INTEGRAL STIMULATION DECONSTRUCTED: A TREATMENT EFFICACY STUDY FOR CHILDHOOD APRAXIA OF SPEECH

by

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Abstract

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Title: Integral Stimulation Deconstructed: A Treatment Efficacy Study for Childhood Apraxia of Speech.

Childhood apraxia of speech (CAS) is a neurological, sensory-motor speech disorder in which the affected individual has deficits in motor planning, or putting together the motor movements needed to produce volitional speech. These deficits often translate into extremely poor intelligibility, partly because of the unusual types of errors children with CAS make when compared to other children with speech sound disorders. Typical errors often include vowel and rhythm errors, and inconsistency in how words are produced (ASHA, 2007). CAS is a rare but hard to treat speech disorder, with a slow response to treatment frequently reported (Forrest, 2003).

The literature regarding treatments for CAS is sparse. Because CAS is a motor planning disorder, motor based treatments are generally thought to be the most effective methods for treating CAS (ASHA, 2007); however, few studies have actually assessed the efficacy of motor based treatment approaches. The treatment that appears most promising for the treatment of CAS is integral stimulation therapy (ASHA, 2007). It is a motor based, speech focused approach that incorporates the principles of cognitive motor learning, including specific and repeated practice of the desired motor task (Rosenbek, Lemme, Ahern, Harris, & Wertz, 1973). In addition, motor learning principles suggest

the need for specific practice of the target speech sounds in various contexts that mimic real life situations.

This study explores the variable of frequency of repetition in the context of integral stimulation therapy to determine if more practice of speech targets leads to increased in-session performance as well as generalization to untrained words. Two variations of integral stimulation were implemented. The first variation used integral stimulation techniques such as the “watch me, and do what I do” technique, multimodal cueing, and principles of motor learning, but elicited very few (30 to 40) repetitions of each target speech sound during a treatment session. The second treatment variation used all of the aforementioned integral stimulation techniques but elicited 100 to 150 productions of each speech sound target within the same time frame.

Three participants with suspected CAS were studied. Participants were seen between two and three times per week for 40 minute sessions. A single subject, alternating treatments design was implemented across 3 participants. Both treatments were used in every session. Speech sounds chosen for treatment were based on results from standardized testing, the analysis of speech samples, and stimulability.

Two of the 3 participants completed the study. The third participant was removed due to concerns regarding the appropriateness of a CAS diagnosis for him and the concern that integral stimulation therapy was not meeting his speech and language needs. Both of the remaining participants showed improvement in motor performance, in-session production accuracy of treated speech sounds, as well as some motor learning, transfer of skills to novel words. Both participants showed higher levels of in-session performance and generalization for the sounds treated with a higher level frequency of repetition (100+ productions per session). These findings suggest that more frequent and intense practice of speech sounds leads to greater motor performance and motor learning.

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Introduction

Childhood apraxia of speech (CAS) is a neurological, sensory-motor speech disorder in which the affected individual has deficits in motor planning, or putting together the motor movements needed to produce volitional speech. These deficits often translate into extremely poor intelligibility, partly because of the unusual types of errors children with CAS make when compared to other children with speech sound disorders. Typical errors often include vowel and rhythm errors, and inconsistency in how words are produced (ASHA, 2007). CAS is a rare but hard to treat speech disorder, with a slow response to treatment frequently reported (Forrest, 2003). The prevalence of the disorder is not fully known but generally thought to be between 1 and 2 children per thousand children in the general population (Shriberg, 1994). One reason for the lack of evidence of improvement in intelligibility may be due to the lack of efficacy data on treatment approaches for CAS (ASHA, 2007).

The literature regarding treatments for CAS is sparse. Because CAS is a motor planning disorder, motor based treatments are generally thought to be the most effective methods for treating CAS (ASHA, 2007); however, few studies have actually assessed the efficacy of motor based treatment approaches. The treatment that appears most promising for the treatment of CAS is integral stimulation therapy (ASHA, 2007). It is a motor based, speech focused approach that incorporates the principles of cognitive motor learning, including specific and repeated practice of the desired motor task (Rosenbek, Lemme, Ahern, Harris, & Wertz, 1973). Treatment guided by cognitive motor learning includes constant evaluation of the use of blocked versus random practice, mass versus distributed practice, and knowledge of results versus knowledge of performance (Schmidt & Wrisberg, 2004). In addition, motor learning principles suggest the need for specific practice of the target speech sounds in various contexts that mimic real life situations. The ideal treatment is an intense multi-modal treatment approach that contrasts with many current cognitive-linguistic treatment approaches to speech sound disorders.

To date only two studies have been published dedicated solely to determining the efficacy of integral stimulation therapy for children with CAS (Strand & Debertine, 2000; Strand, Stoeckel, & Baas, 2006[1]). These studies show that integral stimulation therapy is an effective treatment for remediating speech sound errors in children with CAS, but more and larger studies need to be conducted which can replicate these results to confirm the benefits of the treatment (Strand et al., 2006). In addition, no study to date has assessed the component parts to determine if one aspect of the treatment is more efficacious than another. If benefit were determined to come from one aspect of the treatment, clinicians could focus their energy in sessions on the one aspect of integral stimulation that works best. The rest of the treatment could be applied in a complimentary fashion or not at all.

This study explores the variable of frequency of repetition in the context of integral stimulation therapy to determine if more practice of speech targets leads to increased in-session performance as well as generalization to untrained words. Two variations of integral stimulation were implemented. The first variation used integral stimulation techniques such as the "watch me, and do what I do" technique,

[1] Strand and colleagues refer to the treatment used in this study as Dynamic temporal and tactile cueing (DTTC). According to Strand, it is based on integral stimulation therapy and the principles of cognitive motor learning. Because of the similarities of the treatments, DTTC will be referred to integral stimulation therapy for the purposes of this thesis.

multimodal cueing, and principles of motor learning, but elicited very few (30 to 40) repetitions of each target speech sound during a treatment session. The second treatment variation used all of the aforementioned integral stimulation techniques but elicited 100 to 150 productions of each speech sound target within the same time frame. Each treatment was assigned to different speech sounds in each participant's speech sound repertoire. Data were tracked for each treatment to determine if changing the intensity of therapy and the frequency of repetition of elicited productions while implementing integral stimulation produced different results for remediating speech sound errors. Three participants with suspected CAS were studied. While it is the belief of the author that all components of integral stimulation can be effective at treating motor speech disorders, it is theorized that the frequency of repetition with which the speech sounds are produced by the client is the key to attaining more accurate in-session productions and generalization to novel words.

Participants were seen between two and three times per week for 40 minute sessions. A single subject, alternating treatments design was implemented across 3 participants. Both treatments were used in every session. Every effort was made to choose speech sounds that were different in class and manner to prevent generalization from one treatment to another. Speech sounds chosen for treatment were based on results from standardized testing, the analysis of speech samples, and stimulability.

Two of the 3 participants completed the study. The third participant was removed due to concerns regarding the appropriateness of a CAS diagnosis for him and the concern that integral stimulation therapy was not meeting his speech and language needs. Both of the remaining participants showed improvement in motor performance, in-session production accuracy of treated speech sounds, as well as some motor learning, transfer of skills to novel words. Both participants showed higher levels of in-session performance and generalization for the sounds treated with a higher level frequency of repetition (100+ productions per session). These findings suggest that more frequent and intense practice of speech sounds leads to greater motor performance and motor learning.

Literature Review

Childhood apraxia of speech is a controversial topic in the speech and language pathology literature. It is generally considered to be a neurological, sensorimotor speech disorder (Caruso & Strand, 1999). The disorder is manifest by the affected child demonstrating difficulties programming, combining, and sequencing the motor movements needed for volitional speech (Jaffe, 1984). It is seen more often in males than females, and there is some evidence to suggest a genetic etiology for the disorder (Aram & Nation, 1982; ASHA, 2007; Lewis, Freebarin, et al., 2004). After an extensive review of the literature, the ASHA position statement released in 2007 recommends defining childhood apraxia of speech in the following manner:

> "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 known or unknown origin, or in planning and/or programming spatiotemporal parameters of movement sequences results in errors in speech sound production and prosody." (p. 3).

There has been debate in the literature to date as to whether apraxia is solely a motor planning pathology (Rosenbek et al., 1973) or whether it is a disorder of motoric as well as linguistic deficit (Ball, Bernthal, & Beukelman, 2002). The distinction of CAS as a purely motor disorder versus one having a linguistic component is an important factor in determining the best treatment approaches for CAS (Yorkston, Beukelman, Strand, & Bell, 1999). Those who argue that CAS has inherent language components refer to evidence that the language deficits seen in children with CAS do not fully resolve as articulation improves (Aram & Nation, 1982; Lewis, Hansen, Iyengar, & Taylor, 2004). Maassen (2002) argues that CAS is a purely motoric disorder in which the child's inability to program the motor movements for speech lead to insufficient motor maps for specific sounds. According to Maassen, the lack of motor planning abilities is the cause of the language deficits seen in children with CAS.

A motoric foundation for CAS is ascribed to by others as well (Davis & Velleman, 2002; Marquardt & Sussman, 1991). Marquardt and Sussman (1991) argue that phonological input to the child's system from hearing and interacting in the world and motoric output in the form of babbling and speaking cannot be separated and are not mutually exclusive systems in development. They argue that the two systems work together to develop a whole system. This complete phonological system lays the groundwork for normal language development. Davis and Velleman (2002) agree that CAS is inherently a motoric deficit. While they concede that receptive and expressive language deficits are common among older school age children with CAS, they contend that the language disorders stem from problems with the production of speech. They propose that expressive and receptive language disorders should not be considered a diagnostic criterion for CAS but a concomitant symptom.

Crary's (1993) "motolingusitic" definition of CAS combines the theories of a motor and a linguistic etiology for CAS but essentially still subscribes to the idea that CAS is first and foremost a disorder of motor processing and programming. He noted that, "Developmental apraxias of speech are a group of phonological disorders resulting from disruption of central sensorimotor processes that interfere with motor learning for speech. Paralysis or weakness may be present, but it is not sufficient to account for the nature and severity of the observed speech disorder" (p. 12).

The literature continues to be contradictory, and more research is needed in order to address the issue of etiology fully (ASHA, 2007). Nevertheless, most experts agree that deficits in motor planning and programming are at the heart of CAS (Crary, 1993; Jaffe, 1984; Maassen, 2002; Strand, 1995). If this is true, treatments which address CAS from a motor planning and sequencing standpoint will target the disorder at its source. Of the motor treatments, integral stimulation therapy shows the most promise because of its effectiveness in treating CAS (Yorkston et al., 1999). No other motor or linguistically based treatments to date have been explored in systematic and controlled research to support that they are effective (ASHA, 2007).

Prevalence and Causation

While CAS is a complicated and multifaceted disorder which has seemingly increased in prevalence over the past few decades, the exact numbers regarding CAS are not known (ASHA, 2007). Several studies have cited figures for CAS including 1 to 2 per thousand of the general population (Shriberg, 1994) and 3.4% to 4.3% of the diagnosed speech sound disorders (Delaney & Kent, 2004). There is some evidence to suggest a genetic link for CAS (Belton, Salmond, Watkins, Vargha-Khadem, & Gadian, 2003; Lewis, Freebarin, et al., 2004; Shriberg, 1994). Belton et al. (2003) studied the brain matter of members of the KE family and discovered reduced grey matter bilaterally in the caudate nucleus, cerebellum, and the inferior frontal gyrus. According to the authors, differences in density in these particular areas of the brain are thought to be due to a defect in the FOXP2 gene. This gene defect can then manifest as deficits in speech and language functioning with signs and symptoms that point to CAS. Other speech sound disorders have also be seen in multiple generations of certain families. Lewis, Freebarin, et al. (2004) found that 86% of children diagnosed with CAS had at least one family member with a speech sound disorder.

Diagnostic Criteria

The term CAS has often been used to diagnose children with severe articulation disorders who fail to progress in treatment or have limited speech sound repertoires but with little regard to other diagnostic criteria (Forrest, 2003; Shriberg, 1994). This may be due to the confusion that surrounds differential diagnosis of CAS. In order to best treat CAS it is important to understand its etiology, signs and symptoms, and what characteristics separate it from other types of speech sound disorders (ASHA, 2007). Many signs and symptoms of CAS are similar to those used to diagnose other disorders such as dysarthria, speech sound delay, and phonological disorders. However, overlapping diagnostic criteria make assessment and treatment of CAS more difficult and confusing. Until recently no universal list of diagnostic characteristics existed for CAS (ASHA, 2007). To date there are no widely accepted or norm referenced protocols for diagnosing the disorder.

Clinicians may be forced to rely on outdated or incorrect information and unreliable diagnostic tests to determine if a child has CAS. Forrest (2003) conducted a survey study of 75 licensed SLPs in the greater Indiana area to determine the criteria most often used by SLPs to diagnose CAS. The results of the survey showed that 50 different criteria were listed by the various participants in the study. The most often cited symptoms were inconsistent productions, groping, general oral motor difficulties, inability to imitate, more errors as the utterance lengthened, and poor sequencing of sounds. These characteristics made up only 51.5% of the responses given. Other responses included vowel distortions, gross and fine motor difficulties, slurred speech, deviant phonological patterns, and reduced MLU. Some criteria given by the SLPs were in direct opposition to one another. For example, some participants listed problems with movements for speech without co-occurring problems for non speech movements while others listed problems with movements for both speech and non speech tasks. It is clear that professionals working in the field are lacking consistency when it comes to identifying CAS.

Over the course of this literature review inconsistent errors, groping behaviors, increased errors as utterances or words become longer, a reduced consonant and vowel inventory, vowel errors, prosodic errors, unusual phonological processes such as initial consonant deletion, backing and glottal replacement, slow progress in therapy, slow diadochokinetic rates, and nonverbal oral and limb apraxia were noted as signs and symptoms of CAS (ASHA, 2007; Ball et al., 2002; Crary, 1993; Davis & Velleman, 2000; Forrest, 2003; Forrest & Morrisette, 1999; Lewis, Hansen, et al., 2004; Maassen, 2002; Strand et al., 2006; Yorkston et al., 1999). This is clearly a long and varied list with many characteristics that overlap with those in other speech sound disorders (Shriberg, 1994). To make matters more confusing, a child may be diagnosed with CAS and not present with all or most of the signs and symptoms described above. The problem then becomes how to differentiate CAS from other speech sound disorders to most effectively treat it.

Differential Diagnosis

The ASHA (2007) position statement was developed after an exhaustive review of the literature by experts in the area of CAS from across the country. The statement is intended to quiet some of the confusion and controversy surrounding the diagnosis and treatment of CAS and provide clinicians with clear, evidence based guidelines for assessment and treatment of CAS. While the position statement acknowledges a lack of consensus regarding diagnostic markers for the disorder, it lists three characteristics most often cited in the literature which have the most evidence base. These include (a) inconsistent errors in the production of consonants and vowels at the word as well as the syllable level, (b) lengthened and disrupted transitions between words and syllables, (c) and inappropriate prosody (Aram & Nation, 1984; Ball et al., 2002; Betz & Stoel-Gammon, 1995; Crary, 1993; Davis, Jacks, & Marquardt, 2005; Davis & Velleman, 2000; Forrest, 2003; Lewis, Hansen, et al., 2004; Marquardt & Sussman, 1991; Shriberg, 1994; Smith, Marquardt, Cannito, & Davis, 1994; Velleman, 2006; Yorkston et al., 1999).

Inconsistent error patterns of children with CAS were studied by Betz and Stoel-Gammon (1995) who showed that children with CAS made more inconsistent errors than peers diagnosed with other speech sound disorders. Studies of vowel errors, although few, show that children with CAS have more variability in the duration of their vowel productions (Smith et al., 1994) and a persistence of vowel errors despite long term intervention (Davis et al., 2005). The literature regarding prosodic errors shows that in general, children with CAS make more timing errors, due in part to an increase in vowel duration, than typically developing peers (Beate & Stoel-Gammon, 2005). Timing errors may affect not only prosody, but disrupt the sequencing of sounds and the transitions between sounds and words. A study by Odell and Shriberg (2001) showed that children with CAS make more stress errors in conversational speech in the form of equal and excess stress than typical peers.

Although place of error (Thoonen, Maassen, Gabreels, & Schreuder, 1994) and language deficits (Aram & Nation, 1982; Ball et al., 2002; Lewis, Hansen, et al. 2004) have been proposed as other possible diagnostic criteria for CAS, no study to date presents enough conclusive evidence to support these claims (ASHA, 2007; Davis & Velleman, 2000; Forrest & Morrisette, 1999). More research is warranted in these areas. For the purposes of this study, the diagnostic criteria used to include participants will adhere to the ASHA recommendations.

