible services informed by the highest quality of evidence available” (Johnson, 2006, p. 22). This current narrative review reveals that the evidence for CAS interventions is lacking in quantity

and quality (Johnson, 2006, p. 22). Future research for intervention studies with strong research designs and high-quality evidence is needed (Johnson, 2006, p. 22).

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About the Author

Katherine Mahoney is a senior majoring in Communication Sciences and Disorders. Her research project was conducted in the summer of 2014 under the mentorship of Dr. Suzanne Miller (Communication Sciences and Disorders). This project was fully funded by an Adrian Tinsley Program summer research grant. Katherine is deeply grateful to her mentor, Dr. Miller, for her continued support. Katherine plans to attend graduate school for Speech-Language Pathology in the fall of 2015.

Table 3
13 Intervention Studies for Childhood Apraxia of Speech

Reference	Intervention Approach	Research Design	Participant Number and Age	Service Delivery	Study Duration	Consistent Outcomes	Statistical Significance	Level of Evidence (ASHA)
Morgan & Vogel (2009)	No intervention approaches met the criteria for this systematic review # (Cochrane Review)	Systematic Review (RCTs)	N/A	N/A	N/A	N/A	N/A	IIa
Murray, McCabe, & Ballard (2014)	Various motor and linguistic based intervention approaches and AAC approaches	Systematic Review (All research designs)	23 articles spanning 42 years	Varied across studies	Varied across studies	Varied across studies	Varied across studies	IIa
Dale & Hayden (2013)	Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT)	Mixed Single Subject Design with random distribution (RCT) (2 groups of 2)	n = 4 (3;6-6;0)	1:1, speech-language pathologist (SLP), 50 min 2 x week	8 weeks (16 sessions)	Yes	No statistical analysis reported Raw data only	Ib
Ballard, Robin & McCabe (2010)	Treatment of enhancing intonation patterns	Single subject design with multiple baselines and behaviors across participants	n = 3 (7;8-10;10)	1:1, SLP graduate students with supervision, 60 min 4x week	3 weeks	Yes	Normalized average duration of the first two syllables of real words [NORMDUR] ($p = .0001$) For all three participants Kruskal-Wallis Test	IIb
Gildersleeve-Neumann & Goldstein (2014)	Cross-linguistic generalization treatment:#1. Promoting child's meta-awareness of speech goals 2. Drill play 3. Articulatory and phonological components with cueing strategies 4. Intensive production practice on targets 5. Minimal pair strategies.	Single subject with multiple probes across behaviors design	n = 2 (1 participant with CAS) (5;6)	1:1, SLP student with supervision, university, 50 min 2-3 x week	8 weeks	No	Effect size Cohen's d : Target 1 ($d = 2.35$) Target 2 ($d = 3.173$) Overall ($d = 2.644$)	

Table 3 (cont)
13 Intervention Studies for Childhood Apraxia of Speech

Reference	Intervention Approach	Research Design	Participant Number and Age	Service Delivery	Study Duration	Consistent Outcomes	Statistical Significance	Level of Evidence (ASHA)
Iuzzini & Forrest (2010)	Dual treatment approach. Goal is to decrease the variability of errors (stimulability training protocol [STP] and modified core vocabulary treatment [mCVT])	Single subject design with multiple baselines across subjects	n = 4 (3;7-6;10)	1:1, 10 min of STP, 45 min of mCVT	10 weeks (20 sessions)	No	“Substantial” decrease in variability of errors No statistical analysis provided	IIb
Lagasse (2012)	Melodic Intonation Therapy (MIT)	Single-subject design with an AB design	n = 2 (5, 6)	1:1, Board certified music therapist, home, 40 min 1 x week. Participants also continued to receive treatment session from their typical speech-language pathologist as usual concurrently with the MIT sessions	4 weeks	No	($p > .05$) Statistics applied were non-parametric. Wilcoxon test used. Significance only reported as “ $p > .05$ ”(No actual significant data)	IIb
Martikainen & Korpiolahti (2011)	Combination of Melodic Intonation Therapy (MIT) and the Touch-Cue Method (TCM)	Single subject design with ABA design	n = 1 (4;7)	1:1, SLP, 30 min, 6 week sessions including a 6 week withdrawal block	18 sessions per 6 week block including a 12 week follow up	Yes	Generalized Cochran-Mantel-Haenszel statistics for repeated measures used for statistical analysis. Percent of correct vowels (PVC) following MIT block ($p = .033$) (PVC) following TCM during follow-up ($p = .019$) Percent of correct consonants (PCC) 6 weeks after MIT block ($p = .000$) (PCC) during TCM block ($p = .003$)	IIb

Table 3 (cont)
13 Intervention Studies for Childhood Apraxia of Speech

Reference	Intervention Approach	Research Design	Participant Number and Age	Service Delivery	Study Duration	Consistent Outcomes	Statistical Significance	Level of Evidence (ASHA)
McCabe, Macdonald-D'Silva, van Rees, Ballard, & Arciuli (2014)	ReST intervention: Goal is to target the production of lexical stress	Single subject design with an AB design	n = 4 (5;5-8;6)	1:1, SLP, 60 min 4 x week	3 weeks (12 sessions)	Yes	No statistical analysis reported. Raw data and percentages of correct vowels, consonants, and stress patterns reported.	IIb
McNeill, Gillon, & Dodd (2009)	Integrated phonological approach: 1. Decrease speech error patterns 2. Increase phonological awareness 3. Increase letter-sound knowledge	Single subject with an AB design	n = 12 (4-7)	1:1, SLP or SLP students with supervision, home or school, 45 min 2 x week per 6 week session including a 6 week withdrawal bloc	18 weeks	Yes	Suppression of two speech error patterns ($p < .001$) and ($p < .001$) Paired t tests used to analyze data over therapy period	IIb
Preston, Brick, & Landí (2013)	Ultrasound biofeedback	Single subject design with multiple baselines across behaviors	n = 6 (9;10-15;10)	1:1, SLP, 60 min 2 x week	10-16 weeks (18 sessions)	Yes	($p = .028$) Non-parametric Wilcoxon test used.	IIb
McNeill, Gillon, & Dodd (2009)	Integrated phonological approach	Case study with a longitudinal design	n = 2 (4;5)	1:1, SLP, home, 18 total hours of intervention	18 total hours of intervention	Yes	No statistical analysis provided. Percentages of consonants and vowels correct were reported	III
Vashdi (2013)	Verbal Motor Learning (VML) using the Distal Dynamic Stabilization Technique (DDST): 1. Decrease vocal intensity 2. Differentiation of low and high pitch 3. Reduce word duration	Case study	n = 1 (14)	1:1, VML therapist, 30 min 1 x week, with home practice	4 weeks	No	Paired t tests were used for statistical analysis Word length ($p < .001$) Vocal intensity ($p < .001$) Frequency ($p < .0001$)	III