

EFFECTS OF INTEGRAL STIMULATION THERAPY ON SPEECH
INTELLIGIBILITY OF A CHILD DIAGNOSED WITH CHILDHOOD APRAXIA OF
SPEECH

by

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ABSTRACT

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Title: Effects of Integral Stimulation Therapy on the Speech Intelligibility of a Child
 Diagnosed with Childhood Apraxia of Speech.

Childhood apraxia of speech (CAS) is a communication disorder characterized by an impaired ability to perform the purposeful and sequential movements necessary for speech. The speech of children with CAS is often highly unintelligible due to their inconsistent speech errors for consonants and vowels, prosodic differences, and difficulty in performing the oral movements needed for sequencing complex words and utterances. While the etiology of CAS is currently unknown, speech-language pathologists face the daunting task of treating children with this lifelong communication disorder. Parents and clinicians have few resources in identifying efficacious intervention strategies for children with CAS due to a lack of research in this area.

This research project contributes to a small but growing body of research that suggests treatment based on principles of motor learning using the Integral Stimulation Therapy approach increases the intelligibility of children affected by CAS. This study evaluates the effects of integral

stimulation therapy on a 5-year-old boy diagnosed with childhood apraxia of speech over the course of 6 months. Results of this study suggest that using multisensory cueing approaches, short and frequent individualized motor practice sessions in a variety of communicative contexts increased the child's accuracy of target speech sounds in single-syllable carrier phrases. Speech accuracy for target sounds was maintained after a 2-week break from treatment in 3 of the 4 target sound categories taught. Results from this study suggest that motor learning had occurred resulting in increased speech intelligibility.

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Effects of Integral Stimulation Therapy on Speech Intelligibility of a Child Diagnosed with Childhood Apraxia of Speech

Childhood apraxia of speech (CAS) is believed to be a neurologically-based motor speech disorder that impairs a child's ability to plan and/or execute the motor movements needed to produce volitional speech. Children with CAS often present with moderate to severely unintelligible speech due to inconsistent vowel and consonant production, rate and prosodic disturbances, and difficulty sequencing speech sounds in multisyllabic words and utterances (American Speech-Language-Hearing Association [ASHA], Technical Report, 2007). It is estimated that between 1 and 2 children per thousand are diagnosed with CAS (Shriberg, 1994). The disorder is difficult to identify and treat as there is very little research on the etiology, diagnostic markers, and treatment of CAS. In 2007, after conducting a comprehensive review of the literature and research on CAS, an ASHA Ad Hoc committee submitted the following definition of CAS,

“Childhood apraxia of speech (CAS) is a neurological childhood (pediatric) 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 may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of 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” (p. 3) (ASHA, 2007).

The committee recognized that identification of diagnostic features and efficacious treatments for the speech disorder is particularly difficult because characteristics of CAS may change significantly over the course of a child's development and treatment history.

Characterization of CAS first appeared as a result of similarities that were noted between the childhood form of apraxia and the acquired adult form of apraxia of speech (AOS) (Morley, 1972). Acquired Apraxia of Speech involves cortical damage (most often associated with strokes or other neurological insults) resulting in difficulty with volitional motor sequencing of speech movements (Chapey, 2001). Like AOS, childhood apraxia of speech's core deficit is believed to involve the disruption of motor planning and/or motor execution processes (Caruso & Strand, 1999; Nijland, Maassen & van der Meulen, 2003). However, there has been no definitive delineation linking the neurological etiology of AOS with CAS. In addition to motor deficits, implications of core deficits in language processing have been suggested by many in the field of speech-language sciences (Aram & Nation, 1982; Crary, 1984; Dewey, 1995; Velleman & Strand, 1994). There is disagreement as to whether the linguistic symptoms associated with CAS should be considered a core deficit of the disorder, or whether linguistic impairments arise as a result of underlying sensory motor impairment (Hall, Jordan, & Robin, 1993). Lewis, Freebairn, Hansen, Iyengar, and Taylor, (2004) found that children diagnosed with CAS are likely to present with expressive and receptive language deficits and experience impaired academic performance in areas of reading, spelling, and written expression.

The scarcity of large scale research on the differential diagnosis, treatment, and etiology of CAS has left many clinicians discontent with their abilities to provide efficacious and appropriate intervention to clients who present with the symptoms associated with CAS. Effective treatment, thus far, has been driven largely by research and case studies conducted for CAS's adult counterpart, acquired apraxia of speech (AOS). Although the two disorders differ on many accounts, there are numerous motor-related characteristics shared by the disorders that appear to be responsive to treatments based on cognitive motor learning principles that implement visual, tactile, and auditory hierarchical cueing systems (Jakielski, Webb, & Gilbraith, 2006; Rosenbek, Hansen, Baughman, & Lemme, 1974; Shea & Morgan 1979; Strand & Debertine, 2000).

Motor learning is defined by Schmidt and Lee (1999) as: "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement" (p. 346). The results of research in the area of motor learning suggest that cognitive processes during motor practice play an important role in the acquisition of motor skills (Schmidt & Lee, 1999; Shea & Morgan, 1979). Further, motor learning is enhanced by variables of practice such as frequency, intensity, and variability that promote cognitive effort from a learner. Speech is a complex motor skill that when impaired, as in CAS, can be improved by systematic, hierarchical, and repetitive practice of speech movements (Rosenbek, et al., 1974; Strand & Debertine, 2000).

Many treatment approaches for CAS employ strategies shown to be efficacious to improved motor speech performance. They may provide visual, auditory, and tactile/gestural cues to facilitate greater articulatory accuracy. Some utilize rhythmic and

melodic support to overcome sound sequencing difficulties. Others offer specific feedback following motor responses so that the child's self awareness of his/her own performance is fostered (Caruso & Strand, 1999).

Integral stimulation is a treatment approach that has been used with greater frequency in treatment of motor speech disorders such as dysarthria, acquired apraxia of speech, CAS, and other severe speech disorders (Caruso & Strand, 1999). Integral stimulation therapy utilizes a multitude of strategies (gestural, tactile, and prosodic cues) in a hierarchical manner to facilitate long term learning and generalization of speech motor skills. Methods include a "bottom up" approach to learning that begins practice with simple syllable shapes and builds on speech complexity as accuracy progresses using systematic drill exercises.

Motor practice during integral stimulation treatment is supported by the use of a "watch me and listen to me" strategy. Visual and auditory models of target sounds and sequences are provided to the child to provide maximal support for successful productions. Early speech success can be facilitated by simultaneous productions or imitative productions that are gradually withdrawn as competence increases. Once a criterion for success is reached, supports are faded appropriately and higher levels of complexity (word positions, sentence levels, and utterance lengths) are introduced.

Central to integral stimulation therapy is the focus on long term motor skill retention and generalization, using the principles of cognitive motor learning. Specific attention is paid to the parameters within which motor learning best occurs; assuring precursors for motor learning exist, manipulation of conditions of practice, facilitation of knowledge of results, and influencing the rate of speech during practice (Caruso &

Strand, 1999; Yorkston, Beukelman, Strand, & Bell; 1999). Perhaps the most important premise of motor learning is that cognitive effort must be repeatedly stimulated through practice and/or experience in order for one's motor planning processes to be trained well enough to allow for long term, generalized motor skill learning to occur. Ayres writes:

Planning requires thinking. If one has to think about actions, one is probably motor planning. If one does not have to think about them, the actions have probably become automatic and no longer require planning...If therapy is designed to promote planning that requires thinking, then a variety of tasks that require thinking should be available. Once learned well, a task may no longer be therapeutic. (Ayres, 1985, p. 24)

Determining which treatment methods for CAS are most appropriate is a difficult task even for the most well informed speech-language pathologist. The vast majority of research for treatment of apraxia has been conducted on adults with acquired apraxia of speech. Treatment efficacy results have often been obtained by measuring performance of speech tasks rather than the long term retention and generalization of speech skills to novel speech contexts. Integral stimulation uses the principles of cognitive motor learning, to maximize the generalization and transfer of speech skills to unfamiliar speech contexts. Research in the fields of sports training, physical therapy, and movement learning have provided a body of convincing evidence as to the effectiveness of motor movement learning. This single-subject design examines the efficacy of integral stimulation utilizing principles of cognitive motor learning on the speech intelligibility of one child diagnosed with CAS.

Literature Review

The differential diagnosis and treatment of individuals affected by childhood apraxia of speech (CAS) has long been a source of debate for speech-language pathologists. Speech-language professionals have found the prospect of providing efficacious and defined treatment methods for communication disorders such as CAS a challenging and often confusing task. Given the suspected disorder's undefined diagnostic markers, shared features with other disorders, and variable course of development, effective diagnosis, treatment, and research explorations of CAS have proven difficult at best. However, ethical standards within the field of speech-language pathology require clinicians to provide intervention that is consistent with the individual needs, skills, and preferences of their client. Clinicians are expected to provide services that draw from their own clinical expertise and theoretical perspectives as well as from high-quality research sources. The ethical obligation for the use of evidence-based practice by those in the field of communication sciences has ignited an interest in establishing diagnostic markers for CAS and identifying efficacious treatment methods (ASHA, 2007). This literature review is intended to present its readers with estimates of prevalence of CAS, its speech characteristics, suspected etiologies, and various treatment options according to standards of evidence-based practice. Theories of cognitive motor learning will be explored as they relate to the application and efficacy of treating motor planning disorders using integral stimulation.

Prevalence

The exact prevalence of CAS is presently unknown. A lack of consensus on the differential diagnostic characteristics and theoretical viewpoints as to the etiology of CAS has compromised comprehensive counts of and valid research on the disorder (Davis, Jakielski, & Marquardt, 1998). Further, the suspected low prevalence of the disorder and disagreement on behavioral markers have prevented large scale studies on CAS from being conducted (ASHA, 2007). CAS is thought to be both an over-diagnosed communication disorder and a variably defined one (Crary, 1993; Davis et al. 1998; Shriberg & McSweeny, 2002). Although the exact incidence remains unknown (Forrest, 2003; Pannbacker, 1988), researchers such as Shriberg, Aram, and Kwiatkowski estimate that the prevalence of CAS is 1 to 2 children per 1,000 (1997). The incidence of CAS in relation to all other speech sound disorders is estimated to be 5% (Shriberg, 1994).

The tendency for overdiagnosis was investigated in a study conducted by Davis, Jakielski, and Marquardt (1998). The researchers evaluated 20 children suspected as having CAS by speech-language pathologists. Only 5 of those children (20%) were found to have CAS according to their diagnostic criteria.

Despite a lack of definite numbers for the prevalence of CAS, the incidence of diagnosis has been noted to be on the rise within the past decade (Delaney & Kent, 2004). A number of explanations for this increase were explored by the 2007 ASHA technical report. First, legislative changes in early intervention statutes in recent decades may be, in part, responsible for a population of children identified as having CAS earlier than they would have been before the addition of new birth-to-three legislative statutes. Similarly, insurance guidelines requiring justification of evaluation and treatment of CAS may in

part affect the numbers diagnosed as having the disorder. Further, increased interest and information on the subject of CAS may be a possible contributor to the apparent increase in diagnosed cases of CAS (ASHA, 2007). Many researchers suggest the most plausible factor in the over diagnosis of CAS is a “lack of diagnostic guidelines” for the disorder (Shriberg, Campbell, Karlsson, Brown, McSweeny, & Nadler, 2003; Shriberg & McSweeny, 2002). Clearly, the variability of characteristics and ambiguity of defined parameters for CAS leave ample opportunity for inclusion of children who may (in the presence of clinically agreed upon diagnostic markers) be otherwise excluded from that diagnosis. In short, without clear etiological or large scale diagnostic studies on suspected childhood apraxia of speech, the over-diagnosis (and at times under-diagnosis) of the disorder seems inevitable.

Etiological Characteristics

Childhood apraxia of speech has been assigned many names since Morely first described the disorder as “articulatory apraxia” in 1954 (Crary, 1993). Since that time CAS has been referred to as dyspraxia, developmental apraxia of speech, and childhood verbal apraxia, among others. Many of the titles used until recently reflected the etiological viewpoints of those who study and work with individuals affected by CAS. The frequently used term developmental apraxia of speech (DAS) reflected theories of motor-programming impairment and contrasted the disorder with adult acquired apraxia of speech (AOS) (Darley, Aaronson & Brown, 1975). The term developmental verbal dyspraxia (DVD) has been used by those who believe the disorder involves both phonological and language processes in addition to motor-programming impairment (Ekelman & Aram, 1983). Recently, the term “childhood apraxia of speech” was

suggested as a new option for the disorder by the Childhood Apraxia of Speech Association of North America. The organization's deliberate exclusion of the term "developmental" was a result of many insurance companies' hesitation to cover speech-language services for the disorder on the grounds that, by nature of its name, the impairment would resolve itself over time without treatment (Velleman, 2003). Many who question whether a "pure" childhood apraxia of speech even exists suggest the use of "suspected childhood apraxia of speech" until a definitive diagnostic criteria for the suspected disorder is developed.

Similarly, the term "apraxia" is recommended for use over the alternative word "dyspraxia" as it is assumed to be closely associated (in symptomology) with the acquired form of apraxia of speech (ASHA, 2007). For the purpose of this discussion, the term *childhood apraxia of speech* (CAS) will be used as it has been recommended by the American Speech-Language-Hearing Association (2007).