Apraxia Treatment

While we are continually learning more about differential diagnosis for CAS, the literature regarding the efficacy of treatments for CAS is sparse. One is often referred to the literature regarding adult acquired apraxia of speech (AOS) when searching for treatment options for CAS. AOS can be caused by a variety of neurological insults to the brain including but not limited to stroke, tumors, and traumatic brain injuries (Brookshire, 2003, Freed, 2000). Like CAS, AOS is considered a motor speech disorder which results in difficulties with programming and sequencing the motor movements needed to produce volitional speech; however, large differences exist between the two disorders (Duffy, 2005). Time of onset for adults versus children is obviously different. Adults acquire the disorder through an insult to the brain and have a formerly intact linguistic system that treatment is attempting to tap back into (Maassen, 2002). Children with CAS have an innately defective system for learning the motor movements needed for speech. This may cause problems with language acquisition as well as academic difficulties in reading, writing, and spelling (Lewis, Hansen, et al., 2004).

Despite the differences between the two, adults with AOS often present with signs and symptoms which are similar to children with CAS, such as inconsistent articulatory errors, prosody errors, groping behaviors, sound substitutions, and increased amounts of errors as words or phrases become longer. Due to the similarities of symptoms and motoric nature of both disorders, treatment guidelines for CAS and AOS are often similar in nature (Bose & Square, 2001; Davis & Velleman, 2000; Marquardt & Sussman, 1991; Pannbacker, 1988; Strand, 1995; Velleman, 2006; Wambaugh, Duffy, McNiel, Robin, & Rogers, 2006).

A variety of approaches have been cited throughout the literature as possible treatments for CAS (Ballard, Granier, & Robin, 2000; Brookshire, 2003; Chumpelik, 1984; Caruso & Strand, 1999; Duffy, 2005; Marquardt & Sussman, 1991; Rosenbek et al., 1973; Sparks, 2001; Wambaugh, Kalinyak-Fliszar, West, & Doyle, 1998; Yorkston et al., 1999). Prosodic treatments such as Melodic Intonation Therapy (MIT) and metronomic pacing, Augmentative Alternative Communication (AAC), and articulatory and kinematic treatments such as prompts for restructuring oral muscular phonetic targets (PROMPT) and integral stimulation therapy have been cited as potentially effective means for treating apraxia of speech (Brookshire, 2003; Freed, 2000). Despite these many recommendations, relatively few studies have been conducted regarding efficacy of these individual treatments and even fewer have compared treatment approaches.

Augmentative and Alternative Communication devices (AAC) have been used to increase the communicative output and quality of communicative interactions of those with CAS and have given many individuals with communication disorders the opportunity and independence to interact with peers and family members in ways that they otherwise would not have been able to. Cumley and Swanson (1999) define AAC as, "the use of aided and unaided techniques that successfully supports natural speech attempts and facilitate the access and participation in communication interactions." (p. 111). Studies of AAC devices have been conducted in several cases related to CAS (Bornman, Alant, & Meiring, 2001; Culp, 1989; Cumley & Swanson, 1999), however, the main focus of these studies was on improving the participants' abilities to increase expressive language output, maintain topics during conversation, and repair communication breakdowns. Studies of AAC devices have not been used to increase intelligibility of speech production or to target the motor aspects of CAS.

Prosodic treatments like Melodic Intonation Therapy (MIT) aim to use the intact, right side of the brain to promote recovery of language abilities (Sparks, 2001). MIT was originally developed for use with severely aphasic patients and has since been adapted for use with other populations, namely adults with apraxia of speech (Freed, 2000; Sparks, 2001). MIT is a hierarchical, three-tiered treatment plan which involves the client practicing mono and polysyllabic words at the first two levels and eventually moving on to lengthier phrases and sentences in the highest level. Treatment begins with the clinician and client intoning key words and phrases in unison. The client is gradually moved toward exaggerated prosody, and finally to typical speech (Sparks, 2001). MIT is a treatment which focuses on expressive language and is not geared specifically toward speech intelligibility.

Efficacy studies for MIT are rare, and only three small treatment studies could be found which assessed MIT with children (Helfrich-Miller, 1994; Krauss & Galloway, 1982; Miller & Toca, 1979). Across these three studies only 6 children were assessed. Five of the 6 were diagnosed as having CAS (Helfrich-Miller, 1994; Krauss & Galloway, 1982), and the other child was diagnosed with autism (Miller & Toca, 1979). None of the studies cited outlined the exact MIT treatment plan used and all included at least one other treatment besides MIT during the course of the study. While increased speech intelligibility and a decrease in articulation errors were reported in all studies, the lack of data regarding treatment protocols, implementation of alternate treatments, and natural maturation of the participants cannot conclusively prove that MIT was responsible for the changes seen (Roper, 2003).

A large study by Popovici and Mihailesci (1992) assessed the efficacy of MIT with 80 adults with a combined aphasia and bucco-lingual apraxia of speech. A control group of 80 other aphasic-apraxic patients were given other non-specified treatments. Results indicated that all participants improved in their language goals, but that those in the MIT group showed greater improvement in language skills such as naming and repetition of words and sentences. A lack of data regarding the severity of the participants' apraxias, pretreatment assessment measures, exclusionary criteria, and information on the treatments implemented with the control group leave questions as to the reliability of the data. While textbooks may propose MIT as a viable option for treating AOS and CAS (Brookshire, 2003; Freed, 2000), there are no data in the literature to suggest that MIT is efficacious for remediating speech sound errors or improving intelligibility in the CAS population.

Articulatory and kinematic treatment methods are a cluster of treatments which focus on the motoric practice of speech sounds and often involve modeling, repetition, and various forms of tactile, visual, and verbal cues (Wambaugh et al., 2006). Prompts for restructuring oral and muscular phonetic targets (PROMPT), many vowel therapies, and integral stimulation therapy fall under the category of articulatory and kinematic treatments (Wambaugh et al., 2006). The motor planning and sequencing deficits seen with CAS result in poor execution of speech sounds and poor intelligibility. These treatments make the most sense as far as treatment options because they target articulation and motor planning specifically and intensely (ASHA, 2007). PROMPT, vowel therapy, and integral stimulation are discussed in detail below.

PROMPT is a touch cue treatment developed by Chumpelik (1984). In this therapy, each phoneme is assigned its own unique touch cue. The rationale of the treatment is that the touch cues provide kinesthetic feedback to the brain regarding the appropriate placement of the articulators as well as voicing cues needed for each phoneme. Timing of the prompts given by the clinician are important when moving from syllable to syllable or between words. The clinician using PROMPT decides when and how often to cue the patient. Stress is prompted through variations in the firmness of pressure applied during the prompt.

Originally developed as a treatment for CAS, PROMPT has also been adapted for use with adults with AOS (Freed, Marshall, & Frazier, 1997). The limited research regarding the efficacy of PROMPT for children with CAS cites some improvement of speech intelligibility, transfer of speech targets to untrained words, and a change in the production of target words after being treated with the PROMPT system (Chumpelik, 1984; Chumpelik & Sherman, 1980; Chumpelik & Sherman, 1983). Small study sizes and few studies which show replication of results leave questions as to the true efficacy of the PROMPT system.

While the PROMPT system does indeed target articulation and aim to improve intelligibility of those with CAS, there are several disadvantages to this treatment. PROMPT not only takes many hours of training to be certified in its application but requires many more hours of practice on the part of the clinician to become proficient at implementing the various cues. Therefore, it may not be a viable or affordable option for many clinicians. The individual prompts for each phoneme can become complicated, requiring multiple steps to implement depending on the phoneme's place in a word or sentence and co-articulatory considerations. The clinician may also need to cue voicing, stress, or mouth positioning for vowels. Another potential difficulty in using this treatment is the requirement that the clinician touch the face and neck of the client. Varying levels of comfort on the part of the clinician as well as the client may make this difficult. As with other recommended treatment approaches, PROMPT has little research evidence to suggest its efficacy in treating CAS (Chumpelik, 1984; Chumpelik & Sherman, 1980; Chumpelik & Sherman, 1983).

While vowel errors are an unusual but persistent characteristic of CAS, vowel treatments are generally hard to find in the literature. One vowel treatment study out of the United Kingdom (Reid, 2003), although not specifically targeted toward CAS, produced promising results. Twenty-five children classified as having a Specific Language Impairment (SLI) participated in the study. All participants presented with deficits in phonological awareness and correct production of vowels. The children participated in designing a "child-friendly representational framework for vowels" (p. 158) to help them visualize vowel placement within the mouth and create a concrete representation of an abstract phonetic concept. Each vowel was given a representative picture symbol, name, color, and living space within the vowel house.

Treatment included vowel discrimination tasks, spelling, tasks, and segmenting vowels out of spoken words. All treatment tasks we used in conjunction with the visual representation of the vowel house that the children had developed. Treatment was implemented over the course of the school year on a weekly basis, and all children made gains during the year. Positive aspects of the study include the fact that treatment was intensive, long term, conducted in a natural environment, and was meaningful to the children because of their participation in designing the vowel house. Whether or not this phonological treatment for vowels would be beneficial for children with apraxia of speech whose vowel errors are due to motoric difficulties producing speech remains to be seen. More research is warranted.

Integral stimulation therapy

Integral stimulation therapy is a motor-based, hierarchical, speech sound treatment which incorporates the principles of motor learning and is designed to target the specific motor deficits seen in apraxia of speech (Freed, 2000). Originally designed for use with adults with AOS (Rosenbek et al., 1973), integral stimulation has been adapted and implemented with children with CAS (Strand & Debertine, 2000; Strand et al., 2006). Rosenbek and colleagues (1973) outlined an eight step continuum which incorporated the principles of motor learning into a treatment called integral stimulation therapy. Originally, three adults with severe apraxia of speech were treated using integral stimulation therapy. The treatment plan included principles of therapy such as organizing treatment goals and activities from easiest to hardest, keeping the client successful in order to motivate them, intensive drill work, and the use of functional targets. Principles of motor learning such as conditions of practice were also emphasized. A hierarchical, bottom up approach to the practice of treatment targets is one of the main components of integral stimulation therapy (Rosenbek et al., 1973).

The hierarchy can be used in a variety of ways, including beginning treatment with the easiest speech targets and moving the client on to more challenging sounds, as well as varying the length of stimuli practiced in a hierarchical fashion. Targets can be practiced at the syllable, word, phrase, or sentence level. The client may be moved up and down the hierarchy depending on the amount of support needed and level of success achieved. Multi-modal cueing techniques are to be used in a hierarchical fashion as well. Integral stimulation incorporates auditory, visual, and tactile cues into the practice of speech sounds. These cues can be used together to provide maximal cueing to the client and be reduced when less support is needed (Rosenbek et al., 1973). To fully understand integral stimulation therapy, one must understand the principles of motor learning. Following is a summary of the principles of motor learning and how they relate to integral stimulation therapy.

Motor learning. Cognitive motor learning is a set of principles designed to most efficiently and effectively facilitate the learning of a new task (Schmidt & Wrisberg, 2004). These principles have generally been used with limb motor learning and to aid elite athletes in refining their skill sets (Keetch, Schmidt, Lee, & Young, 2005). Because the act of speaking is ultimately a motor task, these principles have been incorporated into various treatments for speech sound disorders including integral stimulation therapy (Rosenbek et al., 1973; Strand & Debertine, 2000). The cognitive motor learning literature distinguishes between motor performance and motor learning. Motor performance is the accuracy of in-session performance while motor learning is how the client transfers that knowledge or generalizes skills outside of the practice session (Schmidt &Bjork, 1992). Schmidt and Wrisberg (2004) define motor learning as, "…an internal process that reflects the level of an individual's performance capability for producing a particular movement" (p. 249). The ultimate goal of cognitive motor learning is the generalization of skills to novel situations. This is an indication of true learning and is achieved using the four main tenets of cognitive motor learning; (a) precursors to motor learning, (b) conditions of practice, (c) feedback, and (d) influence of rate. Each of these principles is defined in the following paragraphs.

Precursors to motor learning. Precursors to motor learning refers to concepts that should be established with the client before treatment begins. Trust is an integral part of any clinician/client relationship. The client must trust that the clinician has their best interest at heart, that they are well versed in the treatment, and that the clinician has professional as well as research-based knowledge which shows that this is an effective treatment approach. In addition, precursors to motor learning include informing the client that the goal of the treatment is to practice the movements necessary for speech. It is also important that the client fully understand the tasks and procedures being implemented and why. Finally, the client must be focused and motivated to change. Motivation is key to any treatment plan, but especially to integral stimulation therapy (Rosenbek et al., 1973). This treatment may not be appropriate for clients with cognitive impairments and those who are unable to self monitor or fail to comprehend the task at hand. Once the precursors to learning are in place, treatment can proceed.

Conditions of practice. After the clinician has established trust and a rapport with the client, explained the reasons for treatment, and assessed the motivation of the client, conditions of practice can be determined. Conditions of practice include repetition, blocked vs. random practice, mass vs. distributed practice, and variability of practice (Ballard, 2001; Duffy, 2005; Schmidt & Wrisberg, 2004; Strand, 1995; Yorkston et al., 1999). Repetition is key to motor learning. Hundreds of repetitions per session are required in order to help the client establish the motor movements needed for speech.

Blocked vs. random practice. Both blocked and random practices are important to motor learning and are effective at different times in the learning process (Schmidt & Bjork, 1992). Blocked practice is a type of practice in which one target is practiced at a time. In limb learning it may be that one action (such as a free throw) is practiced over and over to establish the skill. In articulation treatment it means that one phonetic target is practiced at a time. In random practice, all targets are practiced within the same activity. Blocked practice has been shown to produce better in-session results, motor performance, while random practice may produce lower in-session results but leads to better generalization, motor learning, outside of the session (Schmidt & Wrisberg, 2004). Both types of practice are valuable for different reasons. Blocked practice may be necessary for establishing a new target. For instance, when the client is first learning a new skill, blocked practice provides repetitive and numerous opportunities to practice the motor movements necessary to acquire the skill.

Random practice becomes important for generalization of the skill to novel contexts and promotes learning (Schmidt, Young, Swinnen, & Shapiro, 1989; Swinnen, Schmidt, Nicholson, & Shapiro, 1990; Wulf & Schmidt, 1989; Wulf & Schmidt, 1997). Random practice more closely mimics real life situations in which the client will be using all phonemes at the same time to communicate in conversational speech. For a child with CAS, blocked practice will be important when introducing a new speech target into their repertoire. Providing multiple and specific opportunities to practice the new target will facilitate the acquisition of the target sound. Random practice will become important when the child with CAS is ready to use that newly acquired sound in the context of a phrase, sentence, or conversational speech and generalize the skill to novel contexts. In the context of integral stimulation therapy, both blocked and random practice may be used within the same treatment session and within the same activity in a hierarchical fashion depending on the level of support the child needs.

Blocked versus random practice has generally been studied with limb learning (Schmidt & Bjork, 1992; Schmidt & Wrisberg, 2004; Wulf & Schmidt, 1997) however, one study by Knock, Ballard, Robin, and Schmidt (2000) assessed random versus blocked practice of speech sounds. An alternating treatments design study involved 2 participants with acquired apraxia of speech (AOS) secondary to aphasia. The study measured the participants' abilities to generalize learned speech sounds to novel words trained with either blocked or random practice. In post-treatment probes both participants had greater retention of targets trained randomly than those trained with blocked practice. The results of this study are promising for adults with AOS and have the potential to be adapted for use with children with CAS.

Mass vs. distributed practice. Along with varied types of practice, children with CAS need massive amounts of practice to aid their learning of the motor plans needed to produce intelligible speech (ASHA, 2007). Mass vs. distributed practice refers to the time allotted for each session. An example of mass practice is one 60 minute session a week. Distributed practice would be several 30 minute sessions over the course of the week. Distributed practice has been shown to be an effective measure for increasing not only the amount of repetitions of speech targets produced in a given week, but it has been shown to lead to greater learning (Strand & Debertine, 2000; Strand et al., 2006). In the current health care climate, three or four treatment sessions a week may not be a feasible or affordable option for clinicians or families. If several sessions a week are not feasible, other aspects of motor learning can be implemented to increase learning.

Variability of practice. Variability of practice in and out of the clinic room can be implemented to promote learning (Schmidt & Bjork, 1992; Wulf & Schmidt, 1997). Variability of practice is important for promoting generalization not only to novel versions of speech sound targets but to novel situations in which those targets may be used (Wulf & Schmidt, 1997). For clinicians using integral stimulation therapy, variability of practice may mean asking the client to practice speech targets in varied places within words, phrases, or in conversational speech. Targets may be practiced in one or many syllable words, at the beginning, middle, or end of words, and in phrases with co-articulatory features. Variable practice of target sounds ties back to the treatment hierarchies outlined in integral stimulation therapy. The clinician can modify practice of a speech sound by scaling practice down to the syllable level or, if the client has been successful and needs less scaffolding, the clinician can move up the hierarchy and ask the client to practice speech targets in words, phrases, or sentences.

Variability of practice may also come in the form of treatment sessions taking place outside of the clinic room in real life, functional settings. Families may vary practice by taking an active role in incorporating the practice of speech sounds into their everyday lives and routines. Conditions of practice do not need to be consistent in order for an individual to acquire a new skill in a timely fashion (Schmidt & Wrisberg, 2004). Variability of practice promotes generalization and learning more effectively than consistent practice in which the environmental and practice conditions are always the same (Wulf & Schmidt, 1997).