To date, there is no known etiology for CAS. It is thought by many to be a neurologically-based disorder in part because of its shared characteristics with acquired apraxia of speech (AOS) (Freed, 2000). Many of the oral groping and poor sequential movement tasks (diadochokinetic) present in adults with AOS are also present in children demonstrating CAS. AOS is typically regarded as a neurologically-based disorder of motor planning. Research using brain-imaging devices identified consistent damage to the left precentral gyrus of the insula in patients diagnosed with AOS (Dronkers, 1996). Support for a non-acquired (developmental) form of apraxia of speech (CAS) has increased as a result of several familial studies and gender-related patterns of prevalence. It is reported that 75% of children diagnosed with CAS are male. This gender

discrepancy suggests the probability of some degree of genetic involvement. The isolation of a section of chromosome 7 of the FOXP2 gene linked to one London family's common occurrence (50% of sampled members) of orofacial apraxia and apraxia of speech is further evidence of neurological involvement (Lai et al., 2000; Lai, Fisher, Hurst, Vargha-Khadem & Monaco, 2005). Further studies in the United States, Europe and Australia tested individuals with CAS for FOXP2 mutation and identified several as having mutations or deletions. Despite some clear indications for neurological impairment, the specific neurological processes remain ambiguous. Researchers such as Crary (1993), Hall, et al., (1993), and Caruso and Strand (1999) argue that impairments occur at one or more levels of motor processing. Others posit that linguistic as well as motoric impairment is at play affecting underlying representation of phonemes and/or syntax (Aram & Nation, 1982; Ekelman & Aram, 1983) as found in Crary (1993). Whether studies finding deficits in syntactic comprehension (Ekelman & Aram, 1983) reflect a core impairment feature of CAS or whether they are deficits secondary to the motor processing disorder is unclear.

Theories of non-linear phonology and biologically-based models of phonology suggest the deficit is a result of multiple components. Velleman and Strand (1994) reason that CAS is a disorder of hierarchical organization within both speech and language processes. Most clinicians recognize that various linguistic and motor processes are interactive and thus impairment in one process will, in time, most likely influence the other.

Clinicians depend largely on their theoretical perspectives of language development and efficacy research to guide their decision-making for treatment. In the

absence of empirical evidence of the origins of suspected CAS, and the processes that are implicated, clinicians may find themselves unsure of their etiologic beliefs in relation to CAS.

Definition and Diagnostic Markers

CAS is often broadly described as a motor-planning disorder typically occurring without the presence of motor weakness. Others describe CAS more specifically as “an inability to perform accurate and coordinated oral movements during speech in the absence of oral movement deficits in non-speech volitional motor tasks (no paresis)”, (Crary, 1993, p 110). The importance of consistent and defined diagnostic markers for CAS was illustrated by Forrest (2003) in a study of practicing speech-language pathologists. Forrest examined 50 characteristics identified by 75 SLPs as diagnostic criteria used in determining a diagnosis of CAS. The SLPs were found to have little inter-diagnostic consistency as to which diagnostic characteristics were used. Diagnostic inconsistencies not only diminish a clinician’s ability to examine the efficacy of their own intervention methods, but compromise researchers’ abilities to examine larger scaled treatment efficacy, prevalence, and etiological links to CAS.

Remediation/ Treatment Methods for CAS

Determining which treatment methods for CAS are most appropriate is a difficult task for even the most well-informed speech-language pathologist. To date, surprisingly few studies evaluating treatment approaches for CAS have been conducted. The most appropriate treatment methods are thought to be those that address aspects of the generally agreed upon definitions of the disorder, suggesting impairment in the planning, the initiation, and the coordination of sequencing of speech sounds in the absence of

neuromuscular impairment (Caruso & Strand, 1999; Crary, 1993; ASHA, 2007). The vast majority of research for treatment of apraxia has been conducted on adults with acquired apraxia of speech (Chumpelik, 1984; Freed, Marshall & Frazier, 1997; Rosenbek, 1985; Rosenbek, Lemme, Ahern, Harris, & Wertz, 1973; Square, Chumpelik, Morningstar, & Adams, 1986; Wambaugh, Kalinyak-Fliszar, West, & Doyle, 1998). Among these approaches claiming beneficial effects for adults with AOS, several have indicated positive results when used as treatment methods for CAS. Treatment research employing multiple modalities of visual, auditory, and tactile feedback, such as Chumpelik and Sherman's studies of Prompts for Restructuring Oral Muscular Phonetic Targets (1983), Edeal's study of frequency of motor practice (2008), Jakielski et al's., (2006), and Strand and Debertine's study of integral stimulation (2000) have all cited increased intelligibility for children diagnosed with childhood apraxia of speech.

Square highlights the most frequently used categories of treatment methods for CAS which include, "tactile-kinesthetic facilitation, rhythmic and melodic facilitation, and gestural cueing" (1999 p. 149). Among these treatment approaches is *integral stimulation therapy* which utilizes combined elements of tactile, rhythmic, and melodic treatment approaches with the addition of specific conditions of practice consistent with principles of cognitive motor learning.

Tactile-kinesthetic treatment techniques (Moto-Kinesthetic Speech Training and Prompts for Restructuring Oral Muscular Phonetic Targets [PROMPT]) attempt to help children with CAS obtain better oral movement control by direct motor manipulation of the structures used for speech and tactile cues directed at appropriate locations (Bose & Square, 2001; Chumpelik, 1984). PROMPT seeks to facilitate oral-verbal feedback for

the client with apraxia. PROMPT uses unique hand movements as cues for English phonemes, resonance features, voicing components of speech, and various jaw movements used in speech. There are conflicting opinions on whether or not PROMPT is an efficacious treatment method for CAS that results in the generalization of speech sound productions. Although studies on two children with CAS (Chumpelik, 1984) and an adult with acquired apraxia of speech (Freed et al., 1997) all showed improvements to speech production after using the PROMPT system, there was little evidence that speech progress then generalized to non treated contexts (Freed et al., 1997; Pannbacker, 1988). Square (1999) states, “convergent information from the area of motor skill learning, language, and cognitive development as well as developmental oral physiology and neurophysiology, provides a compelling argument for the effectiveness of tactile-kinesthetic approaches for establishing and modifying speech motor behaviors”(pp.150).

The use of intraoral devices to direct tongue placement is used as a part of Stichfield and Young’s Moto-Kinesthetic Speech Training (Caruso & Strand, 1999). The literature reveals very little information regarding the effectiveness of such treatment methods.

Another group of remediation methods used with CAS are rhythmic and melodic speech treatments, such as tapping strategies and Melodic Intonation Therapy (Helfrich-Miller, 1994). These treatments target a child’s impaired speech rhythm (coordination) or inappropriate stress through simple rhythmic repetitions of single sounds and syllables (Caruso & Strand, 1999; Dozak, McNeil & Jancosek, 1981; Hall, et al., 1993; Sparks, 2001). These methods emphasize the melodic patterns of phrases or sentences and require the client to tap, sing, use intonation and sequential speech movements to initiate and

execute smooth and accurate speech. Few studies have evaluated the efficacy of Melodic Intonation Therapy with CAS. Studies by Helfrich-Miller, (1994) and Krauss and Galloway (1982) reported that subjects with CAS demonstrated increased speech intelligibility and fewer articulation errors following treatment with MIT. It is unclear if MIT was the only source of improved speech or whether other treatment methods employed over the course of the study had contributed to the subjects' gains.

A third treatment category for the management of CAS employs gestural strategies with the intent of aiding the reorganization of speech output. Methods include Adapted Cueing (ACT) (Klick, 1985), Jordan's Gestures (Hall et al., 1993) and Signed Target Phoneme (STP) therapy (Shelton & Graves, 1985). Gestural methods seek to demonstrate "patterns of articulatory movement and manner of production" (Klick, 1985, p. 256). Several studies report students with CAS exhibited increases in utterance lengths, conversational turns, and communicative functions with their communicative partners using augmentative and alternative communication materials and strategies in the form of gestures, communication books, and speech generative devices (Bashir, Graham-Jones, & Bostwick, 1984; Culp, 1989; Cumley & Swanson, 1999). It has been suggested that treatment strategies that require a learner to discriminate between symbols and gestures not physically representative of the actual speech sound movement can present a cognitive processing load that may decrease the accuracy of speech movements (Strand, 1992).

Perhaps the most important consideration for clinicians choosing treatment approaches is to create a plan that serves the individual needs and specific symptomatology of the child. Successful approaches target a child's various cognitive

and motor strengths, attempting to expand those strengths to other areas of speech. The use of simple syllable shapes for sound production success, slow rate, focused attention during movement performance drills, and attention to intonation and prosody have all been identified as important strategies for effective treatment for CAS (Pannbacker, 1988; Strand, 1995). Additionally, intervention that includes providing cues at various levels of support that are then faded as competency increases, providing multiple modalities of supportive cues such as visual models, auditory models, tactile/sensory feedback strategies, and creating maximum opportunities for the practice of speech sounds in combinations rather than in isolation, have all been indicators of successful treatment strategies for CAS (Pannbacker, 1988; Strand, 1995).

Integral Stimulation

Rosenbeck et al. developed an articulation treatment method, integral stimulation, for acquired apraxia of speech in adults that proved efficacious in remediation of many of the articulatory and prosodic characteristics of AOS (1975). The findings of this method were confirmed by Wambaugh et al., (1998) in a secondary study using the integral stimulation approach to therapy for individuals with AOS. Table 1 outlines the eight-step task continuum using applications of integral stimulation used with adults with motor speech disorders (Rosenbek, et al, 1973).

Table 1.

Rosenbek et al.'s Hierarchical Eight-Step Continuum Treatment Program for AOS (1973)

1. The client is instructed to watch and listen to the clinician. The clinician and client produce the target utterance simultaneously. Meanwhile, the clinician encourages the client to attend carefully to the auditory and visual cues of the correct production.
 2. The client repeats the target utterance, after the clinician models the production, while the clinician mouths the utterance (simultaneous auditory cues faded while visual supports remain).
 3. The clinician produces the target utterance and the client repeats it. No other visual or auditory clues are given during client's production.
 4. The clinician produces the target utterance and client repeats it several times (correctly) with no intervening cues.
 5. The client reads/names the target utterance written/pictured on a card.
 6. Similar to step 5, but the client responds after the target card (stimulus) has been removed.
 7. Client uses the target utterance spontaneously when asked an appropriate question by the clinician. The imitative model is no longer in use. This allows the client to produce the target utterance volitionally.
 8. The target utterance is incorporated into role-playing situations. The clinician, staff, parents, and friends assume roles appropriate to the target utterance and the client responds appropriately. (With children target utterances can be practiced in the context of games and theme-based role-plays.
-

Following the successful treatment of adults with acquired apraxia of speech, the method has been applied to children diagnosed with non-acquired apraxia of speech (CAS), and is producing positive treatment results as well (Edeal, 2008; Jakielski, et al., 2006; Jensen, 2005; Strand & Debertine, 2000). Integral stimulation employs multiple modalities of cueing systems for the stimulation of speech. Clinicians using this approach draw from a wide range of visual, auditory, and tactile cues to model for the child. The child is instructed to "watch me and listen to me." The speech movement is then explicitly modeled for the child who then attempts the production. Depending on the level of need, a child is provided with a hierarchy of supportive cues. Maximal support starts with tactile cues and visual and auditory models, with both child and clinician

producing the target sound/word simultaneously (Yorkston et. al., 1999). Next, (depending on the client's level of success) the clinician whispers or mouths the oral movements while the child produces the target sound/word. With success, the auditory and visual support cues are faded further until the child begins the next stage of immediate repetition of targets. Repetition of modeled targets gives way to successive repetitions of target sounds/words. Delayed repetition decreases the level of support by distancing the provided auditory model from the point of client production. For instance, the clinician may instruct the client to listen, wait 1 to 5 seconds, then imitate what he/she has heard. By varying the temporal relationship, a gradual autonomy is achieved for motor speech movements. The intended effects of temporal variance methods are that holding motor plans for sequential speech movements in one's memory results in better long term retention of speech skills. It should be noted that for young children with short attention spans, longer delay of repetitions may cause them to lose focus on their speech tasks (Caruso & Strand, 1999). It is necessary to adapt treatment procedures to the specific abilities and attention needs of clients. Incorporating activities such as games into treatment sessions may provide children with enough motivation to maintain attention when asked to perform delayed responses.

The hierarchy of cueing options continues to include reading, writing, responding to questions, and role playing or conversation as appropriate for individual needs and abilities. If at any point in the treatment process, a client fails to respond correctly, the level of support is increased to ensure correct production and awareness of performance.

Integral stimulation operates from a motor processing/programming impairment perspective using the theories of cognitive motor learning as a basis for treatment. Other

methodologies have yielded less convincing treatment results. Auditory and rule-based phonology treatment approaches have not yielded documented efficacious results when investigated by researchers in the field of speech-language pathology (Darley et al., 1975; Pannbacker, 1988; Powell, 1996). In fact, Rosenbeck and Wertz (1972) write “classical reliance upon auditory discrimination training is probably inappropriate” (p.32).

Although the level (or levels) at which motor planning/programming impairment occurs is unclear, Caruso and Strand (1999) recommend targeting a number of the parameters that we know to be involved in the development of motor skill. Targeting multiple parameters can aid in the self-regulation of correct articulator placement and movement sequencing of oral structures during drilled and spontaneous speech productions. Further, practiced sounds in a variety of contexts (sound, syllable, word, phrase, and conversation) allows for greater generalization of learned motor skills.

Cognitive Motor Learning

In treating motor speech disorders clinicians must not only attempt to provide their clients with efficacious treatment methods, they must also ensure that the conditions under which treatment occurs will ensure that long-term learning of skills persists. Cognitive motor learning theories address the conditions under which acquired motor skills may best be learned and preserved. Given the general consensus on the motor impairment component of CAS and AOS and preliminary studies indicating integral stimulation as an efficacious treatment approach, researchers and clinicians have looked to models of motor rehabilitation outside the field of speech-language pathology to inform their beliefs about the effectiveness of their treatment applications. The theories of cognitive motor learning have been shown to be efficacious in the teaching of sequential

motor movements needed for simple and complex sets of physical movements (Schmidt & Lee, 1999). Physical and occupational therapists successfully employ motor learning practices for the reacquisition, retention, and generalization of gross and fine motor skills. Speech is clearly a motor skill that has been shown to benefit from the application of cognitive motor learning practices (Rosenbek et al., 1973; Strand & Debertine, 2000; Wambaugh et al., 1998). Although research is scarce, there is an increasing interest in examining the potential benefits of pairing traditional multimodal cueing strategies such as integral stimulation with the practices under which motor learning occurs.

The principles of cognitive motor learning aid in the development of skilled movements which are influenced by structured practice and supportive levels of performance feedback (Ballard, Granier, & Robin, 2000). The frequency and intensity of motor movement practice (including speech sound production) appears to have a dramatic impact on the speed of acquisition and the long-term retention of that skill. Strand and Skinder (1999) state that, “it is important to keep in mind the distinction between motor performance during practice (acquisition of motor skill) and motor learning, which is retention of the motor skill and the ability to generalize the movement gestures to other contexts” (p.120). Additionally, Magill (1998) states that distributed practice (short frequent sessions) results in better long-term retention of motor skills than does massed practice (longer less frequent sessions) when practicing the serial movement skills needed for normal speech.

Schmidt (1988) highlights important components of the principles of motor learning: precursors to motor learning, conditions of practice, knowledge of results, and effects of rate. The authors define cognitive motor learning as, “a set of processes

associated with the practice or experience leading to relatively permanent changes in the capability for responding” (p.13). Cognitive motor learning is not a treatment application in and of itself; rather it is a set of parameters under which a treatment approach can be implemented.

In order for motor learning to occur, some precursors must exist. The client must have some degree of motivation to improve, participate, or use what is practiced in clinic. A child’s level of motivation can be influenced by his or her cognitive functioning, comfort level, social/self awareness, and rapport with the clinician. Similarly, a child must be capable of applying focused attention (at least for short periods of time) during speech sessions. Motor learning requires the learner to evaluate his or her own performance and make minute place and manner adjustments for improvements. If a child is unable to attend to visual, auditory, and tactile models for correct speech production, then the potential for motor learning may be severely reduced. Stimuli selection (type and number) should be determined, in part, by a client’s capacity for focused attention. Pre- practice factors include how the child is prepared for participation before the motor practice begins. In the case of speech treatment, the clinician may show the child a schedule, describe what tasks he or she will be asked to perform, and discuss or demonstrate the motivating reasons for working towards improving speech.

Conditions of practice involve how repetition of modeled stimuli are obtained (in what contexts) and the *frequency* in which they are produced. Repetitive motor drill activities often create the most opportunity for speech productions. However, care should be taken as to how often and in what amounts those productions are made. Clinical decisions as to what stimuli are to be targeted will also influence how targets should be

practiced. As previously mentioned, Magill (1998) suggested that when learning discrete motor skills (such as isolated phonemes or simple consonant-vowel productions) larger less frequent practice results in greater long-term learning. However, once those isolated sounds are mastered, then a schedule of short and frequent practice drills within the context of continuous speech sounds (words and phrases) are more efficacious to long-term motor learning (Yorkston et al., 1999). The aim of cognitive motor learning, as applied in Integral Stimulation for CAS, is to maximize the opportunities for the retrieval of information necessary for accurate production of speech. This repeated retrieval is what is thought to be responsible for creating the learned automaticity of the sequential movements in specific motor movement task (including speech tasks) (Schmidt & Wrisberg, 2000). It is generally thought that producing sounds without the context of speech (word or phrase) is not efficacious to longterm learning or generalization of skills (Caruso & Strand, 1999). Treatment success is also contingent on the appropriateness/complexity of goals and the variety and degree of cues provided during instruction.

Another condition of practice is one of *random practice*. Random practice refers both to the variation of rate of stimulus practice and the conditions under which those targets are produced. Once again, research has shown that although large unchanging blocks of practice may increase one's motor performance within a session, long term generalization of that skill is poor in relation to skills practiced in a more randomized fashion (Caruso & Strand, 1999; Magill, 1998). The potential for repeated learning of initial processes needed for planning new speech movements is maximized by shorter drills that simulate a naturalized on-line system of speech production (Ballard, 2001). The

very nature of speech itself occurs within a multitude of settings, communicative partners, and psychological states. Practice that mimics these contexts (with hierarchical supports to ensure success) is more likely to result in the ability to apply motor learning skills to novel communicative experiences.

The most important element of motor learning is that it must include frequent opportunities for practiced skills in the areas of greatest need for the individual with CAS. It is believed that practiced speech movements are most effectively learned when specific knowledge of performance (or *quality*) is provided to the speaker and knowledge of results (or *accuracy*) is given. Information regarding one's performance may come from extrinsic sources such as clinician feedback in the form of specific placement, manner, and voicing details. Knowledge of performance may come from feedback in the form of visual (mirror use or video recorded images), auditory experience of one's own production (on-line or audio recorded), or from tactile information in the form of observed sensations of specific sounds and movement on speech structures.

Knowledge of results provides the speaker feedback on whether or not the utterance was correct and thus helps them allocate their attention to either making corrections of incorrect productions or cognitive mapping of the motor movements associated with the correct production. Results may come in the form of naturalistic consequences that occur as a result of correctly producing a request, statement, or word (e.g., child is handed a requested toy). Knowledge of results may also be provided by giving the client verbal or gestural information that indicates correctness of speech. Providing a speaker with knowledge of performance and results after every trial can be counterproductive and distracting for the speaker (Strand & Skinder, 1999; Yorkston et

al., 1999). A clinician's sense of what level of feedback support their client needs and when to allow pause times for reflection on performance to occur is a refined skill that varies according to the individual cognitive capacities, motivational levels, and impairment severity of individual speakers.

Knowledge of results has been shown to be most effective during the acquisition phase of cognitive motor learning (Ballard, 2001). Feedback is most helpful when it is slowly withdrawn over time with the goal that the speaker will learn to assume more of the responsibility for self judgment of speech performance.

Influence of reduced rate on speech intelligibility has been shown to facilitate proprioceptive feedback for the speaker when rate is slowed (Caruso & Strand, 1999; Yorkston et al., 1999).

Integral stimulation utilizes the four principles of cognitive motor learning: precursors to motor learning, conditions of practice, knowledge of results, and the influence of rate of speech. These four parameters frame an environment in which specific treatment approaches such as integral stimulation can be implemented with efficacious results. The "bottom up" approach to treatment begins with accurate production of the simplest syllable shapes and gradually introduces more complex forms as client proficiency increases. Multimodal cues in the form of visual, auditory, and tactile models provide individuals with apraxia of speech a hierarchical system of support. Modeled support is carefully withdrawn, requiring more independence, as practice and self monitoring skills increase.

Integral Stimulation and Childhood Apraxia of Speech

To date, there are few treatment approaches for CAS other than integral stimulation (and Dynamic Temporal and Tactile Cueing [DTTC], which was derived from integral stimulation) that systematically combine the multimodal cueing systems shown to be efficacious in speech remediation with the principles of cognitive motor learning. The ASHA Position Statement (2007) advises SLPs to use treatments based on the principles of motor learning and varied multimodal cuing techniques for children with CAS. Small scale studies have begun to mount suggesting integral stimulation therapy as being the most efficacious treatment approach to date.

Two single subject studies published in the *Journal of Medical Speech-Language Pathology* reported increases in speech intelligibility for children treated with integral stimulation therapy. Strand and Debertine (2000) evaluated the effectiveness of integral stimulation therapy on a 5-year-old girl diagnosed with CAS. Multi modal cueing techniques were used in conjunction with motor learning practice to teach functional phrases over a series of short but frequent therapy sessions. The results indicated an increase in intelligibility for all speech sound targets.

Strand, Stoeckel, and Baas (2006) included 4 children with CAS treated with DTTC, a revised version of integral stimulation therapy. This study used short and very frequent therapy sessions (2 sessions each day and 5 days per week) for a 6-week period. Three of the 4 children demonstrated increased speech intelligibility following the study. Generalization of some speech sounds were noted as well.

Other research projects and thesis studies have added to the body of research suggesting that integral stimulation therapy is an efficacious treatment approach for CAS

(Edeal, 2008; Jakielski, et al., 2006; Jensen, 2005). Jensen (2005) used integral stimulation therapy with a 10-year-old boy for 15 weeks. Post-treatment data suggested increased intelligibility for 2 of the 3 targeted phonemes and a 5% increase in overall speech intelligibility. Similarly, Jakielski et al. (2006) treated 3 siblings diagnosed with CAS with integral stimulation therapy. At the end of the study, all 3 participants showed improved speech accuracy for target sentences. Results showed that the oldest sibling made the most progress while the youngest participant made the least progress.

The most recent study of integral stimulation therapy was conducted by Edeal in 2008. This study explored the frequency of repetition of target sounds in the context of integral stimulation therapy with three children suspected of having CAS. The single subject, alternating treatment design explored the efficacy of multimodal cueing approaches with varying amounts of speech motor practice opportunities. Two treatment conditions (target phonemes) were chosen for each child. Each condition used all of the components of integral stimulation therapy (cuing and motor practice), but one demanded less practice (30 to 40 repetitions) of speech sounds during treatment sessions and the other required more practice (100 to 150 repetitions) of speech sounds. One of the participants was withdrawn from the study as his diagnosis of CAS and the benefits of integral stimulation treatment were in question. The remaining 2 participants completed the study showing improved motor performance of treated sounds (in both treatment conditions) in non trained words. Integral stimulation therapy that incorporated the higher speech practice condition (100 to 150 repetitions) yielded higher levels of in-session accuracy and generalization to novel words than did the condition demanding fewer (30 to 40) repetitions per session. Post treatment results of this study illustrate that integral

stimulation therapy is effective in increasing the intelligibility and generalization of speech skills of children diagnosed with CAS. Further, it identifies the importance of frequent and intense practice of speech sounds in order for motor learning to occur.

The purpose of this study was to evaluate the effectiveness of an integral stimulation treatment approach on the intelligibility of a 5-year-old child diagnosed with childhood apraxia of speech. CP's intelligibility was measured by analysis of target phonemes within carrier phrases before each treatment session and during post-treatment speech probes. It was hypothesized that the accuracy of target phonemes would increase over the course of treatment and would generalize to novel carrier phrases 2 weeks after treatment had ended. This study adds to the small, but growing body of research examining the treatment efficacy of integral stimulation approach for children diagnosed with CAS.

Method

Study Design

This study used a single subject, multiple-baseline across behaviors design. The speech and language of the participant, CP, were evaluated by standardized assessment protocols, and by independent and relational analyses of a conversational speech sample. Analysis of speech features determined the speech sounds and speech behaviors targeted during the application of integral stimulation intervention. CP's response to treatment determined the levels at which treatment occurred (phoneme, syllable, word, phrase, or sentence level) and changed over the course of treatment.

Throughout data collection, CP was audio and video recorded while he imitated a series of 20 carrier phrases containing target speech sounds. CP repeated these phrases for data collection during periods of baseline data gathering and (when baseline results were stable) at the beginning of each treatment session. Speech sound stimulus probes consisted of a series of 5 functional carrier phrases paired with target speech sounds. For each session, a list of 20 phrases was selected randomly from a corpus of 400 possible phrases. Data were gathered over 40 sessions, and occurred over 3 phases: baseline, treatment, and post treatment. Baseline data were collected for a minimum of 5 sessions before treatment began. Treatment began when there was a consistent baseline performance, defined as no systematic trend upward or downward in the target sound speech intelligibility for a period of at least 5 consecutive sessions (Schiavetti & Metz, 2002). The treatment phase of this study consisted of 33 treatment sessions. Change in production of target speech sounds was tracked over time to monitor the level of change in target sounds and behaviors. Post treatment sessions were conducted after a 2-week

period of no treatment for speech sounds targeted in this study. The probes included four (10 minute) sessions of data collection at Portland State University's Speech and Hearing Clinic and at CP's home.

Participant

CP was a 5-year, 5-month old male at the onset of this study, diagnosed with childhood apraxia of speech. A parent interview revealed that there were no medical complications associated with their child's prenatal development or birth and that CP was reported to have reached early developmental motor milestones within age appropriate timeframes. Concerns over their son's speech development began when his mother noticed that CP's speech sounds were delayed in comparison with their first son's speech development. CP made predominantly cooing sounds during his first year, and then at approximately one year of age he began to babble. His speech sound productions were described as being inconsistent. His parents reported that they often needed to say a word for him (model) before he could produce it himself. CP's first words were "mama" and "dada" at approximately 14 months of age.

Parental concerns for CP's speech development increased at 2 years of age. His sound productions remained inconsistent and began to take on unusual qualities such as consonant and vowel distortions. His mother recalls, "CP would produce a sound one day and then the next day couldn't make the same sound." His parents noticed that CP relied heavily on gestures for communicating his needs. He was described as being in good general health, having experienced no high fevers, hospitalizations, and only two ear infections: one in infancy and the other at 4 years of age. Neither infection presented significant medical concerns.

At age 3 1/2, CP's pediatrician referred him to the Oregon Health Sciences University for a speech-language evaluation where he received a diagnosis of childhood apraxia of speech. At the age of 4, CP began receiving speech and language services from a private speech language pathologist and briefly through a pre-school early intervention program. Early intervention services included a 90 minute language group once a week. CP's private individual speech-language services twice per week for 45 minutes were ongoing. CP's parents discontinued intervention from early intervention services when they decided his speech needs would be better served by increased individual speech-language services. During this period CP was enrolled in a child-parent sign language class to increase his natural use of gestures to facilitate communication at home. CP's parents and speech services provider found that his use of signed words alleviated frustration during CP's miscommunications and increased his verbal attempts for words when paired with gestures. Speech therapy consisted primarily of establishing simple syllable shapes using early developing speech sounds. As CP's phonetic inventory increased, new developmentally appropriate sounds were added to treatment goals, and syllable shapes moved from open to closed and reduplicated syllable shapes. Therapy techniques utilized multimodal means of support including gestural, tactile, kinesthetic, auditory, visual, oral motor exercises, and bite block treatment strategies. Drilled practice activities were numerous yet brief to discourage fatigue. Further, objectives were changed on an ongoing basis to provide the support and flexibility needed to adapt to his communicative progress.

CP was referred to the Portland State University Speech-Language and Hearing Clinic for a second diagnostic evaluation. Findings of the assessment supported the

diagnosis of moderate to severe childhood apraxia of speech. His parents expressed an interest in receiving speech-language services through PSU which lead to two consecutive terms of individualized speech therapy by this study’s clinician.