Feedback. Conditions of practice are an important factor in the learning and generalization of new skills, but motor learning also requires that the individual learn to monitor their own performance under different practice conditions through the use of feedback (Ballard, 2001; Duffy, 2005; Schmidt & Wrisberg, 2004; Schmidt et al., 1989; Swinnen et al., 1990; Wulf & Schmidt, 1989). There are two types of feedback associated with motor learning; intrinsic and extrinsic. Extrinsic feedback is information and critique which comes from the clinician or instructor regarding the client's task performance. Two levels of extrinsic feedback include knowledge of results and knowledge of performance. Knowledge of results refers to the clinician telling the client whether the production of a speech sound was correctly articulated or not. Knowledge of performance involves specific comments from the clinician regarding what the client did with their articulators, voice, or rate that led to the correct production of the target.

Both types of extrinsic feedback are valuable and helpful during the learning process (Schmidt & Wrisberg, 2004). Knowledge of results feedback on every trial may lead to faster acquisition of the target, but feedback that is systematically faded over time leads to greater retention and generalization to novel situations of a learned motor sequence (Wulf & Schmidt, 1998). Schmidt et al. (1989) conducted a study which looked at the effects of the amount of extrinsic feedback given during the learning of a motor task. Knowledge of results (KR) after every practice trial did indeed lead to faster acquisition of a motor task, but the group which received KR after every 15 trials in the acquisition phase performed statistically better on the delayed retention tasks.

Intrinsic feedback is information or critique which comes from the client's own assessment of their performance. This intrinsic feedback helps the client to develop self monitoring abilities. The ability to monitor one's own productions leads to self awareness and the ability to analyze and correct one's productions leads to true learning (Schmidt & Wrisberg, 2004).

To promote self evaluation and awareness, feedback must be faded over time. This allows the learner time to process and evaluate their performance. Feedback is most effective in promoting self monitoring when it is given in 30% to 60% of trials (Ballard, 2001; Duffy, 2005). Delayed feedback of between 3 and 4 seconds allows the client to assess his or her performance in order to self-correct.

Immediate feedback from the clinician may prevent the client from self evaluating and lead to poorer retention of learned skills post-treatment (Swinnen et al., 1990).

Rate. The last principle of motor learning is the influence that rate has on learning a task. Reduced rate is generally thought to reduce the mental load on the client and provide adequate processing time (Caruso & Strand, 1999; Strand, 1995; Wambaugh et al., 2006). The downside of reduced rate is that prosody may be affected (Duffy, 2005). The goal for the clinician is to slow the target utterance down enough to lighten the mental load for the client. As the client becomes more successful at producing the utterance at the slower rate, the clinician can slowly begin to increase the utterance rate until it is similar to that of conversational speech (Duffy, 2005; Caruso & Strand, 1999). The manipulation of rate is tied to the hierarchical nature of integral stimulation therapy in that the clinician modifies rate in accordance with the level of support that the client needs to successfully produce the target. Concepts of motor learning have been shown to be effective methods for promoting learning and generalization of motor movements (Schmidt & Wrisberg, 2004). Motor planning and processing disorders such as CAS require treatments which address these specific deficits (ASHA, 2007; Ballard et al., 2000; Davis & Velleman, 2000; Strand, 1995; Velleman, 2006; Yorkston et al., 1999).

Research on integral stimulation therapy

While integral stimulation therapy shows great promise for treating apraxia of speech because of its focus on specific and intense motor practice of speech sounds, there is little research which assesses its efficacy for children with CAS (ASHA, 2007). Although AOS and CAS are different disorders, the similarities of their presenting characteristics suggest that effective treatments for AOS can be adapted for use with CAS. Aspects of integral stimulation are often combined with other treatment approaches in the adult literature (Knock et al., 2000; Wambaugh et al., 1998; Wambaugh, Martinez, McNiel, & Rogers, 1999; Wambaugh, West, & Doyle, 1998).

A study from the adult literature on AOS which combined articulatory placement cues from integral stimulation therapy and minimal contrast pairs was conducted by Wambaugh, Kalinyak-Fliszar, et al. (1998). Three males with a severe aphasia and apraxia of speech were treated using cueing techniques such as modeling of the target sounds, visual cue cards, and tactile articulation cues. During each of the steps the participant was told by the clinician to, "watch me, and do what I do." All participants made gains in the accurate production of trained sounds. While the data showing gains in trained sounds and words is important, the question of generalization to untrained exemplars always lingers.

A case study by Wambaugh, West, et al. (1998) assessed response generalization of speech sounds across untrained exemplars for an adult woman with aphasia. The treatment incorporated the integral stimulation techniques: "watch me, and do what I do," response contingent feedback, modeling, visual cueing in the form of written cue cards, and multiple opportunities to practice the targets. Several classes of targets were trained at the same time in a random practice fashion at the sentence level. Accuracy of articulation improved rapidly for each sound class targeted once treatment was started. Generalization to untrained sentences was noted, although not to the same extent as the trained exemplars.

While studies of integral stimulation therapy for adults with AOS show promise, they should not replace or be equated to studies of integral stimulation for CAS. More data are needed to show that integral stimulation is an effective treatment for CAS (ASHA, 2007; Strand & Debertine, 2000). There has been little research on the effectiveness of the exclusive use of integral stimulation for children. Marquardt and Sussman (1991) looked at a multitude of treatment approaches for a 10-year-old child with CAS. Several of the treatments incorporated components of integral stimulation therapy into other treatments. Treatment approaches used over the 10 semesters of the study included a sensory motor approach, a multiple phoneme approach, phonological process remediation, melodic intonation therapy, and traditional articulation treatment. While one could argue that too many treatments were used with this child and none were given enough time to be effective considering the slow progress of children with CAS, there were some general treatment guidelines which showed promise. For this particular child, auditory and visual cueing together in the form of “look and listen” cues as well as written cues were more effective than auditory stimulation alone. Nursery rhymes that emphasized stress and rate were successful at reducing prosodic abnormalities. Articulation treatment in the tradition of Van Riper which targeted a single consonant at a time was less effective. All aspects of their treatment that were found to be effective are parts of integral stimulation therapy and can be used as guidelines for future study.

Several unpublished studies and master’s theses with small numbers of children with CAS have shown integral stimulation to be a beneficial treatment

(Berman, Garcia, & Bauman-Waengler, 2007; Jakielski, Webb, & Gilbraith, 2006; Jensen, 2005). Jensen (2005) treated 1 male child with CAS with integral stimulation over a period of 15 weeks. The child's accuracy of productions of consonants and vowels increased over the course of treatment, and his overall intelligibility rose by 5%. Jakielski et al. (2006) treated 3 siblings with CAS. All children were essentially non-verbal at the beginning of the study. By the end of the treatment phase, all children showed improvements in the ability to accurately produce sentences targeted in treatment.

Two published studies to date have been dedicated solely to determining the efficacy of integral stimulation therapy for children with CAS (Strand & Debertine, 2000; Strand et al., 2006). The study by Strand and Debertine (2000) was a single subject design with one 5-year-old female with CAS. A limited set of functional phrases were trained according to the principles of integral stimulation therapy and motor learning. The child was seen in short blocks of time 4 days a week. Multiple opportunities to practice the movements for speech were used as well as various modes of cueing. Improvement in intelligibility was seen for all targets treated.

The second study by Strand et al. (2006) used principles of integral stimulation in combination with a multi-modal cueing system. The single subject design included 4 male participants with CAS. The children were seen two times per day 5 days a week for 6 weeks. Again, a small number of functional phrases were trained, and the parents of the participants were asked to practice target sounds at home each night. All participants were non-verbal at the outset of the treatment. By the end of the 6 weeks, 3 out of 4 participants showed marked improvement in speech intelligibility. Some generalization effects were seen as well. Although these two small studies and a handful of unpublished studies and theses are the only data available to suggest the efficacy of integral stimulation for children with CAS, the results showing improved intelligibility and generalization are promising. More research is needed with larger groups of participants in order to generalize the findings of these studies.

As far as best practices for children with apraxia, the ASHA position statement recommends treatments based on the principles of motor learning as well as those that use varied cueing and modeling techniques be implemented in cases of CAS (AHSA, 2007). ASHA recommends that treatment sessions be intensive, individual, brief sessions, three to five times per week. Integral stimulation therapy is the only treatment approach which incorporates all of the recommended guidelines laid out by ASHA for treating children with CAS. This study will look at the efficacy of integral stimulation therapy for remediating the speech sound errors of three children with suspected CAS.

While the limited data on integral stimulation has shown it to be effective for treating CAS, it is unknown as to whether one aspect of the treatment is more efficacious than another for remediating speech sound disorders (Strand et al., 2006). The author believes that all components of integral stimulation are effective for treating motor speech disorders. It was theorized, however, that the intensity and frequency of repetition of speech sound production is the key to attaining more accurate in-session productions, increased intelligibility, and generalization of skills for children with CAS. This study explored the variable of frequency of repetition in relation to integral stimulation therapy. Two variations of the same treatment were used. Treatment A used integral stimulation techniques such as "watch me, and do what I do", multimodal cueing, and principles of motor learning, but elicited few (30 to 40) repetitions of each target speech sound during a treatment session. Treatment B used all of the aforementioned integral stimulation techniques but elicited 100 to 150 productions of each speech sound target in the same time frame. The hypothesis of the study was that the participants would show greater in-session production accuracy of the speech sounds treated with Treatment B (100 to 150 repetitions) as well as greater generalization of treated sounds to untrained words than sounds treated with Treatment A (30 to 40 repetitions).

Methods

Design

An Alternating Treatment A-B design was used for this study. Alternating treatment designs compare the efficacy of different treatments across behaviors. In this study, two treatment protocols were implemented across 3 participants. Each treatment was used in each session in a random order determined before the session began. Specific speech sounds were randomly assigned to each treatment, and the speech sound was treated only with its assigned treatment plan over the course of the study. For example; if /s/ and /t/ were the targeted speech sounds, /s/ would always be treated with Treatment A and /t/ would always be treated with Treatment B. The particular sounds assigned to the treatment were randomly assigned. All aspects of the two treatments were the same except for the frequency of repetition variable. All other integral stimulation techniques were used in both treatments. These included blocked and random practice of speech sounds, feedback, self-monitoring skills, variability of practice, the “watch me, and do what I do” technique, and multimodal cueing. Frequency of repetition of speech sounds elicited was the only variable altered between the two treatments. In Treatment A, integral stimulation was used, but only 30 to 40 productions of the target were elicited over the time that Treatment A was implemented in the session. In Treatment B, the same integral stimulation techniques were used but target sounds were elicited between 100 and 150 times over the course of the time that the treatment was implemented in the session. Probes were administered in a drill fashion at the conclusion of each of the treatment phases. Probes consisted of words with the targeted speech sounds. Probes were used to determine whether generalization had occurred to non-trained words and word positions.

Data were obtained and analyzed for all sessions and all phases of the study including pre-treatment, baseline, treatment, and post-treatment. Baseline sessions were conducted until stability or a downward trend was noted for each speech sound target. For all participants baseline sessions were conducted over three or four sessions. Treatment occurred between 6 and 12 weeks, with two to three sessions per week depending on the participant. Participants were seen at the time of day that was convenient for their families, and that time was consistent across the study. JG was seen at either 1:00 or 1:30 for every session. JS was seen at either 11:00 or 11:30, and AG was always seen at 3:30. After the conclusion of the study, a 2 week break was taken during which time the participants did not receive speech therapy of any kind. Maintenance data in the form of a standardized articulation test, a language sample, and probes were collected after the break from treatment.

Participants

Participants for this study were 3 male participants. All had previously been given a diagnosis of suspected Childhood Apraxia of Speech (CAS). Two were recruited from the Portland State University Speech and Hearing Sciences outpatient clinic, the other was recruited from a private clinic in the Portland metropolitan area. Families received a letter outlining the goals of the study and were asked to sign permission for their child to participate. The participants were also asked to sign a “Child Informed Consent” document that they agreed to participate in the study (see Appendixes A and B for the full forms). The parent or guardian of each child was also asked to fill out a family and medical history questionnaire. All children were in good health prior to participating in the study. Socioeconomic status was not taken into account for this study.

Each participant was administered the Goldman-Fristoe Test of Articulation Second edition (GFTA-2; Goldman & Fristoe, 2000) and either the receptive portions of the Clinical Evaluation of Language Fundamentals Preschool-Second Edition (CELF Preschool 2; Wiig, Secord, & Semel, 2004) or the receptive portions of the Preschool Language Scale (PLS-4; Zimmerman, Steiner, & Ponds, 2002) to obtain baseline articulatory and receptive language scores. A play based speech sample was collected from participants using toys or topics of interest to each child to assess intelligibility in running speech, to gather a speech sound inventory, and to perform an error pattern analysis. A Percent Consonants Correct (PCC) measure was calculated for all consonant sounds produced during the speech sample. All testing took place at the Speech, Language, and Hearing Clinic at Portland State University.

Treatment targets were chosen based on GFTA-2 scores, developmental appropriateness of the speech sound, and stimulability. Treatment began for each participant in the session after stable baseline measures were obtained. Results of each participant's pre-treatment test scores are reported in the results and discussion section to follow. Each participant's developmental history and reasons for inclusion in the study are outlined in the following paragraphs.

Participant 1, JG. At the beginning of the study JG was a 6 year 2 month old boy. He had been adopted from China at the age of 26 months. JG was born with a cleft lip and palate, and at the time of the adoption his lip had been repaired but the palate had not. His palate was repaired shortly after arriving in the United States at 27 months. His parents reported that he was a happy toddler who seemed to grow in every way but speech and language development. He began to see a private speech-language pathologist just after the repair of his palate. This therapist worked with JG for 2 years with limited success and informed his parents that he may be apraxic. He also received early intervention services from the Northwest Education Service District (NW ESD) until he entered Kindergarten. His private speech-language pathologist referred him to the PSU Speech and Hearing Clinic to be assessed for Childhood Apraxia of Speech.

JG had been receiving speech services in the PSU Speech, Language, and Hearing Clinic for one term in the fall of 2006 before this clinician first began working with him. From the winter of 2007 until spring of the same year, this clinician worked with JG using integral stimulation techniques. During this time he was also receiving speech services from a private SLP in the greater Portland metro area. After the spring of 2007 JG went on to work with two other student clinicians at PSU before being recruited to participate in this study.

JG was recruited into the study because of his severe speech sound disorder which had many characteristics of CAS. Upon first meeting JG at the age of 5, the lack of speech sounds in his repertoire was remarkable. He produced few vowels and the phoneme /m/ only. JG was not given a diagnosis of CAS right away, but after working with him for 6 months, it became apparent that he had many of the characteristics of a child with profound CAS (ASHA, 2007). During treatment sessions JG was noted to make inconsistent errors of consonant as well as vowel sounds at the word and syllable level. Errors often included substituting glottal stops for the target phoneme, omission of the target, or substitution of another sound. He had great difficulty sequencing individual sounds into words and at times even syllables. His prosody was affected, possibly due to his inability to sequence, and the result was a halting and uneven sounding production.

During the course of this study JG was also receiving language focused treatment through the use of an AAC device. He participated in the AAC treatment one time per week for a total of eight sessions over the course of the term. The language treatment included work on story grammar, syntax, turn taking, and topic maintenance skills. No articulation or speech treatment of any kind was administered during the course of the AAC treatments, and all AAC treatments took place after his normally scheduled treatment session with this clinician. It was decided that because the two treatments were so different and there was little chance of overlap in treatment goals, his participation in the AAC treatment would not affect his participation in this study.

Participant 2, JS. JS was 3;7 at the start of the study and was recruited from a private speech clinic in the community. The speech-language pathologist with whom he had been working recommended him for the study due to his lack of progress over the year that she had been treating him, his reduced phonemic repertoire, and his difficulties sequencing individual sounds into words. JS's parents reported that he had only recently begun to make progress in therapy, within the past 3-4 months. According to parent interview, JS never babbled and did not speak his first word, “bye”, until he was 3 years old. At the point of his participation in the study, he was reported to have a vocabulary of between 15 and 30 words. All other motor milestones were reportedly met in a timely fashion. JS was reported to have taught himself all the sounds of the alphabet as well as numbers up to 10. Despite his knowledge of the sounds of English, he was unable to sequence sounds together to create words.

JS was recruited into the study partially on the recommendation of his speech-language pathologist and partially because during the first meeting with him, he presented with several of the signs and symptoms of CAS. The most notable sign was his odd prosody which sounded almost robotic in nature. While he knew every sound and could produce them individually, JS had difficulty sequencing sounds together to form words. JS did not present with inconsistent errors in either consonant or vowel productions at the time of the evaluation.