As part of this study, CP attended two 50-minute articulation therapy sessions per week using integral stimulation techniques. Therapy was conducted by the examiner at the PSU clinic and at CP’s home when university facilities were closed.

Prior to the collection of baseline data and treatment application, a series of assessments and screenings were administered to identify CP’s speech and language needs and abilities. CP’s articulatory skills were formally assessed using the Goldman-Fristoe Test of Articulation-2 ([GFTA-2], Goldman & Fristoe, 2000) and by a 100-word spontaneous speech sample. CP completed the Sounds-in-Words portion of the GFTA-2. Analysis of the GFTA-2 indicated that CP made errors on 46 out of 73 opportunities for sounds and sound clusters, which resulted in a standard score of 49 (Table 2). These results placed CP’s speech productions in the first percentile for his age.

Table 2. Summary of tests administered to CP at the onset of the study.

Test Administered	Test Score
Goldman Fristoe Test of Articulation 2 nd Edition	Standard Score: <49 Percentile Rank: <1
Preschool Language Scale (PLS-4) 4 th Edition (Zimmerman, Steiner Ponds, 2002)	Total Language Standard Score: 87 Total Language Percentile Rank: 19
PLS-4 Auditory Comprehension Portion	Standard Score: 104 Percentile Rank: 61
PLS-4 Expressive Communication Portion	Standard Score: 73 Percentile Rank: 4

Tables 3 through 5 show the results of CP's speech sound inventory analysis. CP displayed a variety of speech sound errors across sound classes. Consonant place and manner errors are shown in Table 4. Substitution errors occurred in 44% of CP's single word productions. Although many speech sounds were produced inconsistently, the most commonly occurring errors (100%) were the substitution of fricatives /f, v, ʃ, ʒ, θ, ð / with an approximation of a distorted bilabial fricative, either [β] or [ϕ]. These distortions were often accompanied by groping and pausing during attempts at words. Sounds requiring lip rounding such as /w/ and /ʃ, ʒ, tʃ, dʒ, ɹ / were produced in error 100% of the time during the GFTA-2. The deletion of consonant sounds occurred in 12% of CP's single word productions. All clusters (tested word initially) were reduced to single sounds in both the GFTA-2 and during CP's spontaneous speech. A detailed description of cluster errors is shown in Table 4.

Table 3. Summary of CP's consonant speech sound errors by manner & word position

Stop	Errors		
Target	Initial	Medial	Final
/p/	[b] *	*	*
/b/	*	[d]	*
/t/	*	*	*
/d/	*	*	*
/k/	[n] *	*	*
/g/	[d] *	*	[t] *

Fricative	Errors		
Target	Initial	Medial	Final
/f/	[ϕ, s]	[ϕ]	[ϕ]
/v/	[β]	[β]	[β ,b]
/s/	[z] *	*	*
/z/	[d]	*	*
/ʃ/	[s,ϕ,β]	*	[s]
/ʒ /	[s, z]	*	N/A
/h /	*	N/A	
/θ /	[ϕ,b,d]	*	[ϕ]
/ð/	[β, b,d]	*	N/A

Note: the symbol * indicates omission of phoneme

Table 3. (continued) Summary of CP's consonant speech sound errors by manner & word position

Nasal	Errors		
Target	Initial	Medial	Final
/m/	*	[p]	[b]*
/n/	[d]	*	*
/ŋ/		*	*

Liquid	Errors		
Target	Initial	Medial	Final
/l/	[w] *	[ts] *	*
/ɹ/	[d,w]	[w] *	*

Glide	Errors		
Target	Initial	Medial	Final
/w/	[β]	*	
/j/	*	*	

Affricate	Errors		
Target	Initial	Medial	Final
/tʃ/	[ts,d,s] *	*	[ts,t]
/dʒ/	[dz,d,ʔ]*	/d/	[dz,s]

Note: the symbol * indicates omission of phoneme

Table 4. Summary of CP's consonant cluster speech sound errors

Consonant Cluster	/bl/	/br/	/dr/	/fl/	/gl/	/gr/	/kl/	/kr/	/kw/	/pl/	/sl/	/sp/	/st/	/sw/	/tr/	/ts/
Error	[b]	[b]	[d]	[β]	[β,z]	[d]	*	*	[d]	[b]	[s,β]	[s,β]	[b, ø]	[s, ø]	[s,β]	[t]

Note: the symbol * indicates omission of phoneme

Speech Sound Inventory

Further analysis of CP's speech sound inventory and language abilities was obtained with a 100 word spontaneous speech sample. Analysis of the sample utterances supported findings of the GFTA-2 by identifying a wide range of speech sound errors within a limited phonemic repertoire. CP's independent phonetic inventory was greater than his relational phonemic inventory. Many errors were made inconsistently and increased in frequency as the number of sounds in a word or phrase length increased. The percent of consonants CP produced correctly (PCC) was 52%, suggesting a moderate to severely impaired level of speech intelligibility (Shriberg, 1994). The most prominent consonant error patterns that occurred in CP's speech sample included substitutions (27%), final consonant deletions (37%), cluster reductions (76%) and occasional instances of metathesis. Speech sound distortions and prolongations were also noted as part of CP's speech analysis. Words that required motor sequencing of sounds produced in differing places in the oral cavity proved most challenging for CP.

Vowel errors in CP's speech occurred with a frequency of 59%. Vowel sounds [ɛ, ʌ, and ə] were erroneously produced in 82% of vowel substitutions (Table 5). CP did not produce (nor was he stimulable for) /i/, /u/, /ʊ/ or any rhotic vowels. CP substituted

mid-front and mid-center vowel sounds for high-front and back vowel sounds 82% of the time, as well as for low vowels in all positions. Table 5 shows CP's vowel errors.

Table 5. Summary of CP's vowel errors

Monophthong	Errors
/i/	[ɛ,ʌ,ə,eɪ]
/ɪ/	[ɛ,ʌ,ə]*
/ɛ/	No errors
/æ/	[ɛ]*
/ʌ,ə/	[ɛ]*
/u/	[ɛ]
/ʊ/	[ɛ,ʌ]*
/ɔ/	[ɛ,ʌ,æ]
/ɑ/	[ɛ,ʌ]

Diphthong	Errors
/eɪ/	[ɛ]*
/oʊ/	[ɛ]
/aɪ/	[ɛ,æ]
/aʊ/	[ɛ,æ]
/ɔɪ/	[ɛ,ə]

Rhotic	Errors
/iɹ/	[ɛ]
/ɛɹ/	[ɛ]
/ɑɹ/	[ɛ]
/ɛɹ/	[ɛ]
/oɹ/	[ɛ]

Note: the symbol * indicates omission of phone

Word Shapes

Simple word shapes such as C + V, V+C, and CVC were less challenging for CP than CVCV, CVCVC, and CCVC word shapes. Again, increases in complexity of the words (both in number of speech sounds and the articulatory movements required between sounds) had a clear impact on CP's number of speech errors, resulting in a greater frequency of errors.

Language

CP's receptive and expressive communication abilities were assessed through informal and formal measures of analysis, including spontaneous language sampling of 100 words and the Preschool Language Scale-4 ([PLS-4], Zimmerman, et al., 2002). Due to CP's severe unintelligibility it was difficult to determine CP's full expressive language capabilities. Results from the PLS-4 indicated that CP's expressive language skills placed him in the 4th percentile for his age group (Table 2). There was a significant discrepancy between CP's expressive and receptive language skills (which were in the 61st percentile). CP's Mean Length of Utterances was 1.3 which indicated that despite his understanding of utterances containing many words, he did not often combine words during conversational exchanges. This clinician had observed CP using multiword utterances with family members more often than he did with less familiar conversational partners. CP's score of 45% on a type token ratio taken from his spontaneous language sample indicated that he had the lexical diversity consistent with his age matched norms. CP demonstrated the correct use of nouns, verbs, pronouns/reflexive pronouns, and modifiers to describe and discuss objects and events around him.

Sequential Motion Rates

CP performed a diadochokinetic test of sequential and alternating motion rate. CP sequenced open syllables with the same initial consonant to repeat “puh,-puh,-puh,” and experienced difficulty producing “tuh-tuh-tuh” and “kuh-kuh-kuh” as both were changed to their voiced equivalents- “duh” and “guh.” His productions were halting with arrhythmic characteristics. When CP attempted sequencing alternating initial consonants with differing articulatory placements such as “puh-tuh-kuh,” the task became significantly more challenging. CP’s rate and correct sequencing decreased after just one repetition of the sequence. Informal tests for signs of oral and limb apraxia revealed no abnormalities in form or function during non-speech related motor tasks.

Suprasegmentals

Analysis of CP’s suprasegmental qualities during a spontaneous speech sample determined his voice pitch to be normal for his age and gender. He was observed using intonation appropriately which offered his listeners some semantic context for comprehension of unintelligible utterances. On several occasions, CP used excess equal stress on two-syllable words. As treatment progressed, the presence of excess equal stress (monostressed syllables) was observed with greater frequency. Vocal loudness was judged as appropriate. CP’s rate was difficult to determine due to his limited production of multi-word utterances. An endoscopic examination had been previously conducted on CP resulting in no observable velopharyngeal closure abnormalities.

Hearing

Hearing evaluations were conducted on two occasions prior to this study. At 3 ½ years, CP's hearing was tested through Oregon Health Sciences University and again at the age of 4 ½ years, through an early intervention program. Results for both evaluations indicated that there were no concerns with CP's hearing.

Cognition

At age 5½, CP completed the block design (scaled score of 9) and the picture completion section (scaled score of 16) of the Weschler Intelligence Test for Children (WPPSI-R form). Scores indicate that CP performed at cognitive levels appropriate for his age.

Materials

Materials used in assessment and treatment were age appropriate and interest-specific to CP. Books, toy animals, puppets, games, pen and paper, mirrors, and anatomical diagrams of the oral structures were used either in the assessment process or in the implementation of integral stimulation therapy. Data were video recorded using a Sony DCR-HC30 digital camera and taped on Sony and TDK digital video cassettes. For data collection purposes, Microsoft Office Excel (2003) was used to generate a randomized list of phrases containing CP's target sounds. All protocols used were listed in the *Participant* section of *Methods* and are included in Appendix A of this manuscript.

Identification of Treatment Targets

The selection of treatment targets resulted from the analysis of formal (GFTA-2) and informal (spontaneous speech sample) assessment data, parental input, as well as

from developmental norms for speech sound acquisition. Other factors that influenced target sound selection for treatment included CP’s stimulability for speech sounds and the degree to which sounds targeted would improve CP’s speech intelligibility.

The speech sounds selected as targets for treatment were /s/ clusters: /sp, sm, sn, st, sw/, labiodental fricatives /f, v/, postalveolar affricates /tʃ, dʒ/ and the unvoiced and voiced interdental fricatives /θ, ð/. Table 6 shows the speech sounds targeted in this study.

Table 6. Speech Sounds Targeted in Treatment for CP

Target Category	Specific Targets				
/s/ clusters	/sp/	/sm/	/sn/	/st/	/sw/
Labiodental Fricatives	/f/	/v/	-	-	-
Postalveolar Affricates	/tʃ/	/dʒ/	-	-	-
Interdental Fricatives	/θ/	/ð/	-	-	-

Rationales for the goals were as follows. The /s/ clusters included speech sounds that CP was able to produce in isolation in some instances, but did not produce when they occurred initially as part of a consonant cluster in CCVC words. His production of /s/ had been previously established in prior treatment objectives. Oral movements of the articulators were visually available to CP during the production of the targeted /s/ clusters, facilitating the modeling and self-monitoring process that is central to integral stimulation therapy. The /s/ cluster /sk/ was not included as a treatment goal due to the reduced visual availability of the velar /k/ when modeled for imitation. Similarly, the /s/ cluster /sl/ was not selected as an initial goal due to CP’s inability to consistently produce /l/ in isolation. It was thought that introducing a limited number (five in all) of /s/ blend

target sounds would allow CP a manageable number of practice opportunities within a 50 minutes treatment session.

Fricatives /f/ and /v/ in initial and final positions in CVC and CCVC words were selected for treatment due to their stimulability and highly frequent substitution with atypical voiced and voiceless bilabial fricatives [β] and [ϕ].

The interdental fricatives /θ/ and /ð/ in initial positions (and /θ/ in final positions) in a variety of simple word shapes were selected for therapy targets in response to changes in their production during CP's acquisition of labiodental fricatives /f/ and /v/. Before his acquisition of labiodental sounds, CP's substitution errors for /θ/ and /ð/ consisted of alveolar plosive [d], bilabial plosive [b], and most often, unvoiced and voiced bilabial fricatives [β] and [ϕ]. After CP acquired consistent production of /f/ and /v/ phonemes, his substitution errors for /θ/ and /ð/ underwent a distinct shift from the aforementioned substituted sounds, to /f/ and /v/ sound substitutions. Although interdental sounds are among the later developing sounds in a child's phonetic inventory (Smit, Hand, Frelinger, Bernthal, and Byrd, 1990), it was determined that CP was stimuable for /θ/ and /ð/ productions in isolation. It was decided that interrupting the new pattern of substitution with appropriate instruction for [θ] and [ð] productions using integral stimulation methods would benefit his sound system development and increase his level of intelligibility. Furthermore, the oral placement for interdental sounds is a highly visible one that occurs frequently (6%) in the English language, as reported by Shriberg and Kwiatkowski (1982). Affricate sounds /tʃ/ and /dʒ/ were determined to be

appropriate target sounds as CP was stimulative for the sound and (in occasional instances) produced it correctly.

As integral stimulation is a dynamic treatment process, target speech sounds were practiced within a variety of contexts. Attention was given to the level of motor sequencing demands and vowel production difficulty for CP in implementing intervention. New skills were most often practiced in an environment in which old skills were present (new sounds with established vowels) before challenging CP to practice the new sounds in the company of vowels outside of his preferred phonetic inventory. This hierarchical attention to complexity was employed with the intention of ensuring that as many cognitive resources were reserved for the motor planning of speech sounds thought to be necessary for motor learning to occur (Caruso & Strand, 1999). Enabling early success in speech production was intended to provide CP with motivational tools thought to positively impact his ability to attend to volitional speech movements, the immediate application of skills practiced, and his ability to generalize what is practiced in treatment to contexts outside the clinic.