JS participated in the study for a total of 5 weeks at which time it was determined that he was not an appropriate participant for the research project because it was felt that integral stimulation therapy was not addressing his communication deficits. The decision to leave the study was discussed with JS’ family and all parties were in agreement with the decision. A more in-depth discussion of JS and the decision to terminate his participation in the study is discussed later in the results and discussion sections.

Participant 3, AG. AG was 3;4 when he began participating in the study and was recruited from the PSU Speech and Hearing Clinic. This was AG’s first term in the clinic but he had been receiving Early Intervention Services since he was referred by his physician at 18 months of age. He was currently enrolled in a Head Start classroom where he also received speech services. These services were suspended during the course of this study. AG's mother reported that AG babbled normally and spoke his first word at around one year. All other motor milestones were reached within a typical time frame as well. She reported that after the acquisition of his first word, he failed to gain more words and in general does not speak very often at home or with others. She noted that when he did speak, it sounded like jargon with adult like inflection and babbling. AG's mother reported that there is not a family history of speech sound disorders; however, AG's older brother was also being seen at the PSU clinic for a severe speech sound disorder. AG had no history of ear infections or other major illnesses as a child.

The most marked sign in AG's speech for a possible diagnosis of CAS was the disrupted transitions at the word and syllable level. He had great difficulty combining sounds to form words and was often heard to delete consonants or substitute other sounds for the target. His prosody fell within normal limits and his errors were more consistent in nature than not, possibly due to a sound preference for the phoneme /d/. While it was unclear during AG's evaluation if a diagnosis of CAS was appropriate, this clinician felt that his difficulty sequencing sounds as well as his severely reduced speech sound inventory were sufficient to warrant inclusion in the study.

Materials

Assessment materials included the Goldman-Fristoe Test of Articulation second edition (GFTA-2; Goldman & Fristoe, 2000). Expressive and receptive language was assessed through the Clinical Evaluation of Language Fundamentals Preschool-Second Edition (CELF Preschool 2; Wiig, Secord, & Semel, 2004) or the Preschool Language Scale Fourth Edition (PLS-4, Zimmer, Steiner, & Ponds, 2002).

Treatment sessions included the use of toys that were of interest to the child such as pretend play items, blocks, doll houses, puppets, books, and games. An apraxia flip book which pictures a girl making speech sounds and small mirrors were used for visual cueing (Perkins-Faulk & Priddy, 2005). Tracking sheets were used by the clinician to keep a tally of the number of speech sounds elicited in each treatment phase. All sessions were video taped or audio taped. Video taping was done with a Sony DCR PC-101 digital camera and taped on Sony Mini Digital Video Cassettes. Audio taping was done using a Sony TCM-20DV standard cassette recorder.

Treatment Procedures

Treatment order was randomized for every session. Treatment A and B were written on index cards. The cards were mixed up, and one card was randomly chosen by the clinician before each session. The card chosen was given the first treatment slot within the session. The second treatment was assigned to the second treatment phase. Sessions were generally set up in two 15 minute blocks of time with 5 minutes at the end of each treatment slot for the probes to be administered. The speech sounds assigned to each treatment were practiced in various play activities, and data were tracked for all activities and all sessions. Treatment sessions were designed to be fun for the child, but with the understanding that they were there to work on the correct productions of speech sounds.

For both treatment conditions, principles of motor learning were addressed through blocked and random practice, distributed practice, variability of practice, feedback, and attention to rate. Blocked practice was used when the child was acquiring a new speech sound. Blocked practice was completed by the clinician asking the participant to repeat the target sounds at the syllable level only for the entire session. No practice of other speech sounds was done during blocked practice sessions. Random practice was used when the parameters for the speech sound had been acquired and the target was then being practiced in various words, phrases, or sentences. Once random practice was implemented, both types of practice were used in the session in a hierarchical fashion depending on the accuracy of productions of speech targets. The decision to transition from blocked to random practice was made using clinical judgment of the readiness of the participant to move on and their success rate with the current level of support. Blocked practice and random practice were used in a simultaneous, hierarchical fashion. For example, if the child was practicing several speech targets at the phrase level, random practice, and did not correctly articulate one or more of the targets, blocked practice was implemented. The participant would be asked to practice the errored sound alone in a consonant vowel (CV) combination without articulating the rest of the phrase. Once accuracy had been re-established for the sound in isolation, random practice of all sounds was resumed at the phrase level.

Distributed practice was achieved through shorter sessions more times a week and by asking the families of the participants to participate in home practice of target sounds. Home practice was meant to be functional and part of the family's daily routines rather than a structured time set aside for practice each night. For example, families were asked to think of times during the day when they could draw attention to target sounds by pointing them out during reading or on written materials in the environment such as street signs. They were also asked to over-emphasize the target sounds in their own speech. Finally, they were asked to think of daily routines in which they could practice speech sounds, such as counting items during play or when setting the table. Each family brainstormed with the clinician to identify times and activities for home practice.

Two of the 3 participants were seen by the clinician for 40 minute sessions three times a week. AG, the 3rd participant, was seen by the clinician for 50 minute sessions two times a week. Variability of practice was achieved through the use of varied activities which targeted the same speech sounds as well as practicing speech targets at different places within words and phrases. Feedback was given on 30% to 60% of trials. Feedback was specific and aimed at providing information to the participant about the quality and accuracy of the production. Rate was slowed when articulation of a target sound was inaccurate or prosody was deemed to be in error. Once correct articulation was re-established, rate was increased to appropriate conversational levels.

Integral stimulation techniques were addressed in both treatment conditions through the use of the "watch me, and do what I do" technique and implementing cues in a hierarchical fashion. The cues used were implemented simultaneously as integral stimulation therapy suggests and were faded as needed.

Cues used included auditory, visual and tactile input. Auditory cues included the child hearing the clinician say the target word first, choral speaking, and the child receiving auditory feedback from their own production of the target. Tactile or touch cues were developed with the child for each speech sound being targeted. When necessary, the clinician placed touch cues on the child's face to shape his mouth for the speech sound being targeted. Several different visual cues were used, the first being the child watching the clinician say the word. Another was the child watching themselves say the word in a mirror. The third visual cue was a picture flip book which was used when the participant needed a higher level of cueing from the clinician. The spiral bound flip book is a picture book containing five sections. Each section has all of the phonemes of English represented on cards which depict a little girl making the sound. The target sound is also written below each picture. Target words can be phonemically "spelled" out using the flip book.

Clinical judgment was used to determine the level of cueing the participant needed. If the speech sound being targeted was new, the clinician provided multiple forms of cueing including visual, tactile, and auditory. If the target was one that had been previously produced correctly by the child using more support, the clinician began to reduce the level of support and implement fewer cues. If the child correctly articulated the target sound in isolation with the least amount of support, the sound would then be practiced at the word or phrase level. If the child did not correctly articulate the target, the clinician added more cueing support until the sound was correctly articulated.

Each of the treatment techniques described above were incorporated into every activity and both treatment conditions. The various cues were implemented in a hierarchical fashion and used in addition to the principles of motor learning. For example, both random and blocked practices were used within the cueing hierarchy. If the participant was practicing the target phrase, “I want more” with the target sounds being /w/ and /m/, this was random practice condition. If the child misarticulated either of the target sounds, blocked practice of the misarticulated target was implemented. The phrase was then broken down into a single word, “more”, or CV syllable, “mo.” The clinician judged where to begin the blocked practice and what level of cueing was needed. The clinician gradually lessened the support provided by fading cues. Once it was deemed that the desired production of the target in a less complex manner, in isolation or in a syllable, was achieved with the least amount of support, the clinician again returned to random practice of the target sounds.

The frequency of repetition variable was the only treatment condition which was manipulated during treatment sessions. During Treatment A, all integral stimulation techniques and motor learning principles described above were implemented, but only 30 to 40 productions of each speech sound were elicited. In Treatment B, the exact same treatment protocol was employed as in Treatment A, but speech targets in Treatment B were elicited between 100 and 150 times each during the 15 minute slot assigned. In both treatment conditions, the same types of activities and games were used to elicit speech targets. Treatment A differed from Treatment B in that there was more playing and less elicitation of the speech targets. For example, if the participant was playing a board game to elicit speech sounds in the Treatment A condition, he was asked to produce the speech target one to two times before taking his turn in the game. All integral stimulation and motor learning principles were used to evaluate and give feedback regarding the productions. In the Treatment B condition, the participant was asked to produce the target 10-15 times before taking a turn. In this way, all treatment conditions were the same except for the frequency of repetition of production between the two treatment conditions.

Because this study involved learning, the same speech sounds or behaviors could not be used across treatments as is typically done with single participant designs. Each treatment was assigned particular speech sounds so that the sound did not receive more than one type of treatment. Every effort was made to choose speech sounds that were different in class and manner to prevent generalization from one treatment to another. To control for an order effect, treatment order was randomized from session to session and amongst the participants.

Baseline

Baseline probes were administered to each participant for each of the speech sounds targeted. Baseline probes were implemented until stability or a downward trend was seen. Baseline sessions consisted of the clinician and the client participating in language or reading tasks for 15-20 minutes to provide a consistent practice scenario across the study with probes administered at the end of this period. No practice of speech targets occurred during baseline sessions. Probes were administered by the clinician asking the participant to say a single syllable word with the target sound in either the initial or final position of the word. Once the speech targets had been chosen for each treatment, a large list (between 100 and 150) of phonotactically similar words was compiled which had the speech target at the beginning or end of the word. Twenty words were randomly chosen for each targeted speech sound using a random number generator. Each word on the list was assigned a number. Before all sessions the clinician used the random number generator to compile a list of 20 probe words. Ten foil words, words not containing any of the target sounds but which were phonotactically similar to all of the probes, were randomly mixed in with the 20 probe words. Probes were chosen in the same fashion as probes administered in the baseline sessions. No cueing or feedback was given during the administration of the baseline phase. Because of the participants' inability to read, targets were modeled for the participants using a delayed model. The clinician gave instructions to the child such as, "I'm going to say a word, and then I want you to repeat it after me." The clinician then said the word and asked the child to repeat the probe by using a carrier phrase such as, "Ok, it's your turn." The child was then expected to repeat the word or phrase after the delayed model. Treatment began the session after baselines were determined to be stable for each participant.

Data Collection and Analysis

Data were collected during each activity for each treatment, and for all probes administered. Data were tracked using accuracy sheets created by the clinician. During each activity, the clinician manually recorded the number of accurate productions of the target sounds and the number of attempts in a plus or minus column on the accuracy sheet. A manual counter was also used to track the number of productions of speech sounds made by each participant for each treatment phase. All sessions were video or audio taped for reference and assessment of fidelity of treatment. A percent of correct in-session production of target sounds was calculated using the tally of responses for each speech sound in each activity by dividing the number of correct productions by the number of attempts. This was done for both treatment conditions after the conclusion of each session.

Probes were conducted at the end of each 15 treatment slot to track generalization of trained sounds to untrained words. A random selection of probe words was chosen before each session. As with the baseline probes, 20 words were chosen for each targeted sound. Ten foils which were phonotactically similar to treatment targets, but without the speech sound being practiced, were mixed into the list of probes to create a true random practice situation. Delayed modeling, the clinician saying the word or phrase and then asking the child to repeat it, was used to elicit probes from participants. Probe responses were transcribed online during the session. Each transcribed production from the child was compared to the target transcription. A percentage of correct productions was calculated for each set of probes administered in each treatment condition by dividing the number of correct productions by the total number of trials presented. These data were calculated and tracked for each session and plotted to show progress from session to session.

Setting

Each participant was seen either two or three times per week for 40 minute sessions. Most sessions took place at Portland State University. When it was not possible for the family to come to PSU, the clinician conducted treatment sessions at the family's residence. Treatment rooms were equipped with a small table, several child size chairs, and a large chalk board. All other materials in the room including toys and games were for use in the sessions. All other environmental distractions including toys brought from home, jackets, backpacks, and snacks were not permitted in the room. Sessions took place at the table and on the floor.

Each child was seen for a total of between 6 and 12 weeks. Following treatment, a 2 week break was taken. After the break, maintenance measures were collected for each speech sound targeted during treatment and from each participant.

Reliability

A second observer, who was blind to the conditions of the study and who was trained in transcription using IPA symbols, phonetically transcribed random samples of probe words chosen from over the course of the study to ensure inter-rater reliability and consistency of the transcriptions made by the primary observer (see Appendix C for an example of a transcription sheet). Inter-rater reliability was completed for 5% of the data collected and was calculated as 91% reliable. Transcribed words that were not agreed upon during the second observer's transcription were listened to by both transcribers again, and a consensus was established for all differences. The same second observer also viewed 5% of the video taped sessions to ensure fidelity of treatments over the course of the study as well as to ensure comparability of all elements of Treatment A and Treatment B except for that of the frequency of repetition variable. A rubric developed by the clinician was used by the blind observer to track consistency of treatment across the study as well as across treatment conditions (see Appendix D for the rubric). Fidelity of treatment was calculated at 100%.

Results

This study examined the effect of frequency of repetition of productions on the acquisition and accuracy of speech sounds targeted during integral stimulation therapy and generalization of trained sounds to untrained words. Each participant was treated with the two versions of integral stimulation therapy previously described. Specific speech sounds targeted in each treatment were chosen as a result of the standardized tests administered as well as the data collected from the language samples. Baseline sessions were conducted over three to four sessions for each participant, and treatment ranged from 6 to 10 weeks depending on the participant. After the treatment period was completed, a 2 week break was taken and post-treatment assessments were conducted on 2 of the 3 participants. Data were analyzed on 2 of the 3 participants. Data were analyzed for each participant in each treatment condition to compare motor performance and motor learning and determine if increased frequency of repetition and intensity of productions affected motor learning.

Participant 2, JS was removed from the study after 4 weeks due to concerns that a CAS diagnosis was not appropriate for him and that integral stimulation therapy was not meeting his speech and language needs. This is discussed in detail below. Results of pre-treatment testing, baseline measures, treatment conditions, and post-treatment measures are discussed in the following section as well. Results and discussions have been broken down by participant.

Results for JG

Pre-treatment Assessment

During the study JG attended three, 40 minute sessions each week. Two sessions a week were conducted at PSU and one was conducted at his home or in a quiet room at his school. Prior to baseline measures and treatment, pre-treatment assessments were conducted. The GFTA-2 was administered, and JG received a standard score of <40 which placed him below the 1st percentile. Receptive language testing was completed using the CELF Preschool 2. JG received a standard score of 69 on the receptive language measures placing him in the 2nd percentile. It is unclear if his performance on these measures is a true indication of his receptive language skills. JG's desire to participate and the fact that the assessments used were not motivating or fun for him may have played a factor in the poor performance on these tests. Due to his severe articulation errors and severely limited intelligibility, expressive language testing was not completed.

Table 1 shows a summary of the pre-treatment test results for JG. Figure 1 is a speech framework created by analyzing the speech sounds produced during the GFTA-2 and the spontaneous speech sample. A relational analysis of error patterns was derived from analysis of words and phrases produced during the language sample. The speech framework shows a significantly reduced speech sound inventory, with only the consonant sounds /p/, /b/, /m/, /w/, and /h/ being produced. A large number of phonological error patterns are noted as well. A total of 43 errors were made affecting consonants. Phonological error patterns with the highest number of errors included glottal replacement/backing (18%) and labial fronting

(25%). While JG produced a variety of word shapes, he showed a preference for CV (consonant-vowel) shapes (39%). Of the 32 total errors made affecting word shape, significant error patterns included cluster reductions and deletions (100%) and final consonant deletions (58%). Most monophthong vowels were produced, but no diphthongs were produced over the course of the evaluation.

Table 1. Summary of pre-treatment tests administered, JG

Test Administered	Test Score
Goldman Fristoe Test of Articulation 2nd Edition	Standard score <40 Percentile Rank <1%
Clinical Evaluation of Language Fundamentals Preschool, Receptive subtests	Standard Score 69 Percentile Rank 2

Figure 1. Initial Speech Framework Summary for JG age: 6; 2

INDEPENDENT ANALYSIS (PHONETIC INVENTORY)		
CONSONANTS	**VOWELS**	**WORD SHAPES**
Initial:	**Monophthongs:**	**Most Frequent**
p, b	i, ɪ, ɛ, ə, ɑ, æ, u	**CV 39%**
m		**CVC 14%**
w		**CVCV 19%**
h		
Medial:	**Diphthongs:**	
m	**None**	
ʃ		
Final:	**Rhotics:**	
p	**None**	
m		
Clusters:		
None		

RELATIONAL ANALYSIS (ERROR INVENTORY): % Occurrence of Each Error		
CONSONANTS	**VOWELS**	**WORD SHAPES**
Fronting	**Monophthongization**	**Cluster Reduction/Deletion**
25%	**74%**	**100%%**
Backing	**Derhoticization**	**Final Consonant Deletion**
18%	**No opportunity**	**58%**
		PCC: 25%

Overall, JG showed a lack of awareness of his speech errors, reduced phonemic repertoire, and severely limited intelligibility. A total of 65 consonants were produced during the speech sample taken. Of these, JG articulated 16 correctly leading to a PCC of 25%. He rarely attempted to self correct, and facial groping was noted several times during the evaluation. His rate was often faster than normal but prosody was noted to be normal.