Data Collection

Speech Probes. Speech probe sessions consisted of 10 minutes of data gathering at the beginning of each session in the form of 20 randomly-generated carrier phrases containing target sounds, followed by 40 minutes of integral stimulation treatment. Speech probes were audio and video recorded using a Sony DCR-HC30 digital camera. Probes consisted of 20 sentences consisting of the five functional core carrier phrases “I have a,” “I need a,” “I see a,” “I gotta,” and “I wanna.” The phrases were paired with 200 single syllable words containing target sounds. Phrases contained a carrier phrase, an

adjective, and a noun or verb (see Appendix). CP was allowed to look at a book or hold a small manipulative during speech probes as he was often non-compliant without them.

CP was instructed to, “Listen carefully and repeat after me.”

During data collection, the clinician (trained in phonetic transcription using IPA) transcribed online the imitated utterances of CP. CP was instructed to repeat each of the 20 sentences in imitation of the clinician. Occasionally, the clinician offered general encouragements such as “I can tell you’re listening carefully,” or “Thanks for speaking clearly” to maintain CP’s participation in the task.

Baseline Phase. Baseline measures were established in the clinic rooms of PSU Speech-Language Clinic, at the Scottish Rite Speech Clinic, and at the client’s place of residence. CP’s production attempts of stimulus probe carrier phrases were video and audio recorded over a period of 4 data collection events. Resulting data were phonetically transcribed, recorded, and graphed by the clinician to determine levels of stability. Criterion for baseline data stability was consistent with this study’s guidelines for stability (Schiavetti & Metz, 2002). No intervention for target speech sounds and behaviors using integral stimulation therapy was implemented during the baseline period.

Treatment Phase. Treatment sessions were conducted by the examiner at the PSU Child Speech-Language Clinic, The Scottish Rite Speech Clinic, and at CP’s place of residence when university facilities were closed. Methods for treatment of CP’s articulation disorder included the application of integral stimulation techniques in activities with games, books, conversations, self-analysis, and speech production feedback. The eight-step continuum Treatment Program for Apraxia of Speech developed by Rosenbek et al. (1973) as presented in Caruso and Strand in their text, *Clinical*

Management of Motor Speech Disorders in Children (1999), was used as the basis for treatment.

In this study, integral stimulation therapy for target speech sounds remained consistent with principles of motor learning to maximize long term retention and generalization of speech skills. Target sound practice was brief in duration and frequent (treatment twice per week at PSU clinic and twice per week at a private speech practice). Treatment activities consisted of multiple activities, 5 to 10 minutes in length, that stimulated target productions in a variety of contexts (repetitive drills, mirror imitation, book reading, turn taking games, conversation, rhymes, and songs). Within these activities, the clinician encouraged as much practice of target sounds as CP would tolerate while offering feedback on his productions. Discussions of oral structures, placements, and reasons for working toward improved speech were used to clarify session goals and motivate CP to focus his attention on learning tasks. A prize in the form of an activity, plush toy, or card was often offered to CP at the end of sessions as reinforcement for his hard work. Short play breaks were offered to CP when his focus on tasks waned. Play breaks allowed CP time to redirect his attention from repetitious and imitative tasks to opportunities to use practiced skills in a conversational context with supportive feedback. Repeated breaks offered CP consistent practice in relearning the motor programming steps necessary for long term retention of motor skills.

The practice schedules for target sounds were randomized in order and frequency throughout the course of the sessions. Throughout the 30 sessions, adjustments were made to activities and treatment objectives that failed to stimulate CP's interests, speech progress, and/or abilities to self-monitor his speech. Suggestions and feedback were

welcomed from CP's parents who were often the first to notice speech skills worked on in clinic being used spontaneously at home.

Treatment techniques began by establishing consistent production of target sounds in single syllable productions using first established vowel sounds. As CP's consistency increased during drill practice, the environment in which the targets were presented increased in complexity. Word shape complexity, syllable numbers, phrase lengths, and conversational contexts were increased as CP's proficiency grew.

A variety of visual, auditory, and tactile supports were employed by the clinician to assist CP in achieving correct productions of target sounds. Clinician models included visual and auditory productions of target sounds using a mirror and face to face interaction. CP was instructed to watch the clinician's mouth and listen carefully. CP was directed to produce sounds first simultaneously, then imitatively, and later with delayed imitation, and with a variety of visual supports such as foam letters, written words, mouthed imitations, and pictorial depictions of oral placements. Tactile gestures were provided to indicate the location of articulator contacts. CP was encouraged to feel his throat during voiced productions and feel oral air emissions with his hand during appropriate sound productions (stops and fricatives). Signed letters were occasionally used to stimulate CP's awareness of upcoming target sounds before producing them. Supports were faded as the accuracy of CP's productions increased.

Feedback of CP's speech sound performance was offered in the form of specific knowledge of results. Both correct and incorrect productions were given feedback. Correct productions would often be followed by statements such as; "Hey, those top teeth are touching your bottom lip!" or "I heard a hissing /s/ sound." Incorrect productions of

CP's target sounds were made known to CP and specific information on how to correct it was provided. Feedback ranged from statements such as "I heard the /s/ sound, but not the /m/ sound, I need to hear /sm/" or "Did you feel your lips come together?..... Let's try again in the mirror and watch." Self monitoring skills were encouraged by asking CP to rate his online productions by pointing to "thumbs up" or "thumbs down" cards, by rating others' productions, and by teaching puppets correct oral placements by modeling sounds and manipulating their mouths for them. As soon as target sounds were able to be produced in isolation, practice began at simple word levels to ensure transfer of the skill. Practicing target sounds in words was not only more motivating to CP, but more functional for the transfer of skills to words and short phrases.

Sample activity using integral stimulation techniques and rationales for use

The following is an example of a 25-minute activity during which 12 target words (with initial /s/ clusters) were practiced yielding 70 productions of target sounds. Each /s/ blend was attempted an average of 5.8 times and was interspersed with short breaks. The child was presented with a motivating game such as a marble or ball run. The clinician presented the child with a pile of "tickets" that were stimulus picture cards of /s/ clusters. The clinician explained that in order to obtain a ball for the track, he must give the clinician a "ticket" and practice saying the picture on it. For many activities the clinician would discuss either before or during the activity reasons for why we are practicing our speech sounds.

The clinician began by saying "Step right up! Get your ball for the ball-run!" The child handed his ticket (stimulus card) to the clinician and attempted to say the pictured word. Depending on the level of support needed, the clinician may have said the word

simultaneously with the child, provided an imitative model for the child, pointed to the printed word under the stimulus picture, mouthed the /s/ blend sounds, or provided any combination of mirrors and other supportive visuals for the child.

The child was given specific feedback in response to his correct and incorrect productions of target sounds (extrinsic feedback). Feedback such as “I heard the /s/ sound but not the /n/. Let’s try again with both sounds.” Clinician gave the child pictures of /s/ and /n/ with oral placements and letters below to stick on a mirror. The child ordered the cards mouthing each /s/ and /n/ oral placement as pictured. The clinician and the child repeatedly practiced the sound simultaneously, often lengthening the sounds for emphasis. They monitored their own oral placements in the mirror until the sound could be produced correctly and consistently. The clinician gave the child feedback as to the accuracy of his production, and also provided the child with specific feedback so that he could make the minute adjustments needed for improved productions. This feedback is at the core of what makes integral stimulation so effective. Individuals with motor speech disorders are first given the tools to monitor specific speech movements by way of clinician feedback. As they become more proficient with their sound productions, they begin to develop the skills needed to monitor their own speech productions.

The child was encouraged to develop familiarity with how a particular target feels, looks, and sounds (intrinsic feedback). Tactile feedback included questions such as: Does it create wind when it flows out of the mouth (putting hands in front of clinician’s and child’s mouth to feel air flow)? Is it voiced or unvoiced (feeling for vibrations of voiced sounds on the throat for differentiating /v/ from /f/ sounds)? Can the child feel his tongue touching his upper teeth when attempting the “th” sound?

CP was encouraged to create a mental picture of what target sounds look like; first by using mirrors, clinician examples, and pictorial supports, then by linking those visuals with tactile and auditory information. For children who are developing literacy skills, printed letters can serve as cues for the child to include all sounds in target productions.

Auditory information was used first by providing the child with a model for a stimulus sound, then by asking the child to judge the accuracy of his own and others' productions using auditory information ("thumbs up or down?"). Teaching a child how to self monitor his speech using normal auditory feedback is what allows a child to make corrections when misarticulations do occur.

When CP had produced the target sound at syllable level (eg., [snæ]) with repeated success, then this hierarchical process of practice and feedback began again at the word level (eg., /snæp/). CP was given the maximum opportunity for practice without the adverse effects of fatigue and disinterest. One way of maintaining CP's interest was to create short "breaks" in the form of motivating activities (rolling several balls down a track, hammering pegs, looking for hidden cards). The short activity served two purposes that are consistent with the principles of motor learning. First, it provided frequent reinforcement (through play) which may have increased the child's motivation to continue practicing their target sounds. CP needed to be able to maintain focused attention to feedback given to him and apply that feedback to his speech sound attempts. Next, short breaks in speech target practice may increase the number of times a child may have to re-learn the patterns for specific (speech) movements (Magill, 1998; Schmidt & Wrisberg, 2004). In other words, it prevented the over habituation of practiced sounds/words by interrupting the practicing of motor speech enough to require the child

to restart the mental processes needed for long term motor learning to occur. These breaks (or distributed practice sessions) were appropriate when the child's productions had become accurate during mass or discrete practice (activities such as repetition of single syllable words) (Caruso & Strand, 1999; Magill, 1998). After each 10 second ball-run race, the child returned to the task of naming a new stimulus card and again was required to "reset" his mental representations (tactile, auditory, visual) for planning motor speech movements. Research in the areas of motor learning have shown that distributed practice (using small breaks) results in long term retention of motor skills (Schmidt & Wrisberg, 2004). Small breaks also provided an opportunity for the target sound to be used in a naturalized play/conversational context which may have aided in the generalization of learned motor skills.

Another condition of practice necessary for motor learning relates to the number of stimuli within an activity or session and the contexts in which they occur. Schmidt & Lee (1999) claims that although blocked practice can be useful for the initial learning of a motor movement, varying the types of movements and environments under which they occur results in longer term motor learning of skills. In speech, the continued practice of one /s/ cluster in the context of the same word, during a repeated activity is likely to show mastery of that sound in that one context. However, a child's ability to generalize that specific skill to new words containing that s-cluster sound, during different games, or with new partners may be compromised by the "blocked" nature of practice.

Random practice of motor skills (such as in speech) offers children with CAS the option of practicing a number of speech movements in varying order and within many contexts. In the example activity above, the child practiced a variety of /s/ cluster sounds

(/sm, sn, st, sp, sw/) in a more or less random order. In other words, there was no set order to how the s-clusters would be presented from activity to activity within sessions. They were practiced in syllable isolation “/snæ/”, in words, “snap”, and short utterances, “snap it.” Furthermore, the environment in which the s-clusters were practiced varied (simultaneous production, imitated productions, conversational use, and during play). Other activities included having the child shout and whisper target sounds and words, standing on chairs, tossing stimulus cards into a butterfly net, and speaking to multiple partners. Random practice of speech motor skills prepares the child for the online motor planning skills needed for continuous speech in a variety of contexts.

Post Treatment Phase. Post treatment sessions were conducted following a 2-week period during which CP did not receive specific treatment for speech sounds included in this study. Post treatment probes included four (10 minute) sessions of data collection consistent with data-gathering methods used during all phases of this study. CP’s performance on target speech sounds within 20 carrier phrases was collected and added to the body of pre-treatment and treatment data results.

Data Analysis

A multiple baseline across behaviors design was used in this study. Speech sound baseline performances were deemed stable when no upward or downward trend in speech sound errors (measured as % of target speech sounds correct within a carrier phrase) occurred for a period of at least 4 consecutive sessions. Each target speech sound group was introduced into treatment as it was deemed stable during speech probe periods of 4 probe sessions or more. Treatment resulted in the gradual introduction of each speech sound category (listed in Table 6) and continued throughout the duration of this study.

Analysis of speech probe results included tracking the number of target speech attempts and recording the number of those attempts resulting in correct productions. Speech intelligibility was measured by a percent consonant correct (PCC) score for each target sound for every session throughout the duration of this study. Criterion for correct productions included accurate placement, manner, and voicing of target speech sounds according to individual sound characteristics. All three characteristics (place, manner, and voicing) were required to be accurately produced within the carrier phrase in order for it to be judged by the clinician as correct. PCC was calculated by dividing the number of correct productions in the speech probe by the number of possible productions. A percentage correct was obtained and recorded for each sound. Results were graphed over the period of 40 sessions to determine the level of change in percent consonants correct of target sounds.

Adjustments to treatment implementation and client targets were made as the course of CP's communicative needs and specific language profile changed. Changes were made with consideration to parental feedback, child preferences, as well as clinical and research judgments.

Validity and Reliability

Throughout the duration of this study, the graduate clinician was consulted by her adviser, a licensed speech-language pathologist, to ensure the implementation of integral stimulation techniques and principles were valid. Randomly selected treatment videos were reviewed by an authority on the integral stimulation therapy approach, and were found to be consistent with therapy guidelines. Upon completion of this study, reliability testing was completed on 12% of randomly selected audio-video recorded speech probes.

The additional transcriber was trained in IPA phonetic transcription of normal and disordered speech. The percent of target sounds correct was calculated and compared those of the researching clinician's to ensure inter-rater reliability. Agreement was calculated at 94.6%.

Results

This study examined the effectiveness of the integral stimulation articulation treatment on a child with childhood apraxia of speech. It was hypothesized that the participant's (CP) percentage of correctly produced target phonemes would increase over the course of integral stimulation treatment and be retained after a 2-week treatment withdrawal period. Speech probes with phrases containing target sounds were administered before each session, throughout baseline, treatment, and post-treatment phases of this study. Data from the speech probes were charted over the course of this study to monitor treatment effectiveness. Baseline results tracked the generalization of skills to non-trained single-syllable words in phrases containing target speech sounds.

Baseline measures were conducted over four sessions to determine stability of performance for CP's initial target phoneme set /sm, sn, sp, st, sw/. Baseline data for proceeding target sounds were tracked over longer periods of time as phoneme sets were introduced one at a time. Treatment sessions following the initial baseline sessions included short games that familiarized child with sound-to-letter associations, naming mouth parts, and practicing turn-taking skills, but direct instruction of target speech sounds using integral stimulation therapy was not used. The treatment periods for each phoneme set varied as only one phoneme set was introduced at a time. Once treatments began, the treatment continued in each set throughout the duration of this study's treatment phase.

Integral stimulation therapy included 33 treatment sessions. Post treatment data were collected 16 days after the subject's last integral stimulation treatment session. In order to avoid interruptions in treatment sessions, treatment and baseline data were

gathered in the PSU Speech Clinic as well as at CP's residence. This was due to school closures during vacation periods and schedule changes for the participating family. Data collected at CP's residence are indicated by session number below each Figure.

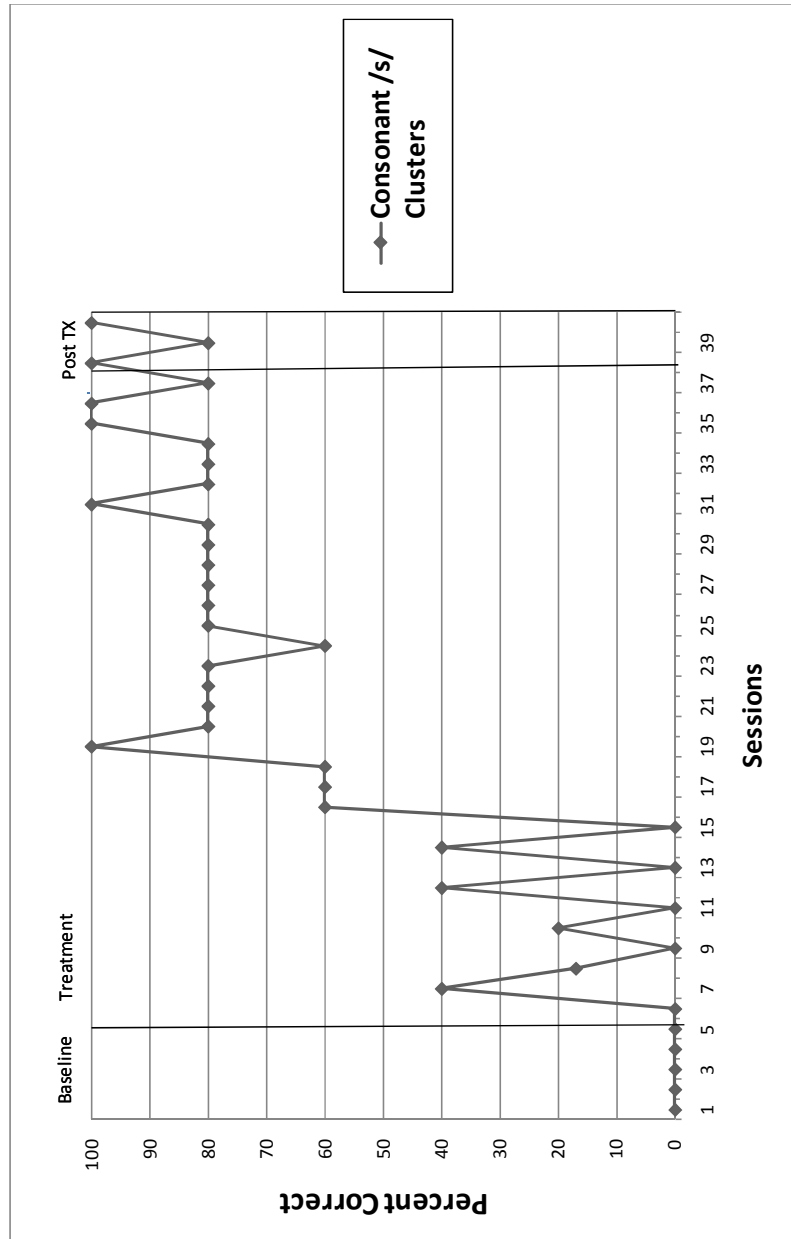
Data Results for /s/ Clusters: /sp, sm, sn, st, sw/

Figure 1 illustrates CP's performance during speech probes as the percent of /s/ consonant clusters /sp, sm, sn, st, & sw/ correctly produced. Data were charted over time during baseline, treatment, and post-treatment phases. Baseline data probes indicated that CP consistently omitted or distorted /s/ consonant cluster phonemes within carrier phrases. Substitution errors were varied (a hallmark of apraxic speech), ranging from omissions of first or second consonant, to substitutions with sounds sharing neither place nor manner characteristics with its intended production. CP's percent accuracy of /s/ consonant clusters was 0% over the 4 pre-treatment sessions. In instances when the subject made multiple productions of a target sound (self-corrections), CP's last attempt was recorded as his response.

After 3 treatment sessions, CP's accuracy of /s/ cluster phonemes moved from 0% correct to 40% correct in carrier phrases. His accuracy continued to fluctuate between 0% correct and 40% correct over the course of treatment sessions 6 through 15. In session 16, CP's percent of correctly produced /s/ cluster phonemes showed a marked increase to 60% accuracy. Figure 6 shows an increase in slope throughout the treatment sessions and following session number 16, the slope did not move below 60% accuracy for all target phonemes (/sp, sm, sn, st, sw/). Following session 24, CP's percent consonant correct for /s/ cluster phonemes in carrier phrases alternated between 80% to 100% accuracy over the course of sessions 25 through 37.

Post-Treatment Results for /s/ Clusters: /sp, sm, sn, st, sw/. Post-treatment data were collected after a 2 week-break from treatment. Data were gathered at CP's residence due to PSU clinic closures for spring break. Figure 1 illustrates the generalization of trained speech sounds to untrained words in the context of phrases. Post treatment results show that CP's production of /s/ consonant clusters remained stable following a 16-day cessation of treatment for those sounds. Over the last 9 sessions of treatment, CP's percent accuracy correct of /s/ consonant clusters achieved a pattern of stability alternating between 80% and 100%. Results from post-treatment probes over 3 sessions did not diverge from that trend, staying within the 80% to 100% range of accuracy, suggesting that motor learning had occurred.

Figure 1. Percent correct for /s/ clusters in single syllable carrier phrases

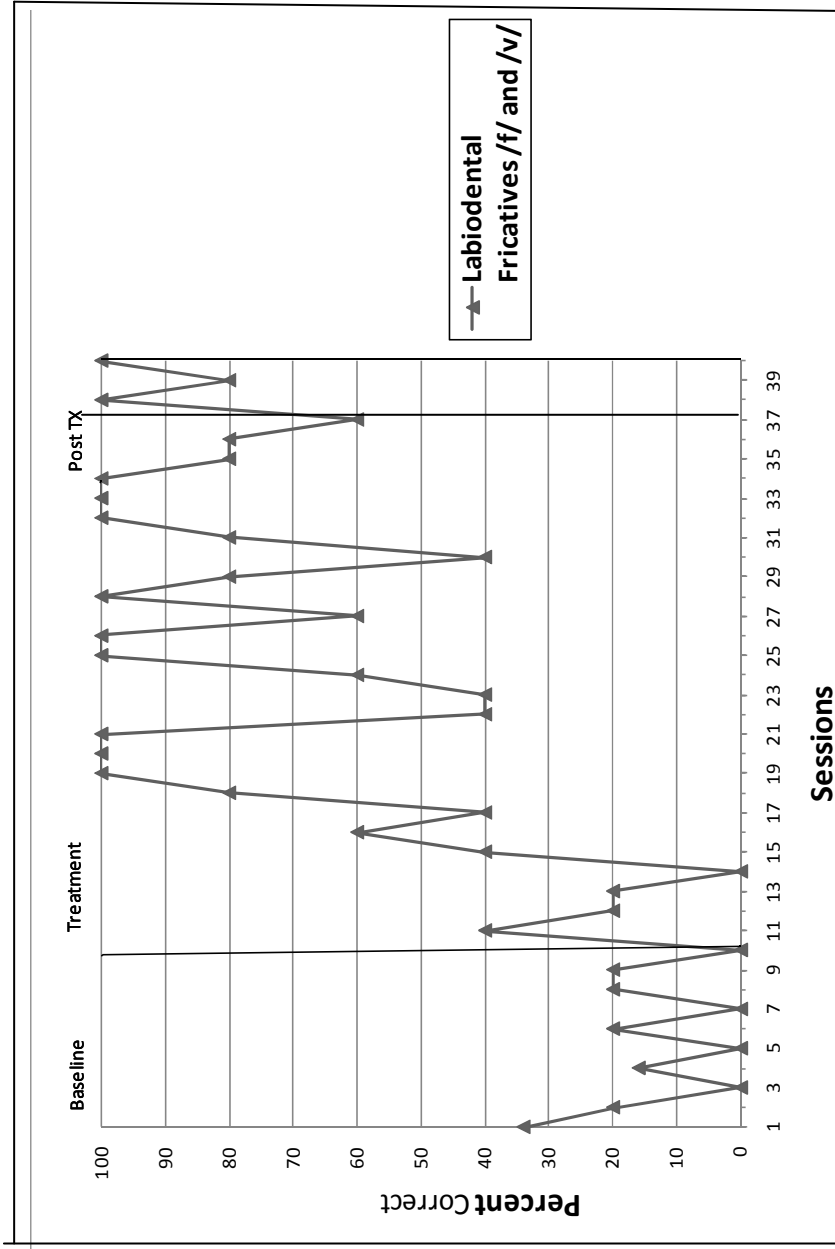


Data Results for Labiodentals Fricatives: /f/ & /v/

Figure 2 illustrates CP's performance as the percent of labiodental fricatives /f/ and /v/ correctly produced during speech probes. Data were charted over time during baseline, treatment, and post treatment phases. Pre treatment data probes indicated that CP produced bilabial fricatives /ɸ/ and /β/ in place of /f/ and /v/ phonemes in the majority of his substitution errors. His errors, however, were not entirely consistent, as he occasionally made substitutions with /b/, /s/, and /m/ phonemes or omitted labiodental fricatives from words entirely. CP demonstrated consistent levels of performance on speech probes during baseline sessions (1 through 11) alternating between 0 and 40% correct production of /f/ and /v/ phonemes. Sessions 12 through 37 include data probes gathered after treatment had begun. A significant increase in accurate production of /f/ and /v/ phonemes was observed following session 15. This upward trend fluctuated between 40% and 100% accuracy for the duration of the treatment sessions. Variance in accuracy continued to stabilize as the treatment progressed, as the upward trend in accuracy shown in Figure 2 illustrates.

Post-Treatment Results for Labiodentals Fricatives: /f/ & /v/. Post treatment data (sessions 38 through 40 in Figure 2) illustrate that CP's correct production of target phonemes /f/ and /v/ remained at or above 80% accuracy in carrier phrases. Data results indicate that CP's accurate production of /f/ and /v/ phonemes increased over the course of 26 treatment sessions and were maintained approximately 2 weeks after treatment ended, suggesting motor learning had occurred.

Figure 2. Percent correct for /f/ and /v/ phonemes in single-syllable words in carrier phrases



Data Results for Affricates: /dʒ/ & /tʃ/

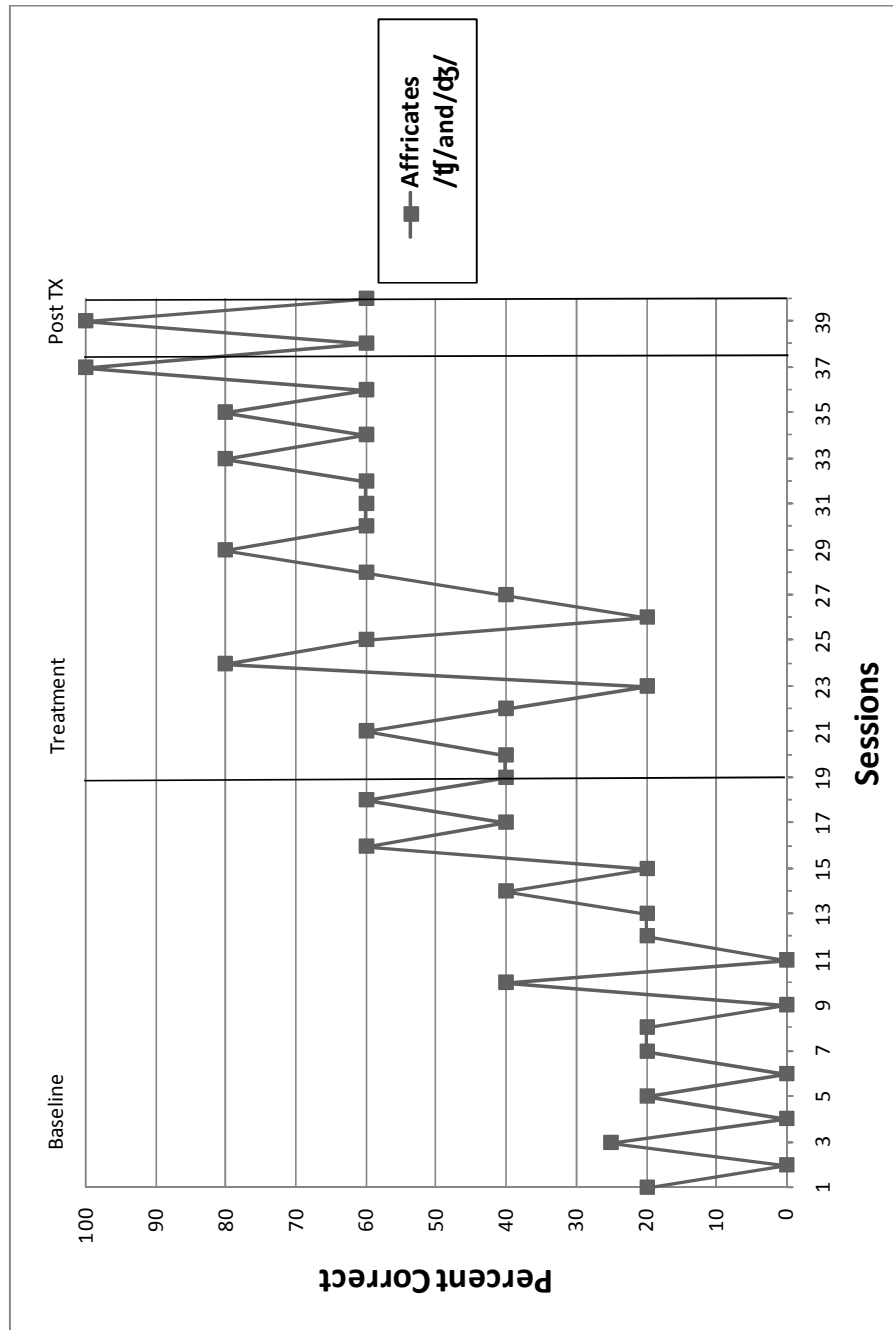
Figure 3 illustrates CP's performance during data probes as the percent of affricates /dʒ, tʃ/ correctly produced in carrier phrases. Data were charted over time during baseline, treatment, and post treatment phases. Pre treatment data probes indicated that CP produced /ds/, /d/, and /f/ sounds in place of / dʒ / and /ts/, /d/, /t/, and /s/ sounds in place of / tʃ / phonemes.