Baseline and Treatment Results

Baseline measures were conducted over three sessions in December of 2007. The speech sounds chosen were based on the results of the GFTA-2, his speech sample, and developmental appropriateness. Speech sounds were randomly assigned to a treatment condition. The alveolar stop phonemes /t/ and /d/ were assigned to Treatment A (30-40 productions) and the labiodental fricative phonemes /f/ and /v/ were assigned to Treatment B (100+ productions). Baseline sessions were conducted in a similar fashion to treatment sessions, but integral stimulation therapy was not used. Sessions were 40-45 minutes long and broken into two sections or treatment phases. During each 15 minute treatment phase the participant participated in language activities such as matching opposites, working on prepositions, letter recognition, and pronouns. This was done so baseline sessions would be similar in format and length to treatment sessions without conducting any treatment for speech production. At the end of the first 15 minute treatment phase, baseline probes for one of the treatment conditions were administered. The second 15 minute treatment phase was then completed with similar activities as those described above. Probes for the second treatment condition were then administered.

Over the course of the three baseline measures, JG did not correctly articulate any of the target sounds in either treatment condition. All baseline sessions occurred at the PSU Speech and Hearing Clinic. Baseline performance is laid out in Table 2 below.

Table 2. JG's percentage correct on baseline probes administered (20 probes plus 10 foils)

Baseline session	Percent correct Treatment A /t/ and /d/	Percent correct Treatment B /f/ and /v/
#1	0%	0%
#2	0%	0%
#3	0%	0%

Data collection during the treatment phase occurred at the PSU Speech, Language and Hearing Clinic, at the participant's school, and at JG's home. JG's family agreed to three treatment sessions per week, but because the family lived an hour away from the University clinic, the clinician agreed to see JG one day a week either at his home or his school. Treatments conducted outside of the clinic room took place in quiet rooms with minimal distractions. Treatments outside of PSU were conducted in a similar fashion to those in the clinic. The participant sat at a table, played games with the clinician, and all materials used were the same as those used at PSU.

JG was seen for a total of three baseline sessions and 32 treatment sessions over the course of the study. Due to the variability of JG's parent's work schedules and the clinician's schedule, treatments that occurred outside of PSU alternated between JG's home and his school. Eight of the 32 treatment sessions took place at his school while four took place at his home. The rest of the sessions were conducted at PSU. Every effort was made to minimize distractions in the different environments and to provide consistency of treatment across settings, but differences across settings were unavoidable. Rather than being a detriment to the study, however, the different settings gave JG an opportunity to participate in variability of practice, a tenet of motor learning. Practice of speech sounds was taken out of the clinic room into real life settings.

After a 2 week break, post-treatment measures were conducted at JG's home. A final GFTA-2 was administered, a speech sample was collected, and probes were collected for each treatment condition. Probes were conducted in the same fashion as had been done during the course of the study.

Motor Performance. Motor performance is defined as the accuracy of in-session productions of target sounds. Motor performance was assessed by tracking JG's in-session performance for target speech sounds in each treatment condition. In-session performance was tracked across all sessions. These results are significant in that in-session practice and performance of target sounds lay the groundwork for learning and transfer of skills to novel environments, but these data are not a measure of true learning. Figure 2 shows the results for JG's in-session (motor performance) progress for the target speech sounds in both treatment conditions beginning with the three baseline sessions as well as all treatment sessions. The clinician consulted with JG's parents to identify words and phrases which were functional for JG in his home and school environments. These words and phrases were targeted in sessions (see Appendix E for a list of targeted words and phrases).

Blocked practice alone, speech sounds were practiced at the syllable level only, was conducted in sessions four and five. Blocked practice was used to lay the groundwork and for JG to participate in intensive practice of the motor patterns for the target sounds. Blocked practice was also implemented to give JG massive amounts of successful practice at the syllable level before moving on to the word and phrase level. Once it was determined that his accuracy of production at the syllable level was high, random practice was begun. Integration of both blocked and random practice in a hierarchical fashion was used for all other treatment sessions.

JG made steady in-session progress on the phonemes targeted in Treatment B (100+). By session 12 he was achieving 95% accuracy on words and phrases practiced in the session. A slight drop in accuracy can be seen in session 13 with only 85% in-session accuracy. Variability of productions is low across treatment sessions. Accuracy fluctuates between 94% and 98% accuracy for the phonemes /f/ and /v/ targeted in Treatment B (100+) with no change in slope noted for Treatment B.

Variability was higher for phonemes targeted in Treatment A (30-40), and an increase in slope can be seen over the course of the treatment. Accuracy fluctuated from 66% correct to 92% correct, but the higher levels of accuracy were not maintained from session to session. Sounds treated with condition A (30-40) show a decline in in-session accuracy of productions as the treatment phase of the study nears the end. Errors noted included leaving the target sound off of the word or reverting to his typical backing pattern and producing a /k/ or glottal stop instead of a /t/ or /d/.

It should also be noted that because accuracy of /f/ and /v/ were so high in Treatment B (100+), JG was able to practice these phonemes in more words and longer utterances during the course of the study. By the last session, he was producing four to five word utterances correctly with /f/ and /v/ target words. Sounds targeted with Treatment A (30-40) were practiced at the phrase level, but in two to three word utterances only due to the fact that in longer utterances accuracy of the target sounds would breakdown and practice would be scaled back to achieve correct production and higher accuracy. These sounds never reached the same phrase length or accuracy levels as /f/ and /v/. It is also of interest to note that JG never accurately articulated /d/ in any of the words practiced and defaulted to the voiceless /t/ for any word with a /d/ in it.

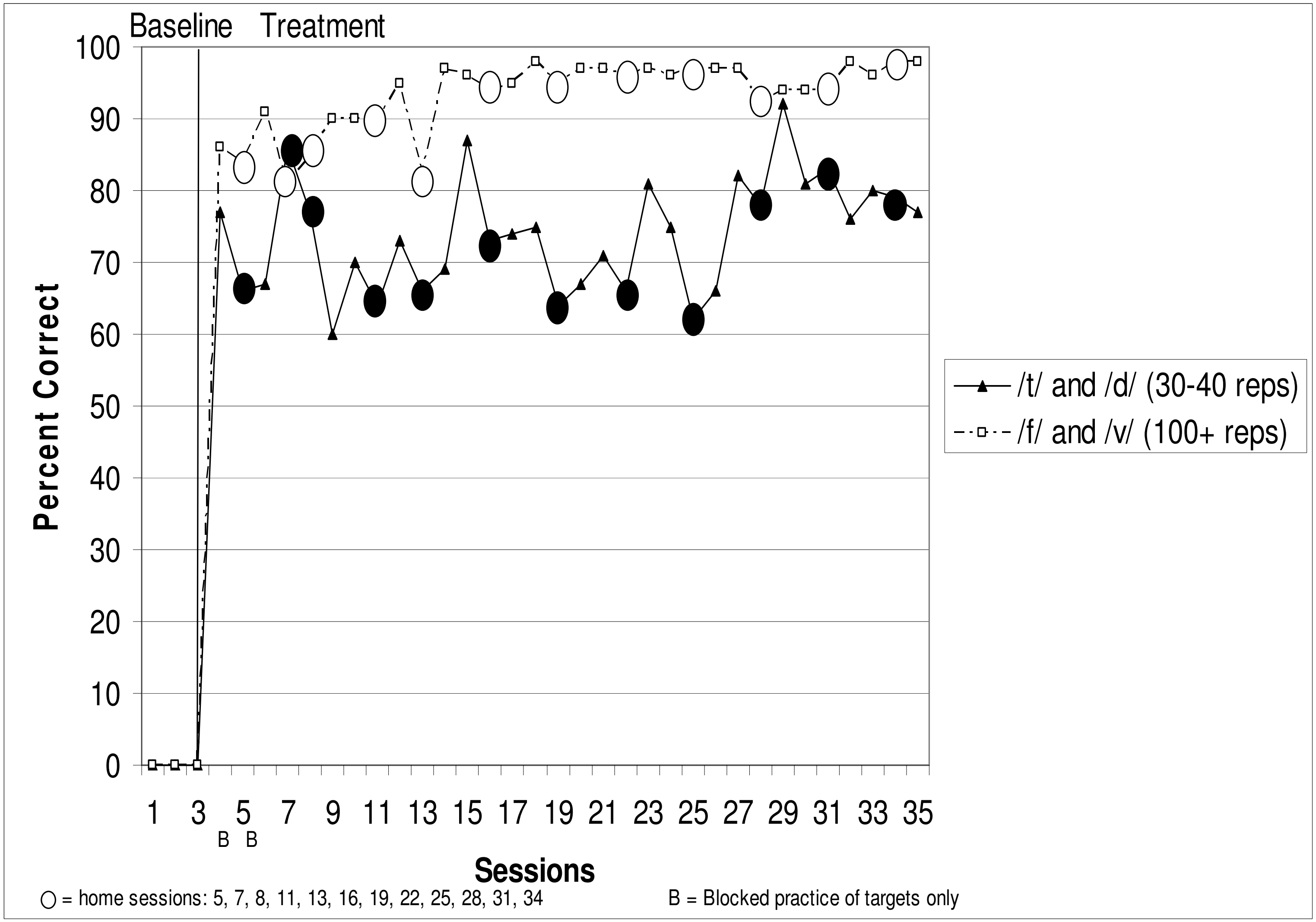


Figure 2. JG percent of in-session production correct for target speech sounds, measuring motor performance

Motor Learning. Motor learning, generalization of trained skills to novel situations, was assessed through the administration of probe words at the end of each treatment phase within the session. Probe words contained trained sounds in untrained CV and CVC words. Figure 3 shows accuracy of probe productions for both treatment conditions beginning with the three baseline sessions, all treatment sessions, and the post-treatment probes that were administered. While accuracy rose as high as 60% for the /f/ and /v/ probes (100+), stability across more than two sessions was never attained. It is significant; however, that JG's accuracy in probe words rose from 0% across three baseline sessions to as high as 60% accuracy. Probes for Treatment A (30-40), while showing improvement over baseline testing, never came close to the accuracy that was achieved for the /f/ and /v/ probe words.

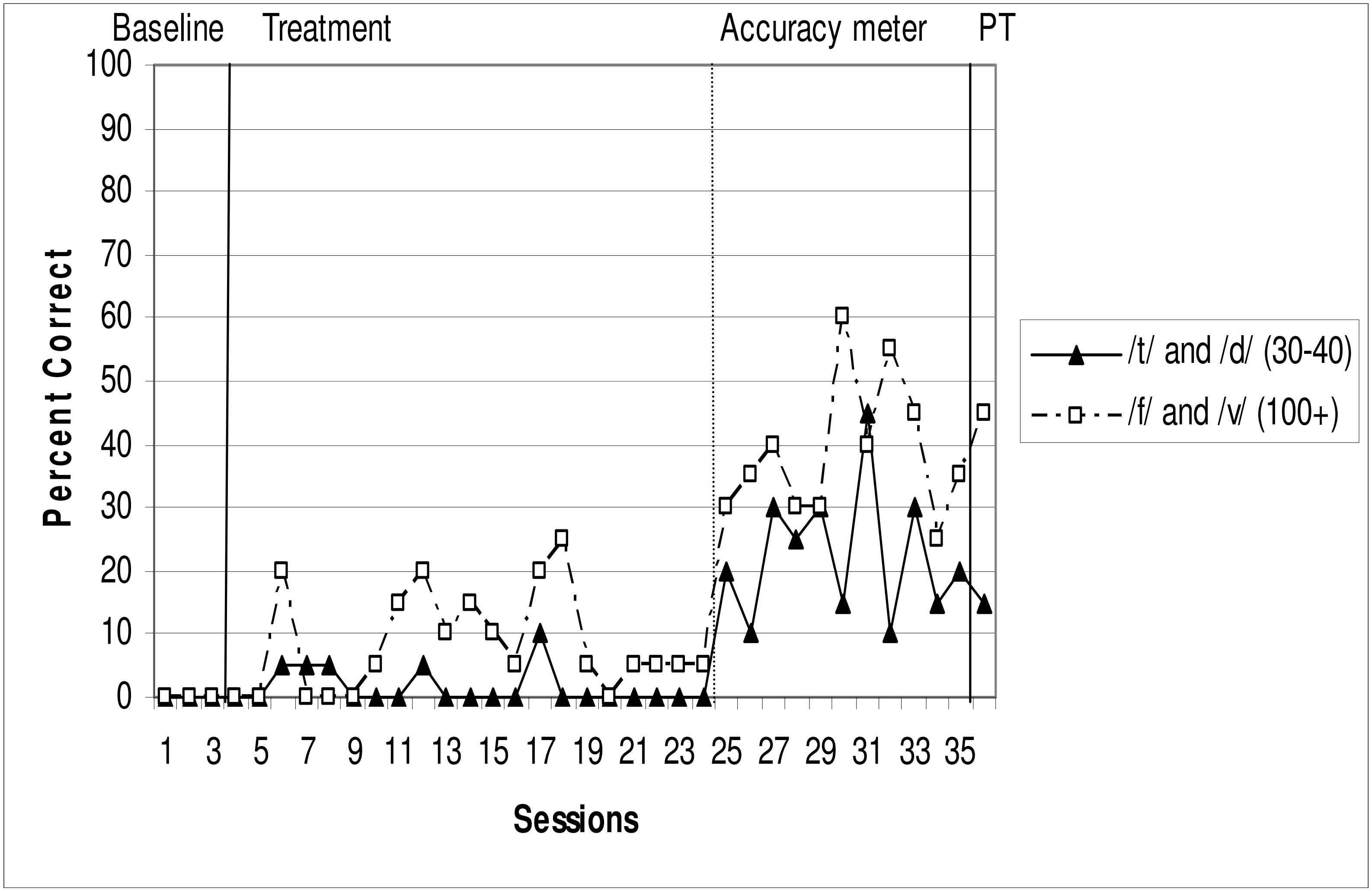


Figure 3. JG percentage of untrained probe words correct for target sounds, measuring motor learning

Post-treatment Results

Post-testing was conducted after a 2 week break from treatment. During this time JG did not receive any speech services. Post-testing was done using the GFTA-2, probes, and a speech sample. JG received a standard score of <40 on the GFTA-2 which placed him below the 1st percentile. Analysis of the results from the GFTA-2 show that while JG acquired some new speech sounds over the course of the study, he did not always articulate these during the assessment. Those sounds he did articulate did not raise his score significantly. It is the opinion of the clinician that JG did not perform up to his ability on this measure. He had participated in this particular assessment many times over the course of his treatment time at PSU. The assessment was neither play based nor interesting to JG and therefore, his performance results are questionable. Post-treatment probe measures were taken for each treatment condition. Probes were administered in the same fashion as those during the treatment phase. Accuracy of production for Treatment A (30-40) was at 15% showing a decline of 5% over the 2 week break. Post treatment accuracy of Treatment B (100+) probes was at 45% showing an increase in accuracy from 35% in the last treatment session. This may indicate that motor learning did indeed take place and motor skills were maintained over the 2 week break for sounds treated with condition B (100+).

During the post-treatment speech sample, JG produced a total of 30 utterances with a total of 96 consonants. His PCC was calculated at 73% which is a significant improvement over his PCC of 25% during pre-treatment measures. All sounds treated over the course of the study were articulated correctly during the speech sample. During the pre-treatment speech sample JG made a total of 192 errors over the course of 53 utterances. In the post-treatment sample, he made a total of 33 errors over 30 utterances. In all JG made a total of five errors affecting consonants in the post-treatment measure. JG eliminated several phonological error patterns such as labial fronting, stopping, and reduplication. Glottal replacement/backing errors were reduced from 18% in the pre-treatment measure to 5% in the pos-treatment measure. Errors affecting word shape were also reduced. A total of 18 word shape errors were made in the post-treatment measure. Final consonant deletion errors were reduced from 58% in the pre-treatment measure to 13% in the post-treatment measure. Weak syllable deletion and epenthesis were eliminated. Cluster reduction and deletion errors remained the same at 100% error. This may be due to the fact that clusters were not targeted during treatment. Derhoticization errors increased most likely due to the fact that no words with rhotics were produced in the initial evaluation. It is significant to note that JG's utterance length increased from one to two word utterances during the pre-treatment speech sample to four to five word intelligible utterances during the post-treatment sample. A post-treatment speech sound inventory is shown in Figure 4.

Figure 4. Post-treatment speech sound inventory for JG

INDEPENDENT ANALYSIS (PHONETIC INVENTORY)					
CONSONANTS		VOWELS		WORD SHAPES	
Initial		Monophthongs		Most Frequent	
Pre:	Post:	Pre:	Post:	Pre:	Post:
p, b	p, b, t	i, ɪ, ɛ, ə	i, ɪ, ɛ, æ,	CV	CV
	f, v	ɑ,æ, u	ɑ, ə, u, ɔ	39%	39%
m	m, n			CVC	CVC
w, h	w, h, l			14%	18%
				CVCV	CVCV
Medial		Diphthongs		19%	15%
Pre:	Post:	Pre:	Post:		VC
m	m, n	None	ʌɪ, oʊ		11%
ʃ	ʃ, h				V
Final		Rhotics			18%
Pre:	Post:	Pre:	Post:		
p	p	NA	None		
m	m, n				
	f, v				
Consonant Clusters					
Pre:	Post:				
None	None				

RELATIONAL ANALYSIS (ERROR INVENTORY): % of Each Error					
CONSONANTS		VOWELS		WORD SHAPES	
All Word Positions		Monophthongization		Cluster Reduction/Deletion	
		Pre:	Post:	Pre:	Post:
Non-Pattern		74%	0%	100%	100%
Place/Manner Errors					
Pre:	Post:	Derhoticization		Final Consonant Deletion	
		Pre:	Post:	Pre:	Post:
Fronting		N/A	100%	58%	13%
Pre:	Post:				
25%	0%				
Backing				PCC:	
Pre:	Post:			Pre:	Post:
18%	5%			25%	73%

Results for AG

Pre-treatment Results

AG was recruited into the study during the 5th week of the term after JS discontinued participation in this study. Due to the late start in the study and the fact that a schedule had already been established with the family, AG attended two, 50 minute sessions a week over the course of the study. All sessions were conducted at PSU. The Auditory Comprehension portion of the Preschool Language Scale Fourth Edition (PLS-4) was administered in January of 2008 by his previous student clinician before he was recruited into this study. AG received a standard score of 96 on these measures placing him in the 39th percentile. Due to his severe articulation issues, the expressive portion of the test was not administered. After AG joined the study, this clinician attempted to administer the GFTA-2, but was unable to complete the assessment. Table 3 shows a summary of the pre-treatment tests administered.

A speech sample was used to analyze AG's speech sound repertoire, errors patterns, and choose targets for treatment. During the speech sample AG produced a total of 82 consonants, 17 of which were correct. His PCC was calculated at 21%. Figure 5 shows the speech sounds AG produced as well as error patterns compiled from analysis of the speech sample obtained. AG presented with a significantly reduced speech sound inventory for his age and a sound preference for the phoneme /d/ which was his default for most sounds. His word shape repertoire was limited to CV and V word shapes. A total of 19 errors were made affecting consonants. Significant error patterns at the phoneme level included fronting (66%), stopping (13%), and voicing errors (12%). A total of 39 errors affecting word shape were made. Significant error patterns affecting word shape included final consonant deletion (100%), initial consonant deletion (10%) and, cluster reduction and deletion (100%). While most monophthongs were heard at some point during the assessment, many monophthongs were diphthongized (19%).

Table 3. Summary of pre-treatment tests administered, AG

Test Administered	Test Score
Receptive Portion of the Preschool Language Scale Second Edition	Standard Score 96 Percentile Rank 39

Figure 5. Initial Speech Framework Summary for AG age: 3; 4

INDEPENDENT ANALYSIS (PHONETIC INVENTORY)		
CONSONANTS	**VOWELS**	**WORD SHAPES**
Initial:	**Monophthongs:**	**Most Frequent**
b, d	i, ɪ, æ, ɛ, ɑ, ə	CV 67%
m, n		V 33%
h		
w		
Medial:	**Diphthongs:**	
None	aɪ, aʊ, eɪ, oʊ	
Final:	**Rhotics:**	
None	None	
Clusters:		
None		
RELATIONAL ANALYSIS (ERROR INVENTORY): % Occurrence of Each Error		
CONSONANTS	**VOWELS**	**WORD SHAPES**
Fronting	**Diphthongization**	**Cluster Reduction/Deletion**
66%	19%	100%
Stopping	**Derhoticization**	**Initial Consonant Deletion**
13%	100%	10%
Voicing		**Final Consonant Deletion**
12%		100%
		PCC: 21%

Baseline and Treatment Results

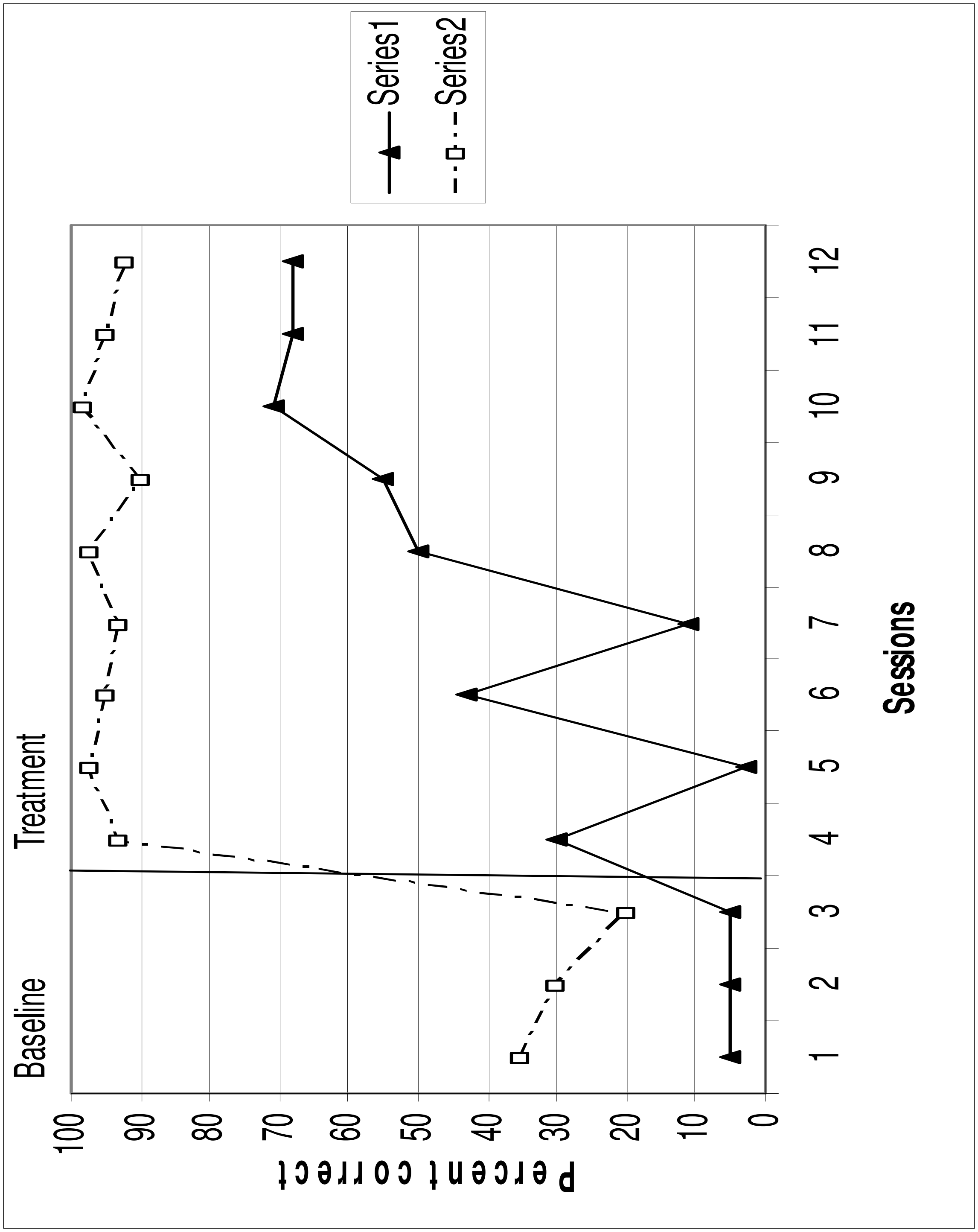
Baseline measures for AG were conducted over three sessions at the PSU clinic. Sessions were conducted in the same manner as those of the other participants. The labiodental fricative phonemes /f/ and /v/ were randomly assigned to Treatment A (30-40) and the bilabial oral and nasal stop phonemes /p/, /b/, and /m/ were assigned to Treatment B (100+). Table 4 below shows AG's performance on baseline measures. Baseline measures and all treatment sessions were conducted at PSU. Because AG was recruited into the study later in the term, he was seen for three baseline sessions and nine treatment sessions.

Table 4. Percentages correct on baseline probes administered (20 probes plus 10 foils).

Baseline session	Percent correct Treatment A /f/ and /v/	Percent correct Treatment B /p/, /b/, and /m/
#1	5%	40%
#2	5%	30%
#3	5%	20%

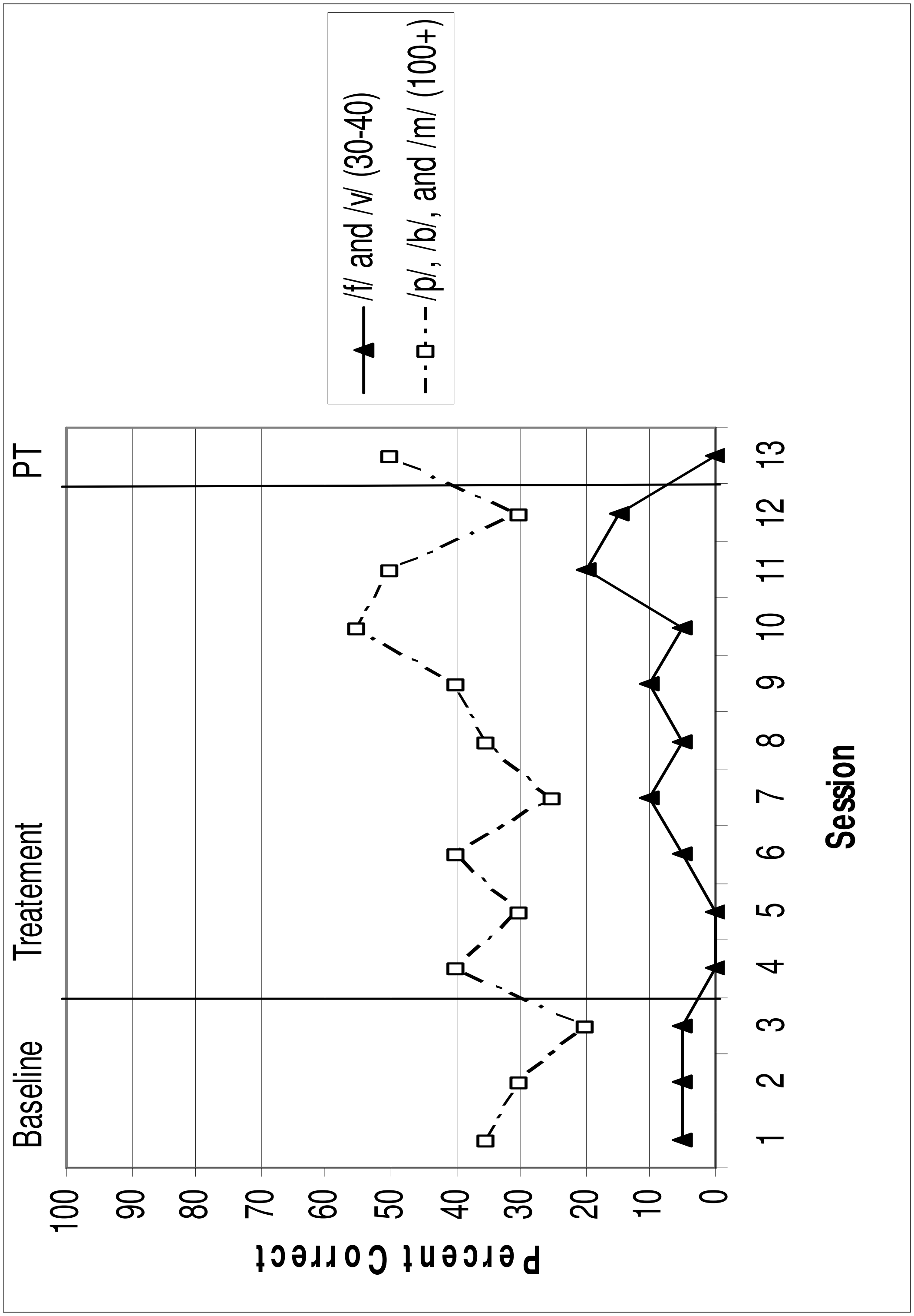
Motor Performance. Figure 6 shows the results of AG's in-session progress, motor performance, for both treatment conditions. Treatment B (100+) shows much greater accuracy and stability over the course of the study with variations in accuracy of between 90% and 97%. Little variability is seen between treatment sessions for sounds treated with Treatment B, and there is no change in slope. The phonemes /f/ and /v/, treated with condition A (30-40), show a much lower level of accuracy overall and much greater levels of variability from session to session. Due to high fluctuation for the accuracy of words treated with Treatment A (30-40), these sounds were only treated at the syllable level and in CV or VC words (see Appendix F for a list of target words for each treatment condition). Accuracy of phonemes treated with Treatment A range from 3% to 71%.

Figure 6. AG in-session percent of correct productions for target sounds, measuring motor performance



Motor Learning. Figure 7 illustrates motor learning and shows generalization of trained sounds to untrained words. Figure 7 depicts performance on the three baseline sessions, the probes administered after each treatment phase, and the post treatment probe measures. Probes for the sounds /f/ and /v/ in the Treatment A (30-40) condition show increased progress over the course of the study with accuracy ranging from 0% up to 20% in session 11. Probes for the phonemes /p/, /b/, and /m/ in Treatment B (100+) show a range of accuracy from 20% in the last baseline measure to 55% in session 10. None of the probes show stability over time, in fact, accuracy of probes administered for Treatment B (100+) decline sharply after session 11. These results may indicate that motor learning and generalization have not yet occurred for the speech sounds being targeted.

Figure 7. AG percentage of correct post-session probe productions for target sounds, measuring motor learning



Post-treatment Results

Post-treatment measures were conducted approximately 2 weeks after treatment sessions had ended. AG did not receive any speech services over the course of this 2 week period. The GFTA-2 was administered, and he received a standard score of 53 placing him below the 1st percentile. Two sets of probes were administered as well, one for each treatment condition, to assess retention and generalization of treated speech sounds. Accuracy on probes administered for Treatment A (30-40) were at 0% showing a drop in accuracy from 15% during the last treatment session. Probes administered for Treatment B (100+) showed 50% accuracy which is an increase in accuracy from 30% during the last treatment session.

A spontaneous play based language sample was collected as well. During the speech sample AG produced a total of 53 one and two word utterances with a total of 144 consonants. His PCC was calculated to be 32% which is an increase over his pre-treatment score of 21%. Several phonological processes show a reduction in frequency over the course of treatment. Fronting was reduced from 66% in the pre-treatment measure to 23% in the post-treatment measure. Stopping was reduced from 13% to 4%, and voicing errors remained about the same for both pre and post-treatment measures. Errors affecting word shape showed improvement as well. Initial consonant was reduced from 10% in the pre-treatment measure to 7% in the post-treatment measure. Final consonant deletion was reduced from 100% to 71%. Cluster reduction and deletion remained the same at 100% possibly due to the fact that clusters were not targeted during treatment. Gliding appears to have increased in frequency from 0% in pre-treatment measures to 62% in post-treatment measures.

This increase may be due to the fact that AG was producing more language overall in the post-treatment measure and there were no opportunities for gilding errors in the initial assessment because he did not produce any words with sounds which could be glided. Word shape was still severely limited in the post-treatment measure with only one CVC word being produced. A post-treatment speech sound inventory is illustrated in Figure 8 below.

Figure 8. Post-treatment speech sound inventory for AG

INDEPENDENT ANALYSIS (PHONETIC INVENTORY)					
CONSONANTS		VOWELS		WORD SHAPES	
Initial		Monophthongs		Most Frequent	
Pre:	Post:	Pre:	Post:	Pre:	Post:
b, d	b, d	i, ɪ, æ, ɛ	i, ɪ, æ, ə	CV 67%	CV 87%
m, n	m, n	ɑ, ə	ɑ,ɔ	V 33%	CVC 2%
w, h	w, h, j				V 11%
Medial		Diphthongs			
Pre:	Post:	Pre:	11%		
None	None	aɪ, aʊ, ei,	Aɪ, aʊ, ei, oʊ		
Final		oʊ			
Pre:	Post:	Rhotics			
None	z	Pre:	Post:		
		None	None		
Clusters					
Pre:	Post:				
None	None				

RELATIONAL ANALYSIS (ERROR INVENTORY): % Reduction of Each Error					
CONSONANTS		VOWELS		WORD SHAPES	
All Word Positions		Diphthongization		Cluster Reduction/Deletion	
Non-Pattern		Pre:	Post:	Pre:	Post:
Place/Manner Errors		19%	15%	100%	100%
		Derhoticization		Final Consonant Deletion	
Fronting		Pre:	Post:	Pre:	Post:
Pre:	Post:	100%	100%	100%	71%
66%	23%			Initial Consonant Deletion	
Stopping				Pre:	Post:
Pre:	Post:			10%	7%
13%	4%				
Gliding				PCC:	
Pre:	Post			Pre:	Post:
N/A	62%			21%	32%
Voicing					
Pre:	Post:				
12%	11%				

Results for JS

Pre-treatment Results

JS was administered the GFTA-2 as well as the receptive portions of the CELF Preschool 2. He received a score of <40 on the GFTA-2 placing him below the 1st percentile. He received a standard score of 71 on the receptive portion of the CELF Preschool 2 placing him in the 3rd percentile. Expressive language testing was not done with JS because of his lack of verbal language. Results of the assessments are laid out in Table 5 below.