CP demonstrated levels of performance on speech probes during baseline sessions (1 through 19) alternating between 0 and 60% accuracy of /dʒ, tʃ/ phonemes. Baseline speech probes show some indication of improved speech production of / dʒ / and / tʃ / phonemes in carrier phrases before treatment for the sounds had begun. This may have been a result of CP's increased awareness and control of speech sounds and articulators acquired over the course of 17 sessions. Sessions 20 through 37 include data probes gathered after treatment had begun. Over the treatment period, CP's accuracy fluctuated between 20% and 100% for / dʒ / and / tʃ / phonemes in carrier phrases over sessions 20 through 37.

Post-Treatment Results for Affricates: /dʒ/ & /tʃ/

Post treatment results (sessions 38 through 40 in Figure 3) illustrate that CP's correct production of target phonemes /dʒ / and / tʃ / remained at or above 60% accuracy in carrier phrases. Data results indicate that CP's accurate production of / dʒ / and / tʃ / phonemes increased over the course of 20 treatment sessions and was maintained approximately 2 weeks after treatment ended.

Figure 3. Percent correct of /tʃ/ and /dʒ/ phonemes in single-syllable words in carrier phrases



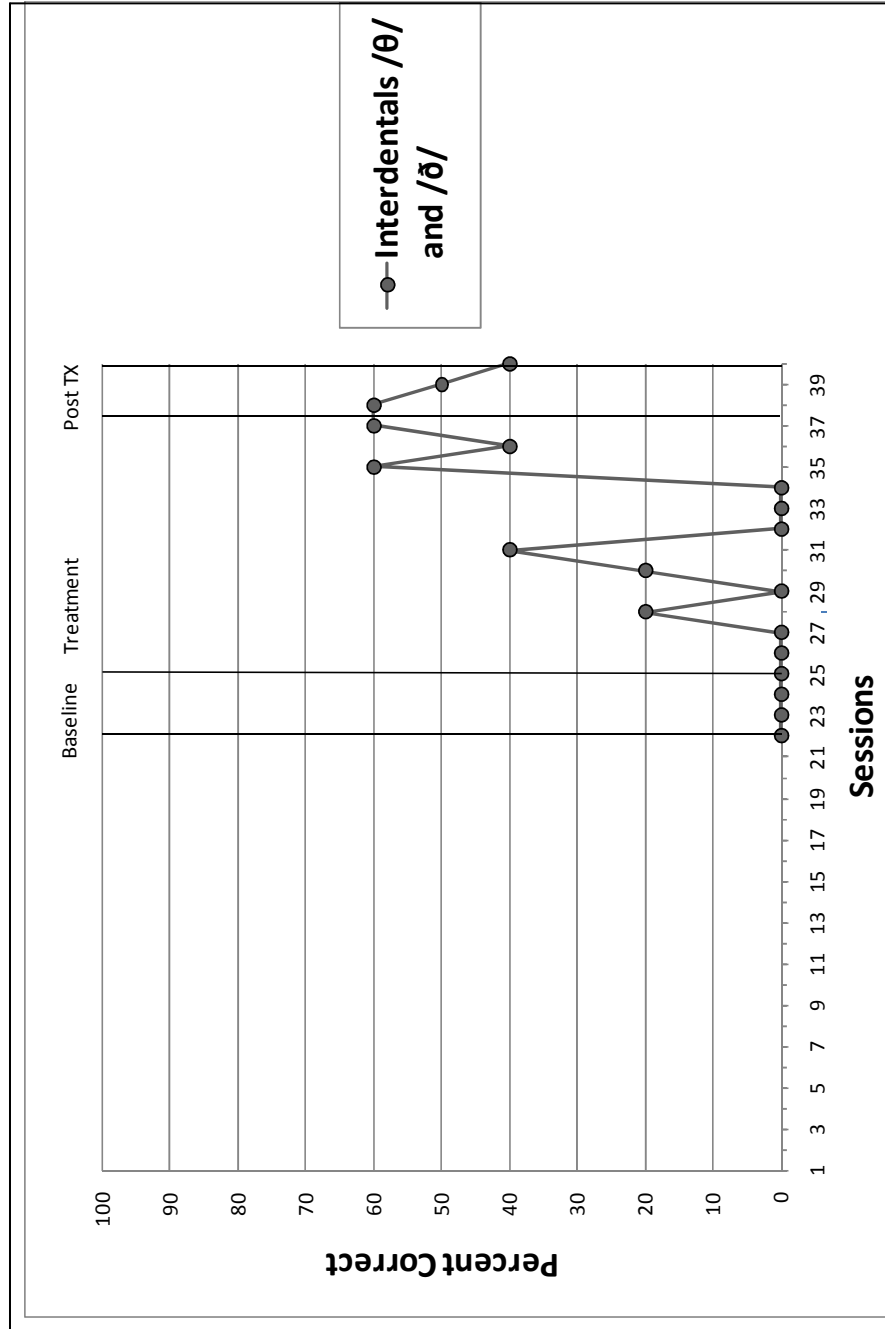
Data Results for Interdental Fricatives: /θ/ and /ð/

Figure 4 illustrates CP's performance during speech probes as the percent of interdental fricatives /θ/ and /ð/ correctly produced. Data were charted over time during baseline, treatment, and post treatment phases. Pre treatment data probes indicated that CP made a variety of substitution errors and omissions when attempting interdental fricative sounds. Most notable was his tendency to substitute bilabial fricatives /ϕ/ and /β/ in place of /θ/ and /ð/ phonemes in the majority of substitution errors. This pattern was also observed in his attempts to approximate interdental sounds /f/ and /v/. CP substituted /v/, /d/, /z/, and /f/ sounds in initial word positions and /f/ in final positions. CP demonstrated consistent levels of performance (0% correct) on speech probes during baseline sessions (22 through 26). Sessions 27 through 37 include data probes gathered after treatment had begun and before the post treatment period. Data gathered over 12 treatment sessions show CP responding to treatment with variable results. Accuracy of /θ/ and /ð/ phonemes ranged from 0 to 60% correct. Despite a short treatment period and fluctuating performance, CP's accuracy showed a pattern of increased improvement over the course of the treatment. His baseline accuracy for interdental fricatives was consistently at 0%. After 4 treatment sessions, his performance increased, but then decreased following 3 cancelled sessions due to illness. CP continued to show symptoms of congestion even after he returned to speech therapy.

Post Treatment Results for Interdental Fricatives: /θ / and /ð /.

Post treatment results (sessions 38 through 40 in Figure 4) illustrate that CP's correct production of target phonemes /θ / and / ð / did not reach a level of stability after a 2-week break from treatment. While post-data accuracy for the interdental fricatives was higher than pre-treatment baseline accuracy, there was a pattern of decline in accuracy over the 3 post treatment data probes.

Figure 4. Percent correct for /θ/ and /ð/ phonemes in single-syllable words in carrier phrases



Prior to the onset of integral stimulation therapy, a 100-word language sample was taken to determine CP's mean length of utterance, phonetic inventory, and overall speech intelligibility. Pre-treatment data were compared with a second 100-word sample to determine if improved accuracy of target sounds in speech probes were reflected in CP's conversational speech. It should be noted that a child's utterance length can be influenced by factors such as familiarity with conversational partner, the presence of a parent for support, and comfort levels in a clinical setting. CP's pre-treatment mean length of utterance (MLU) was 1.3. His MLU near the end of his treatment was 4.5, indicating that his average number of words used in an utterance increased by more than 3 words in length over the course of treatment. CP's overall accuracy of consonants increased over the course of treatment from 52% correct to 79% correct within the context of the two speech samples. Accuracy of target sounds was 60% correct within the final speech sample (14 correct target sounds out of 23 opportunities). It is unclear to what degree CP's improved MLU was due to his familiarity with the clinician and his confidence that his conversational speech would be understood. Despite this uncertainty, CP was noted by both his parents and teachers as communicating with longer sentences and more complexity toward the end of his treatment phase. His improved speech accuracy and increased utterance length are most likely a combination of many contributing factors: CP's family worked daily to support his speech goals at home, speech therapy included weekly work at the Scottish Rite Speech Clinic and school based interventions in addition to treatment at Portland State University. Frequent and intense speech practice is thought to be a critical component of effective treatment for CAS. CP's progress may have demonstrated this point.

Discussion

This discussion examines the effectiveness of integral stimulation therapy approach as it relates to principles of cognitive motor learning and its effect on CP's speech intelligibility. This discussion will also examine the strengths and limitations of this study's treatment design (methods), data collection, and subject participation.

This single subject study evaluated the efficacy of integral stimulation therapy on a 5- year-old child with CAS. Prior to treatment, the child (CP) demonstrated low levels of speech intelligibility for all targeted speech sounds, limited self awareness and correction of speech errors, and a high degree of speech sound variability when attempting target sounds in data probes and during spontaneous speech. Despite many motor speech difficulties, CP possessed many qualities necessary for effective motor learning. The child was able to maintain focused attention during many speech tasks allowing for mirror work, self reflection, and repeated practice of target speech sounds. He was highly motivated to communicate his knowledge and interests to others, often rephrasing his utterances to accommodate his listener's needs. His sound-letter awareness was well developed, allowing him to spell out target words and match letters to lip shapes and phonemes. Finally, CP had a knowledgeable and supportive family. His mother attended each therapy session, practiced target sounds at home with him, and communicated his ongoing progress to this clinician. CP's family played a key role in helping him to generalize his speech skills to his daily communication at home.

Results from this study indicate that CP's performance in each target set improved over the 21 weeks (33 sessions) of integral stimulation therapy treatment. Treatment included a hierarchy of cueing systems that included visual, tactile, and auditory supports

to elicit accurate speech sounds first in isolation, then at syllable level, and finally at word and phrase levels. Supports were added and withdrawn from treatment depending on the child's success. Many successful productions of speech target sounds (blocked) were required before the sound was practiced in a random manner. This allowed maximum opportunity to master speech sounds before applying the motor skills to more challenging contexts (multiple target sounds in one activity, practice in a play activity, practice while discussing a picture book).

The frequency of motor speech practice varied upon the level of difficulty for each task, the child's age and motivation, and activity design. A study by Edeal (2008), including 2 children with moderate to severe CAS, concluded that "frequent and intense practice of speech sounds in the context of integral stimulation therapy resulted in faster acquisition of the targets, better in session performance, and more generalization to untrained probe words..." (p. 95). Every effort was made to maximize as many correct productions of target sounds in a variety of contexts. It was noted that fewer productions (30 to 40) were achieved during sessions that CP was feeling overly tired, sick, or restless. During sessions when CP was highly motivated, attentive, and healthy CP was able to produce up to 100 productions of target speech sounds during a treatment session.

CP's ability to judge, correct, and prepare for accurate speech productions showed marked improvement over the course of this study. He relied on clinician feedback less as his skills at self evaluation developed. After several weeks of treatment, CP's mother noticed him making multiple attempts at words containing target speech sounds, pausing before those attempts, and asking for words to be modeled for him at home. She practiced his target speech sounds with him in a variety of environments which allowed him to

practice his motor speech skills in a distributed and random fashion, building on his ability to generalize his skills to everyday speech contexts.

In this study, 3 out of the 4 speech targets indicated stable retention of learned speech motor skills as indicated by retention of target sound accuracy 2 weeks following the end of treatment. Specifically, CP's accuracy of s-cluster phonemes /sp/, /sm/, /sn/, /st/, and /sw/ in carrier phrases rose from 0% accuracy during 4 baseline probes, to 100% and 80% accuracy in post treatment data probes. Phonemes /f/ and /v/ accuracy increased from 0% and 40% correct during baseline probes to 80% and 100% correct in post treatment data probes. CP's accuracy of affricate sounds /dʒ/ and /tʃ/ increased in accuracy from baselines of 0% and 60% accurate to post treatment results of 60% to 100%. It should be noted that baseline data indicated a pattern of improved production prior to treatment for this sound class /dʒ/ and /tʃ/. CP had been able to accurately produce /dʒ/ and /tʃ/ in some instances (in words and phrases) prior to treatment for these sounds. It is possible that CP's increased self-monitoring skills as well as work on other fricative word classes (/s/ clusters, and /f/, /v/) may have transferred to his motor speech skills during the treatment period. His baseline performance was stable (0 to 20% correct) over the first 9 baseline probes, then began to increase after /f/ & /v/ targets were introduced to treatment sessions.

The fourth speech sound class (interdental fricatives /θ/ and /ð/) may have been introduced too late in the course of the treatment (session # 26) to have acquired stable motor learning (generalization) following the cessation of treatment. CP showed clear improvement in production of /θ/ and /ð/ sounds over the course of the treatment period. His accuracy for interdental sounds was consistently 0% over the 4 baseline data probes

and rose to 60% and 40% accuracy in post treatment probes. Despite clear gains in accuracy during treatment periods, the stability of his motor learning in post treatment probes indicated a pattern of decline (from 60% to 50% to 40%) for /θ/ and /ð/ sounds (see Figure 4). Several factors may have contributed to this decline. This phoneme set received the least amount of treatment sessions during this study as it was the final phoneme set introduced. Interdental sounds spanned only the final 3rd of the integral stimulation therapy sessions (12 sessions in all). Although clear progress was made over the 12 sessions (performance went from 0% accuracy to up to 60 %) there may not have been adequate amounts of motor practice to have achieved motor learning (maintenance of skills after treatment for target sounds had ended) for these speech skills. By the final therapy session, CP was estimated to be only 70% accurate at word level and 40% accurate during speech activities that required him to use interdental fricatives repeatedly in a single sentence, “There’s the spider.” Unlike the other speech sound sets, mastery of /θ/ and /ð/ sounds during speech sessions at phrase levels had not been achieved by the conclusion the treatment phase.

Another factor that may have negatively impacted CP’s performance of /θ/ and /ð/ sounds was that there were fewer opportunities in most speech sessions to practice interdental fricatives as sessions continued to include practice of the previous speech sound goals (/s/ clusters, labiodentals fricatives, & affricates) within a 50-minute time frame. An essential component of motor learning is frequent correct repetitions (100 to 150) of speech target sounds within a speech session. Fewer opportunities to practice speech sounds may have contributed to slower acquisition of motor performance and motor learning for bilabial fricative phonemes.

Indicators that motor learning had occurred were measured by asking the child to repeat short phrases containing target sounds such as, “I wanna go there” and “I gotta loose tooth” before each therapy session. It is not surprising that CP’s motor skills for /θ/ and /ð/ sounds did not achieve stable generalization during post-treatment carrier phrase probes as he had not yet achieved consistent levels of accuracy during in session practice drills.

A final factor that may have negatively influenced the subject’s motor learning progress was decreased attendance during spring sessions. CP’s parents cancelled 4 therapy sessions due to frequent colds. Even after CP had returned to speech, he remained congested and less able to focus during his practice sessions. Effective integral stimulation therapy requires a subject to maintain focused attention in order to judge his own speech sound productions, make corrections, and practice sounds with great frequency. CP’s illness may have impacted his ability to attend to tasks as well as he had in the past. It should be noted however, that accuracy of his other target sound sets did not show patterns of decline over the course of his absences from treatment.

Improved speech intelligibility was not only observed within the context of carrier phrases, but in CP’s spontaneous speech as well. Speech accuracy (within 100-word language samples) for consonants jumped from 52% accuracy (pre-treatment sample) to 79% accuracy (near end of treatment). One important principle of cognitive motor learning is that motor skills practiced in numerous contexts are believed to generalize to those contexts (such as conversational speech) and be retained longer than motor skills practiced in very few contexts. Throughout this CP’s treatment he was encouraged to practice target sound production in isolation, in words, short sentences, and in

conversational contexts. Further, the environments of this practice varied so that his speech was often practiced while performing gross motor activities, reading tasks, and games inside and outside the speech therapy room.

CP demonstrated increased sentence lengths (MLU) suggesting that motor sequencing practice enabled him to say more with less speech errors. Of particular interest is the observation that as CP's utterance lengths increased, his rate of speech remained slow and an unusual prosody became more apparent. Children who speak in 1- or 2-word utterances are less likely to demonstrate prosodic differences as they have fewer syllables to sequence. As CP's utterance lengths increased, his speech was noted as being "halting" or "robotic" in quality. It is difficult to determine whether this prosody difference is due to motor planning deficits intrinsic to CAS, or whether the suprasegmental quality of speech is negatively impacted as a result of the effort required to produce accurate motor speech movements. Clearly, there is much need in the areas of research regarding treatment approaches for CAS that improve both supersegmental and suprasegmental elements of speech.

Conclusion

The results of this study suggest that use of an integral stimulation approach as a treatment for CAS resulted in increased accuracy of target phonemes within untrained carrier phrases in all target sound sets. Post treatment data results indicate that CP's speech sound accuracy was maintained in 3 out of the 4 phoneme sets 2 weeks following withdrawal of treatment. These results suggest that motor learning had occurred within post-treatment carrier phrases. Additionally, CP's parents and clinicians observed an increase in the frequency and accuracy of target speech sounds in conversational speech contexts. Results of spontaneous language samples taken before treatment and near the end of treatment show marked improvement in mean length of utterance and consonant accuracy.

CP's significant speech progress over the course of 21 weeks (33 treatment sessions) was due to the fact that many precursors to motor learning were in place when he began integral stimulation therapy. A child's level of motivation can be influenced by his or her cognitive functioning, comfort level, social/self awareness, and rapport with the clinician. CP demonstrated a high degree of motivation during most of his treatment sessions. He was able to apply focused attention to speech tasks for short periods of time; often evaluating the accuracy of his own speech and making corrections. CP's sound-letter skills were well developed so that many speech tasks were reinforced by his eagerness to read and "sound out" his words in mirrors and when playing games. His mother attended each speech session, often participated in therapy activities with her child, and then used them later at home and in school to facilitate the generalization of speech skills in a number of contexts.

CP's cognitive functioning contributed to his success in being able to understand and respond to feedback provided to him during integral stimulation therapy sessions. Typically, CP responded most favorably to visual, tactile, and auditory cues presented within the contexts of motivating activities (building, games, books). He was able to "be his own judge" with simple supports, and moved toward independently correcting his own speech errors.

Strengths of this study include a solid single subject design and data tracking system. The clinician possessed a high level of understanding of integral stimulation therapy and remained under the supervision of a certified speech-language pathologist specializing in diagnosis and treatment of CAS. Treatment sessions were planned and executed with attention to providing the child with a hierarchy of multi-modal cueing supports that were adaptive to his level of need in each treatment session. Sessions were broken up into a series of short, but fast-paced activities to minimize the possibility of fatigue or disinterest during speech motor practice. Blocked speech practice was initially used to establish CP consistent motor speech skills, then practiced randomly with other speech targets. Therapy sessions were broken into short activities so that CP had to "relearn" motor skills in different contexts and so that he did not tire after frequent and intense motor practice tasks. He was offered "play breaks" when he indicated that he needed them.

Limitations of this study included occasional sessions when the child was feeling ill or uncooperative during speech probes and treatment sessions. At these times, less practice was achieved as more attention was spent on re-focusing this energetic 5 year-old boy.

A number of sessions were missed toward the end of the study as CP was sick with colds. Further limitations in the form of data collection occurred when this clinician inadvertently skipped a speech probe phrase (resulting in less data to include) or when video equipment did not operate effectively. More comprehensive analysis (tracking self-corrections, number of productions, feedback tracking) of CP's treatment would have been possible if every treatment session had been recorded. In this case, each speech probe was recorded when the child was seated, but full sessions were not consistently recorded as therapy required much movement and often practice outside of the speech room (hallway activities).

Perhaps the most significant limitation of this study is that it included a single child rather than multiple subjects. CAS is a relatively rare speech disorder that is often misdiagnosed and difficult to identify, but efficacy studies that include larger samples of children would allow speech language-pathologists and parents alike to seek treatment for children with CAS more assuredly.

The suggestions of this study are that frequent and intense motor practice of speech sounds in a variety of contexts with multi-sensory supports can greatly improve the intelligibility of a child with motor speech impairment like CAS. In this study, CP's speech showed significant improvement for all target sound sets which generalized to spontaneous speech contexts in 3 out of the 4 target sound sets. In addition to greater speech accuracy, CP demonstrated a dramatic increase in the number of utterances used during spontaneous speech (pre-treatment MLU of 1.3 vs. 4.5 MLU following treatment). Family members and teachers commented on CP's ability to communicate his thoughts more clearly and with more complexity than he had before integral stimulation therapy

treatment had begun. In addition to improved speech intelligibility and utterance length, CP frequently demonstrated strategies critical to integral stimulation therapy principles (slowed rate of speech for difficult sounds, frequent self-corrections, requests for modeled sound, increased awareness of own accuracy).

Children and families often invest a great amount of energy and resources in obtaining long-term speech treatment for CAS. The body of efficacy research is currently inadequate to definitively conclude best practices for CAS diagnosis and treatment. Large scale research for CAS can be challenging to conduct given its relatively low prevalence and undefined diagnostic markers. Given these significant challenges, systematic treatment programs can be developed to evaluate treatment efficacy for CAS. This study adds to a growing body of work that suggests that integral stimulation therapy has positive effects on the speech intelligibility of children affected by CAS. Large scale research in the area of treatment efficacy for CAS will enable families to seek therapy with more confidence and assist speech-language pathologists in providing treatment effectively.

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Appendix A

PARENT INFORMED CONSENT FORM

Dear Parents/Guardians,

I am contacting you to invite you to participate in a project involving children with childhood apraxia of speech. My name is Rain Daniel, and I am a graduate student in the Portland State University Speech and Hearing Sciences program.

Conducting research helps us to identify effective treatment interventions for children affected by (CAS). This project is part of a master's thesis and will evaluate the effectiveness of Integral Stimulation Speech Therapy which is a promising treatment approach but has little research to prove its efficacy.

Participation in this project would include an assessment of your child's speech and communication abilities so that we may identify the best treatment goals for your child. Assessment activities may involve pointing to and naming pictures, playing with toys, responding to questions, and participating in joint play conversations. With your input, we will determine your child's greatest areas of speech needs and the most prominent error patterns would be treated with integral stimulation therapy. Therapy will occur two times per week for 50 minutes at Portland State University where your child will receive therapy free of charge during the fall and winter terms. There will be approximately 30 treatment sessions (make-up sessions will be at the discretion of the participant's parents).

Each session will consist of 45 minutes of therapy and 5 minutes of data collection by repeating sentences. I will audiotape and videotape each treatment session so that I can review speech clarity and intelligibility afterwards. At the beginning of each session I will describe the day's activities to your child and ask him if he'd like to participate. Activities will be designed to appeal to your child's particular interests.

Your participation and your child's participation are completely voluntary. If your child is uncomfortable or does not want to complete a task, his wishes will be respected. Participation in this project should not be harmful in any way to your child. Treatment sessions will resemble other treatment he has previously received at PSU Child Speech Clinic. When the project is complete, we will give you a report that summarizes your child's progress and reviews the results of the study. We will keep confidential both your and your child's name and all the information gathered during this project by using pseudonyms on all materials used in this project. All materials will be kept in a locked cabinet in the Speech and Hearing Department at PSU. These tapes will be used for educational and research purposes only. You may withdraw from the project at any point in time if you do not want to continue in the project, and this will not affect your relationship with PSU. The participant will have the option of receiving speech and hearing services through PSU as a regular client at the first available clinic opening. Fees

for regular treatment are determined by a sliding scale with a maximum charge of \$250 per term.

I would be glad to talk with you about the project, and answer any questions you might have. You may contact me at (503) 289-8152. You may contact my adviser, Christina Gildersleeve-Neumann at (503) 725-3230. If you are willing to participate, please sign one copy of the attached consent form and return it to me in the enclosed envelope. Please keep the second copy for your record.

If you have concerns about your participation or about this study, please contact either Dr. Christina Gildersleeve-Neumann at (503) 725- 3230 or the Human Subjects Review Committee, Office of Research and Sponsored Projects, 111 Cramer Hall, Portland State University, (503) 725-4288. Thank you so very much for considering participating in our project. We feel strongly that these kinds of projects will help us better understand speech difficulties experienced by children. This will help us provide better services to help children overcome articulation and phonological difficulties.

Sincerely,
Rain Daniel, Graduate Student, Speech and Hearing Sciences Program, Portland State University

I give my permission for my child, _____, to participate in the research on speech therapy intervention.

Parent/Guardians Name

Signature

The project was explained to _____ and he was willing to participate.

Child's Name

Child's Signature (if appropriate)

Witness to child's agreement

Appendix B

CHILD ASSENT FORM

Child's name _____

Hi my name is Rain and I'm a speech teacher. I help lots of kids say hard sounds and words better. Your mom said it would be okay if I worked with you on speech this year. If you choose to, we'll do lots of different activities to help make your speech get better. We'll do some fun activities with toys and games that help us make really good sounds, and work on those sounds when we speak. I will also ask you to copy what I say each time we meet. We'll work together for 50 minutes a day, two days a week here at PSU. At the beginning of every day, I'll turn on the tape recorder so I can tape you saying some words to see how much clearer your speech is.

If you want to rest or stop, just tell me- you won't get into any trouble. In fact, if you don't want to do it at all, you don't have to. Just say so. If you are curious about some of the activities we will be doing, I can show you a few. I'll explain why we do them and how they can help your speech. Do you want to try coming to speech classes with me?

(Child agrees / does not agree to participate)

Appendix C –Data Tracking Form

TX TARGETS	#	Gloss	Target	Shape	Transcription	Correct	Incorrect	Prod/s/	/m,n,p,t,w/	Place	Manner	Voice Y/N	Error Patterns
/s/ clusters	1												
/s/ clusters	2												
/s/ clusters	3												
/s/ clusters	4												
/s/ clusters	5												
/f/, /v/	6												
/f/, /v/	7												
/f/, /v/	8												
/f/, /v/	9												
/f/, /v/	10												
/dʒ/, /tʃ/	11												
/dʒ/, /tʃ/	12												
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