JS was essentially non verbal when he entered the study. His parents reported that he could make word approximations of “mom”, “dad” and “chips.” A formal spontaneous speech sample was not taken due to his lack of spontaneous verbal language production, his tendency to only imitate the speech of others, and the fact that he was quite upset during the evaluation and wouldn’t leave his mother’s arms. During the assessment he was heard to spontaneously produce CV word approximations such as “mu”, “gu” and word approximations for the numbers one to five. JS attempted to imitate spoken language when asked to but rarely initiated speech. A speech sound inventory was compiled from his results on the GFTA-2 and the few productions he made during the assessment. None of his responses on the GFTA-2 were spontaneous, all were produced after a model by the clinician. Figure 9 shows his speech sound inventory as well as error patterns derived from the speech sample. JS showed a reduced speech sound inventory and a preference for the sounds /m/ and /d/. Speech sound errors noted were a tendency to nasalize stops, fricatives, and liquids (20%), stopping (14%), and fronting (66%). Major error patterns affecting word shape noted were weak syllable deletion (62%), initial consonant deletion (29%), and final consonant deletion (74%). While many monophthong vowels were heard, only the diphthong “oy” was heard, and JS was noted to centralize vowels (25%).

Table 5. Summary of pre-treatment tests administered, JS

Test Administered	Test Score
Goldman Fristoe Test of Articulation 2nd Edition	Standard score <40 Percentile Rank <1%
Receptive Portion of the Clinical Evaluation of Language Fundamentals Preschool	Standard Score 71 Percentile Rank 3

Figure 9. Initial Speech Framework Summary for JS age: 3; 7

INDEPENDENT ANALYSIS (PHONETIC INVENTORY)		
CONSONANTS	**VOWELS**	**WORD SHAPES**
Initial:	**Monophthongs:**	**Most Frequent**
b, d, g, k	i, ɪ, ɛ, ɑ, u	CV 83%
m, n		
w, l		
ʤ		
Medial:	**Diphthongs:**	
d	oɪ	
m		
Final:	**Rhotics:**	
z	None	
Clusters:		
None		

RELATIONAL ANALYSIS (ERROR INVENTORY): % Occurrence of Each Error		
CONSONANTS	**VOWELS**	**WORD SHAPES**
Fronting	**Centralization**	**Cluster Reduction/Deletion**
66%	25%	100%
Stopping		**Weak Syllable Deletion**
14%		62%
Nasalization		**Initial Consonant Deletion**
20%		29%
		Final Consonant Deletion
		74%

Baseline and Treatment Results

Baselines for JS were collected over four sessions with treatment beginning for Treatment B (100+) during session four and treatment beginning for Treatment condition A(30-40) during session five. The phonemes labiodental fricative phonemes /f/ and /v/ were randomly assigned to Treatment A (30-40) while the velar stop phonemes /k/ and /g/ were assigned to Treatment B (100+). Baseline sessions were conducted in a similar fashion to those for the other participants. Sessions were 40-45 minutes long and focused on language activities. Two 15 minute sessions were conducted with baseline measures given in between each treatment phase.

JS was seen three times a week for 5 weeks. He was brought to PSU twice a week and the clinician visited his home once a week. Treatments conducted at JS' home were done in his bedroom at a small table usually with his mother and younger sister playing quietly nearby. Distractions in the form of toys and books were minimized as much as possible.

It quickly became apparent that this treatment was not the best option for this participant. JS demonstrated the ability to independently articulate the sound for every letter in the alphabet when asked to do so, but had significant difficulty sequencing sounds together to form words. He did not imitate short CV or CVC words in a choral fashion or after a model from the clinician. He was able to produce the word when it was spelled out for him with the apraxia flip book. Even with the word spelled out in this visual manner, JS was unable to sequence the sounds into words without touching each picture in the book as he went. His prosody was robotic and halting when sounding out words. He would also perseverate on previously treated words using them in the improper context or to refer to the wrong object.

It was clear that JS was not connecting language to its meaning or proper use. His mother reported that new words he had learned during treatment sessions were being used in improper contexts around the home when he wanted praise or attention from his parents. For example, he was able to sort and match animals and colors cognitively. He matched colors and animals during play, but he did not comprehend that the word "cow" was only used to label a specific farm animal. Often in activities JS would label any farm animal as a cow even with correction from the clinician. The same was true with his ability to understand the various functions of language. In several sessions the word "food" was taught. He picked it up quickly and had a high level of success with the word in the session. At the following session JS' mother reported that he had been using the word "food" during the week. When the clinician inquired further as to the situations in which he used the word, the mother reported that he used "food" when his dad came home from work and JS wanted to be picked up, he used it when he wanted to get either of his parents' attention, and he used it when he wanted to be praised. Several times JS used the word "food" as a greeting when he saw the clinician. Rarely did JS use "food" in its appropriate context to refer to items that he wanted to eat or food items that he saw in daily life.

Other indications that integral stimulation therapy was not the most appropriate therapy for JS included the fact that he did not withstand the intensity of the treatment nor did he achieve the number of repetitions necessary to effectively participate in the study. He never produced the targeted 100+ repetitions for Treatment condition B and never completed any of the probe sessions administered after treatment sessions. He would become overwhelmed and break down forcing the clinician to end the session. Treatments were modified to be more child-centered with less emphasis placed on the number of productions, but it was clear that this participant was not appropriate for this study.

JS' behavior during the course of his participation in the study also raised some red flags as to the appropriateness of this treatment for him. When he became upset or distraught, as happened easily and often, he would begin flapping his hands and scream in a high pitched tone. He was noted to be a toe walker and have odd eye contact with others as though he were looking through or above the other person. His short attention span led to most sessions being cut short. JS showed a lack of awareness of himself as well as others in his environment. Because he did not participate fully in the treatment as well as his behavior during sessions, the clinician began to question whether integral stimulation therapy was the right course of treatment for JS. After 10 sessions, a meeting was held with JS' family to discuss the concerns regarding his participation in the study. It was decided that JS would no longer participate in the study but would continue to be seen in the PSU clinic by another student clinician.

Several weeks later in the term, JS and his family visited a developmental pediatrician who diagnosed JS as having Autism Spectrum Disorder (ASD). Although the lack of speech and language skills that JS exhibited might be interpreted by some as an apraxia of speech, it is clear that his participation in this study was inappropriate. The combination of his overarching diagnosis, lack of attention, lack of understanding of language and its appropriate uses, his perseveratory behaviors, and lack of awareness of self and others made integral stimulation therapy nearly impossible to implement. Treatments based on gaining an understanding of the various functions of language use as well as those dedicated to creating motivation to communicate have proven more productive for JS.

Discussion

This discussion examines the hypothesis that higher numbers of productions of speech sounds within the framework of integral stimulation therapy increases the accuracy of those speech sounds in-session and leads to motor learning, indicated by generalization of trained sounds to untrained words. The overall effectiveness of integral stimulation therapy is discussed in relation to each participant as well as a comparison of the two treatment conditions and their results. The discussion also examines the importance of establishing the precursors to motor learning, and the effects of each participant's age, motivation, relationship with the clinician, and environmental factors on the success of the treatment. Finally, this discussion examines the importance of accurate diagnosis of CAS in relation to the appropriateness of this treatment approach.

Effectiveness of integral stimulation therapy

For the 2 participants who completed the study, the integral stimulation therapy provided in both treatment conditions proved to be beneficial overall. JG expanded his speech sound repertoire and his consonant accuracy rose from 25% to 73% in 12 weeks. Motor learning was accomplished over the course of the study. This is evidenced by the fact that during the three baseline probe sessions JG's accuracy was at 0%, but by the end of the treatment phase his accuracy for Treatment B (100+) probes was at 35%. This accuracy elevated to 45% in the post-treatment session. Accuracy of production of sounds treated with Treatment A rose from 0% at baseline to as high as 92% in session #29. While accuracy was not maintained across sessions it shows that although the sounds treated with a higher frequency of production saw greater overall progress and generalization, sounds treated with the lower frequency of production and all the other principles of integral stimulation, progressed as well. While he never reached 80% accuracy on any probe measure during the treatment phase, post-treatment probe accuracy increased and skills were maintained after the 2 week break, suggesting that learning occurred. Other indications of learning include parent report that JG began speaking more with people outside of the clinic room, began using his trained sounds in more and varied contexts in his daily life, and began to use untrained sounds as well.

The data for AG show that he made progress over the course of the study as well. Motor performance, in-session accuracy, of targeted sounds rose for both treatment conditions over the course of the study. Again, sounds treated with the higher number repetitions showed greater progress, but progress was seen for both treatment conditions indicating that integral stimulation was an effective treatment overall. Accuracy of in-session productions for Treatment A (30-40) rose from 0% at baseline to 68% in the last session. Accuracy for Treatment B (100+) was consistently high throughout the study. AG's consonant accuracy rose from 21% to 32% in just 5 weeks of treatment. He showed maintenance of skills for sounds treated with the higher frequency of production, Treatment B, during post treatment probes. Post-treatment probe scores rose indicating that some learning had occurred. Other indications of the success of the treatment for AG include parent report that he began to use a wider variety of speech sounds in his home environment. While integral stimulation therapy had differing effects for each of the participants, it was shown to be effective for both.

Comparison of Treatment Conditions

Both participants appeared to benefit from all aspects of integral stimulation over the course of the study. For JG, the variety of cues used by both the clinician and JG enhanced practice of target sounds. He benefited from tactile cues to the face to remind him of where to place his articulators. Accuracy of productions increased when he looked in the mirror and received visual feedback about his articulators as well as when he received visual and tactile input from the flip book. Choral speaking improved accuracy as well. As treatment progressed, all cues were faded and accuracy was maintained. Cues were rarely used in the last three or four sessions. While AG still needed cueing at the end of the treatment phase, he was often self cued while practicing target sounds.

Variability of practice and mass versus distributed practice were two aspects of integral stimulation that were different across participants. While every effort was made to make sure all participants received the same treatment, these differences were unavoidable because of scheduling issues for AG's family. AG was seen twice a week as opposed to three times a week like JG. AG was only seen at PSU while JG was seen in three different locations. JG not only received more treatment over the course of the week, distributed practice, but he received more variable practice. JG received 10 weeks of treatment while AG received only 5 weeks. It is possible to speculate that had AG received not only the same number of treatments over the course of 10 weeks as opposed to 5 and the same variability of practice, his progress may have been more dramatic than it was. It is also important to note that this clinician was not able to develop the same kind of positive relationships or systemic treatment approach with

AG's family as she had with JG's family because treatment time was much shorter and schedules did not allow for home visits or for collaboration with AG's family members. Had a more family-friendly approach been achieved, even more progress may have been seen. In spite of these differences in treatment conditions, both participants made gains during the course of the study.

While participants showed benefit from other aspects of integral stimulation therapy, it is clear that learning and maintenance of skills for both participants was greater for sounds treated with higher numbers of repetition. The data show that the speech sounds treated with Treatment condition B (100+) led to higher in-session accuracy and greater generalization effects for both participants than sounds treated with the lesser number of repetitions. Not only did sounds treated with a higher number of repetitions show higher levels of accuracy overall during the course of the treatment, but high levels of accuracy were achieved in fewer sessions than sounds treated with fewer productions. Sounds treated with a high number of productions showed less variability over the course of treatment, meaning accuracy did not vary from session to session, as much as it did for sounds treated with lesser numbers of productions. Sounds treated with more productions generalized better to untrained words and showed more stability overall. Both participants also demonstrated better retention of the sounds treated with more repetitions during the post-treatment probes.

Individual Responses to Integral Stimulation Therapy

The following paragraphs outline each individual participant's response to treatment. Participants are discussed individually because of the variance in severity of their apraxia, their varied responses to integral stimulation therapy, and the challenge of conducting this type of treatment with a participant with multiple diagnoses. The discussion also outlines the importance of establishing the precursors to motor learning, the possible effects those precursors may have had on the success of the treatment, and the importance of proper and careful diagnosis of CAS.

Effectiveness of treatment for severe apraxia of speech

Prior to the current study, this clinician worked with JG for 6 months during the 2006/07 school year and implemented integral stimulation therapy. The results from that 6 month treatment period were not nearly as dramatic as those achieved during this study. There may be several reasons for this. During the 2006/07 school year JG was seen for 50 minute sessions twice a week. While he showed some progress during that time, acquiring several speech sounds which he was not previously able to articulate, he did not consistently combine the target sounds into words or generalize those sounds into communicative attempts outside of the clinic room. JG was shy and had a loving family who anticipated most of his needs, and many months were spent trying to motivate JG to want to communicate at all and to establish the precursors to motor learning.

During this study JG was seen three times a week for 40 minutes at a time as opposed to the two, 50 minute sessions per week in previous terms. It is the opinion of the clinician that the frequency of repetition, intensity, and consistency of the sessions over the course of the study led to greater practice time overall which in turn lead to greater success for JG. As he experienced more success, his confidence grew, and his motivation to practice intensely increased. He began to self cue using the tactile cues developed in treatment and self correct in sessions as well as in his other environments.

Other factors contributing to his success may be an increase in JG's maturity and an increased desire to communicate. In addition, the success achieved in previous treatment likely led to an increase in trust of the clinician and motivation to further develop communication skills. These factors also likely contributed to the family's greater commitment to participate in home therapy. The clinician also made a concerted effort to form a positive relationship with the family by including them in functional goal setting and helping them to brainstorm ways in which they could include practice of speech sounds into their daily lives. The variability of practice situations may also have contributed to JG's success. It seemed that when he had to practice speech in these various environments, it became clear to JG that he needed to use his skills in all areas of his life not just in the clinic room.

While JG experienced great success over the course of the study overall, there were fluctuations in the accuracy of probe word productions leading the clinician to question whether motor learning was not occurring or whether the variability seen was an issue of motivation. Probes were not functional, not motivating, and had never been worked on in the session. No games were played during the probe administration and no praise was given. It became clear that JG had no interest in participating in the probe drills and often protested vocally at the beginning of the administration of the probes. It is the opinion of the clinician that JG's performance on the probes was not a true measure of his learning or his abilities but of his interest in completing the probes. It was decided that the probe administration needed to be altered.

An accuracy meter was created by the clinician on a piece of construction paper. One half was green and one half was red. A fastener was used to attach an arrow to the middle which could be swiveled to the red or green side of the meter. JG was instructed that he was in charge of assessing whether or not he had made the correct sound by moving the arrow to the appropriate side after he said the word. The clinician said the word and asked JG to repeat it. He was then asked to assess his production. By using the accuracy meter in this manner, JG's production of the target word was not altered in any way before his production of the probe. It was only after his production that he was given feedback and asked to self-critique. Accuracy of probes for Treatment B increased from 5% in session 24 to 30% in session 25 when the meter was introduced. Accuracy remained between 30% and 45% with one session reaching 60% using the meter. Probes for Treatment A also saw an increase in accuracy, less so than for Treatment B probes, ranging from 10% to 45%.

While an increase in probe accuracy can be seen after the implementation of the rate meter, no stability was ever reached for the probes over time. Several reasons may have contributed to the lack of stability. It could be that due to the severity of JG's apraxia, motor learning was not yet cemented for the targeted speech sounds and more practice was needed to see generalization to all words with those speech sounds. JG's desire to participate, even with the accuracy meter, still fluctuated over the course of the study. As the rate meter lost its novelty near the end of the study, accuracy once again declined. The final factor that may have contributed to lack of probe accuracy may be due to a huge life change for JG and his family that occurred three quarters of the way through the study. The family adopted an 8-year-old boy from China while

JG was participating in this study. While the family made every effort to maintain the designated schedule, there were missed sessions, and JG was clearly disoriented and distraught by the addition of the new family member.

In spite of these challenges, however, it is clear that JG made progress through participating in this study. Integral stimulation therapy helped JG make gains in the acquisition of speech sounds in general. More specifically, he made the most gains in the sounds /f/ and /v/ treated with Treatment B (100+). The results of the study indicate that integral stimulation alone can be a beneficial treatment for CAS, but the frequency of repetition and intensity with which speech sounds are practiced has an effect on the speed of acquisition of targets, the level of in-session accuracy, and motor learning. Although generalization to untrained probe words never reached levels of 80% or better and showed variability across sessions, generalization was seen for both treatment conditions. While both conditions saw some generalization effects, the greatest generalization was seen for Treatment B.

Importance of establishing the precursors to motor learning

AG is an example of a child with probable CAS who made progress over the course of the study but for whom integral stimulation may have been even more powerful had several other factors been in place. The most important factor was that the precursors to motor learning were not established with AG before treatment began. AG and the clinician had never met before he began to participate in the study, and a friendship and trust were not established prior to the study. The clinician's inability to clearly motivate AG was another key factor for why this treatment yielded lesser results for this participant. He was the youngest child in a family of six. According to his family's report, AG was a shy child who rarely spoke and when he did he was quite soft spoken. Most of the family spoke for him, anticipating his needs and not requiring that he use his own voice. The family also reported a "stubborn streak" which often prevented JS from talking. AG's age may also have played a factor only in that his ability to comprehend the task at hand and why he was doing what he was doing may have been affected by his young age.

Other factors contributing to a lesser amount of success for AG could be that he was recruited into the study late. This late entry meant only 5 weeks of treatment as compared to the 10 weeks that JG received. The lack of motor learning, evidenced by low accuracy of probe productions, could be due to the fact that he received significantly less treatment that JG and learning had not yet occurred. Because of the family and clinician's busy schedules, JG could only be seen at PSU twice a week so distributed practice could not be implemented. Again, this differs from JG who received three sessions per week. In addition to the precursors to motor learning and the lesser amount of treatment he received, the intensity of the treatment may not have been appropriate for this participant. AG had never participated in this kind of treatment in the past and had never been seen in the PSU clinic before. The combination of his maturity and the lack of establishment of the precursors to motor learning may have affected his progress.

It should be noted that integral stimulation may be an even more effective treatment for AG in the future. It is possible that in the future if the precursors to motor learning were met and a longer treatment regimen was implemented, AG's progress could be more significant than it was during his participation in this study. It is also possible that in the future if a more family-focused approach were taken by the treating clinician and the family was included more during the treatment process, even more progress could be seen.

Another factor to consider is the appropriateness of an apraxia diagnosis for AG. He was included in the study because certain signs and symptoms indicated CAS. His difficulty sequencing sounds was the biggest indicator of CAS. Throughout the study, however, it was noted that AG had very consistent error patterns and his prosody was typical. Questions still remain as to whether or not he is an individual with CAS.

Importance of Accuracy of Diagnosis

JS is an example of a child for whom integral stimulation was not the best treatment option. From the beginning of the treatment it was obvious that JS was struggling with the format and rigor of the sessions. As stated previously, he did not complete the sessions or the probes and was removed from the study due to lack of appropriateness.

It is still unclear at this point whether or not JS truly has motor planning issues. It is clear that a diagnosis of ASD ruled him out as a candidate for this type of treatment. The motor learning literature clearly defines the type of candidate who will benefit from integral stimulation therapy (ASHA, 2007; Ball et al., 2002; Lewis, Hansen, et al., 2004; Strand, 1995). Precursors to motor learning such as comprehending the task at hand, being able to self monitor, comprehending instructions from the clinician about what is being practiced and why, and motivation on the part of the client are concepts that must be in place in order for integral stimulation to be successful (ASHA, 2007; Ballard, 2001; Duffy, 2005; Rosenbek et al., 1973; Schmidt & Wrisberg, 2004; Velleman, 2006; Yorkston et al., 1999). JS did not follow one and two step directions, did not demonstrate the ability to monitor his own speech, and demonstrated no internal motivation. He gave no indication of comprehension of any of the speech tasks.

This case is an illustration of the need to be cautious when diagnosing a child with CAS and to take all factors of a child's disorder into account before deciding on the best treatment options. The red flags for ASD should have been looked into more closely by this clinician before beginning treatment. A diagnosis of ASD does not completely eliminate a child from participating in integral stimulation therapy; rather the precursors to motor learning and ability to undergo a rigorous treatment approach are the criteria which should determine a participant's appropriateness for treatment of this kind.

Limitations and Cautions

While the broad outcomes of the study indicate that integral stimulation is an effective and promising treatment approach for children with CAS, there are limitations to the applicability of the data. The small number of participants in the study makes generalization of the data to all children with CAS difficult. Larger scale studies are needed to replicate these results with more children diagnosed with CAS.

The variability seen in the probe data for JG should be interpreted with caution due to the life changes that his family experienced over the course of the study. The data from AG should also be interpreted with caution because of the limited number of sessions that he was seen and the issues relating age and personality that were discussed earlier. Another caution must be noted regarding the data from AG. At first glance it may look as though Treatment B was a huge success with in-session accuracy never dropping below 90% while the numbers for Treatment A show very little in-session accuracy. One could read these data as showing conclusive evidence that more practice of the targeted sounds in treatment B led to such high success rates. The reader is cautioned to interpret the data carefully. The phonemes /p/, /b/, and /m/ were chosen as targets based on the very low incidence of these sounds in the speech sample taken during the assessment period and the number of errors heard for these sounds during the speech sample. The targets /f/ and /v/ were chosen because they were never heard in the speech sample.

The random assignment of /p/, /b/, and /m/ to Treatment B with a higher number of productions allowed AG to practice sounds which he had in his phonemic repertoire but which were not always correctly articulated. The targets /f/ and /v/, on the other hand, were sounds AG did not possess in his repertoire at all and which were extremely hard for him to produce. He did not ever incorporate /f/ and /v/ into anything beyond a CV or VC syllable. The clinician wonders what the results for /f/ and /v/ would have looked like had these sounds been treated with condition B and a grater number of productions.

This study can also be used as a cautionary warning for any speech-language pathologist working with children who may have multiple diagnoses that may include CAS. It is imperative for the clinician to assess a child’s readiness and appropriateness for this rigorous type of treatment by referring to the precursors to motor learning. Integral stimulation treatment should not be implemented until the precursors to motor learning have been met by the child. Clinicians must also weigh the benefit of this type of treatment for children with suspected CAS and other concomitant diagnoses.

Conclusions

The results of this study indicate 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 for two children with moderate to severe CAS. Strengths of the study include a solid single subject design and data tracking system set up by the clinician to capture in-session and probe accuracy. Data were tracked meticulously for every session, and all sessions were audio taped or video recorded so data could be analyzed and reflected upon at a later date. The clinician possessed a high level of understanding of integral stimulation therapy because of previous experience implementing the treatment with JG as well as other children.

In regards to JG's participation and success in the study, all of the precursors to motor learning had been established with JG in previous terms. The participant began treatment quickly and with a strong foundation in place. The fact that the clinician was able to develop a positive working relationship with the family and include them in goal setting as well as finding functional ways for them to practice targets in their daily lives led to a more in depth experience for JG. The involvement of the school personnel was also beneficial and contributed to his success. With the strength of the family and community support as well as the rigorous work in the clinic room, JG generalized his skills to environments beyond the clinic. The family's commitment to the study and regular attendance were also factors in his success.

Limitations of the study include the small number of participants and the limited number of sessions that AG was treated. The data from AG would be stronger had he received the same number of treatment sessions as JG. Another large limitation of the study was that, unlike with JG, the precursors to motor learning were never established with AG prior to beginning treatment. The data would likely show even greater results had the foundation for treatment been laid ahead of time. A final limitation would be that a child with an overarching diagnosis of ASD was unknowingly admitted into the study. While no harm was done by administering integral stimulation therapy to JS, a child with ASD, it is clear that he spent many weeks participating in a treatment that did not benefit him. The family's time would have been better spent had he been accurately diagnosed from the beginning and given the proper treatment.

Research implications of this study mirror those proposed by other authors (Rosenbek et al. 1973; Strand & Debertine, 2000; Strand et al., 2006). Integral stimulation can be an effective tool for remediating some of the speech sound errors of children with moderate and severe CAS. This study also echoes the thoughts of Strand et al. (2006) that motivation on the part of the client and the foundation of therapy in the form of the principles of motor learning are imperative to the success of this treatment. Finally, as is indicated by all researchers in this area (Ball et al., 2002; Davis & Velleman, 2000; Forrest, 2003; Lewis, Hansen, et al., 2004; Shriberg, 1994) children with CAS can be a difficult and frustrating population to work with based on their slow progress in therapy and the severity of the articulation issues that they present with. While small scale studies have shown the effectiveness of integral stimulation therapy for children with CAS, the ability to generalize the data from the studies is limited. Like any population of children with severe speech and language disorders, children with CAS deserve to be treated with the most efficacious and time effective treatment available. More research is needed to address integral stimulation's ability to fill that role.

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Appendix A

Parent Informed Consent Form

Dear Parents/Guardians,

My name is Denice Edeal, and I am a graduate student in the Portland State University Speech and Hearing Sciences Program. I am contacting you to invite you to participate in a research project that I will be conducting at PSU as part of my thesis project for my master's degree. The project will look at the effectiveness of a specific treatment called Integral Stimulation in treating speech sound disorders in children.

Integral Stimulation therapy is thought to be effective for increasing speech intelligibility with children with childhood apraxia of speech (CAS). Integral stimulation therapy is intended to increase motor learning and speech accuracy in children with severe speech disorders. While relatively few studies have assessed the effectiveness of this treatment for children with CAS, there is promising evidence from these studies to suggest that Integral Stimulation therapy can be an effective treatment for remediating the speech sound errors often seen in children with CAS. This study aims to add to the research evidence showing that this is an effective treatment for the CAS population.

Before I begin treating your child I will conduct an assessment to determine the speech goals that we will focus on in our sessions. The assessment will include me asking your child to name several pictures in a book, and engaging your child in conversation. After the assessment is completed I will begin treatment with your child based on their individual treatment needs. Treatment sessions will take place 3 days a week at Portland State University. Each session will last between 40 and 45 minutes. The specific dates and times of sessions will be scheduled at times that are mutually convenient. Assessment measures and baseline measures will be taken over a 1-2 week period. Treatment sessions will take place over 12 weeks. After the completion of the study, a 2-3 week break will be taken, and maintenance measures will be collected in 3 sessions over 1-2 weeks.

Before each session I will explain to you and your child the goals for the day as well as the activities that your child will be participating in. Often your child will be able to choose that activity that he/she would like to participate in first. During the sessions we will play different games and activities that are of interest to your child to keep things interesting, but at the same time we will be working on the speech sounds that I have chosen as goals for your child. Most sessions will be video and or audio taped. At the end of this research project your family will have the option to continue to receive services at the PSU clinic.

During treatment sessions you may see your child engaging in activities such as playing games and reading books that look very similar to other speech sessions that your child has participated in. The difference with Integral Stimulation therapy is that the treatment sessions will focus on getting as many productions of the target sounds possible. Other aspects of Integral Stimulation therapy that you may notice during sessions are that your child will be practicing many different target sounds at once. They will also be asked to repeat target words and sounds in unison with the clinician and watch themselves in the mirror to practice sounds and form words.

You may notice some potential difficulties around participating in this study. You and your family will be asked to dedicate a large amount of time in coming to PSU for treatment sessions. Every effort will be made to accommodate your family's schedule, and at times, sessions can be scheduled at your home if this is more convenient for you. While watching sessions, you may notice that your child is engaged in vigorous and intense practice of speech sounds. You may hear them making may mistakes while practicing during the session. If the clinician senses that your child is feeling uncomfortable in any way or is not achieving a high level of success in their speech sound productions, the treatment will scaled back to an easier level to help your child attain a higher success rate. Your child may seem fatigued after sessions due to the fact that this type of intense articulation work is very difficult for children with CAS. Your child will be informed by the clinician that they will be allowed to take breaks at any point during the session if they feel overly tired or just need to rest.

All of the data that is collected from your child and your family for use in this project will be treated with the utmost respect and confidentiality. All pertinent information including assessments, treatment outcomes, signed forms, video, and audio tapes will be kept in a locked filing cabinet in my thesis director's locked laboratory. Your child will be given a code name, their first and last initial, and this name will be used on all written documents that are produced as a result of this study as well as on all assessment materials. The video and audio tapes will be used to determine the effectiveness of Integral Stimulation and for educational purposes only. You will receive a copy of all signed forms and documents.

Your participation in this project is completely voluntary. You may at any time choose to withdraw from this research project without affecting your relationship with PSU or with the PSU Speech and Hearing Clinic. In addition, if you withdraw you may continue receiving speech therapy services at PSU at the same cost as other non-research clients. If you choose to withdraw from the study you will be placed at the top of the waiting list and you will be contacted when another student clinician becomes available.

If you have any questions regarding further details of the study, I would be happy to talk with you at any time. The best number at which to reach me is (503) 309-1089. If you would like to speak with my thesis advisor, Dr. Christina Gildersleeve-Neumann, she can be reached at (503) 725-3230.

I thank you for your consideration. Your participation in this project will help us better understand speech difficulties experienced by children and the best way to treat them. If you would like to participate in this project, please fill out the information below, sign and date the bottom, and return the form in the enclosed envelope.

Sincerely,

Denice Edeal, Graduate Student, Speech and Hearing Sciences Program, Portland State University

I give my permission for my child ____________________________________, to participate in the research project described in this letter.

_________________________________ _______________________________

Parent/Guardians names Signature

____

Address City Zip Code

____________________________ _______________________________

Home number Work number

This project was explained to _________________________________ and he/she was wiling to participate.

_____________________________ _______________________________

Child's name Date of birth

If you have any concerns about your participation in this study, please contact either Dr. Christina Gildersleeve-Neumann at (503) 725-3230 or the Human Participants Review Committee, Office of Research and Sponsored Projects, 600 Unitus Building, Portland State University, (503) 725-4288 or at their toll free number 1-877-480-4400.

Appendix B

Child Assent Form

Child's name ____________________________

My name is Denice, and I will be working with you on your speech this term. Before we start working together I'd like to find out what kinds of things you are interested in; your hobbies, sports you like, games you like to play. I will try to incorporate some of those things into our sessions together. During our sessions we will play a lot of games that are interesting to you, and you will get to choose some of the activities that we do. I will try to make our time together fun and interesting, but at the same time we will be working hard together.

At the end of our time together I will write a big paper about the work that we did and the great progress that you made. The paper will hopefully help other teachers like me be able to figure out the best way to help kids speak clearer. You and I will be a team, and we will help lots of other people with the work that we are doing.

If you ever have any questions about what we are doing, why we are doing it or are confused in any way, be sure to tell me. If you need a break, let me know and we will take a break. If you want to stop we will stop, and I will never be upset or mad at you. If you don't want to work with me at all that's fine too, you just need to tell me or your parents.

I'm excited to begin working with you. We will both work very hard, but we will have some fun too. Do you want to get started? Denice

Appendix C

Example of a Reliability Transcription Sheet

Session # 4, treatment 1

Participant: JG

1. fife ____________
2. forth ____________
3. whip ____________
4. vet ____________
5. live ____________
6. moat ____________
7. fill ____________
8. vague ____________
9. man ____________
10. vim ____________
11. fuzz ____________
12. bait ____________
13. love ____________
14. move ____________
15. meat ____________
16. goof ____________
17. veer ____________
18. boar ____________
19. vine ____________
20. shove ____________

vile ____________

fad ____________

peep ____________

photo ____________

fight ____________

pop ____________

save ____________

fear ____________

bag ____________

21. boil ______________

Session # 4, treatment 2

Participant: JG

1. add ______________
2. load ______________
3. more _____________
4. wet ______________
5. bait ______________
6. got ______________
7. mush ______________
8. goat ______________
9. bud ______________
10. sill ______________
11. mowed _____________
12. sheet ______________
13. peek ______________
14. Dan ______________
15. deal ______________
16. pack ______________
17. put ______________
18. dude _____________
19. zoo _____________
20. tune ______________
21. road ______________

pea ______________

hut ______________

tip ______________

ton ________________

bag ________________

teen ________________

teeth ________________

sap ______________

mill ______________

Appendix D

Integral Stimulation Checklist

Session # _____________ Participant ____________

Characteristic	1st treatment	2nd treatment
Feedback: Knowledge of results (right/wrong) Knowledge of performance (how right or wrong)		
Practice: Blocked (one sound practiced at a time) Random (multiple targets practiced at once)		
Variability: practice at the syllable level, word, level, or phrase level practice in various places in the word		
Rate: Slowed when necessary		
Cues: Visual (mirrors, watching clinician, flip book) Auditory (choral speaking, "watch me and listen to me") Tactile (cues to the face of child or clinician)		
Hierarchies: moving child up or down depending on success (ex: from sentence to word level and back up)		

Appendix E

Word and phrase list for JG

Treatment A (30-40), /t/ and /d/	Treatment B (100+), /f/ and /v/
eat	have
done	off
tea	feet
hot	fire
two	fireman
ten	food
eight	love
my turn	four
all done	five
I wanna eat	Foo mei (his sister's name)
	I wanna have
	I love
	I'm full
	Hi Foo mei

Appendix F

Word and phrase list for AG

Treatment A (30-40), /f/ and /v/	Treatment B (100+) /p/, /b/, and /m/
off	more
fa	mine
fast	want
voom	bus
	boy
	bear
	moo
	pig
	bow wow
	peep
	no more
	I want more