

Abstract

Motor Learning Guided Treatment with Childhood Apraxia of Speech: Cueing & Feedback

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The aim of this study was to determine if participants with childhood apraxia of speech (CAS) respond with improved speech production when provided motor learning guided (MLG) treatment strategies. Five participants, chronological ages 4;8 to 5;10 years, were provided three different types of treatment where cueing and feedback were systematically manipulated for six weeks. Treatment types included the following: verbal model with knowledge of performance feedback (VMKP), verbal model with knowledge of results feedback (VMKR), and visual model with knowledge of results feedback (KR). Each participant received 24 individual sessions, lasting approximately 15 minutes each for a total of 360 minutes. Following VMKP treatment, participants increased performance accuracy by an average of 13.4%. Following VMKR treatment, participants increased performance accuracy by an average of 4.8%. Finally, following KR treatment, participants increased performance accuracy by an average of 16%. All three treatment types produced positive outcomes; however, KR treatment resulted in the strongest positive outcome. The results of this study suggest that children with CAS may benefit from intervention where no verbal model is provided prior to speech practice and summary knowledge of results feedback is offered at intervals following 5 productions. Intervention in this

study resulted in increased accuracy of speech performance and yielded optimal motor learning of those speech skills.

Motor Learning Guided Treatment with Childhood Apraxia of Speech: Cueing & Feedback

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Motor Learning Guided Treatment with Childhood Apraxia of Speech: Cueing & Feedback

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Chapter 1: Introduction

Childhood Apraxia of Speech (CAS) is a neurological motor planning disorder affecting a child's ability to produce speech accurately. Previous researchers identified children with CAS using inconsistent diagnostic criteria due to a lack of specific guidelines (Forrest, 2003). This variability in diagnostic certainty has made it difficult to determine which treatment model might provide optimal improvement of speech. Heightened interest in CAS research in recent years led the American Speech-Language-Hearing Association (ASHA) to form an Ad Hoc committee tasked at reviewing and interpreting available diagnostic/treatment evidence (ASHA, 2007). The ASHA Ad Hoc Committee on CAS (2007) established CAS as a neurologic speech disorder and set guidelines for the definition of CAS. With diagnostic guidelines now in place, researchers may begin to evaluate what intervention strategies are most appropriate for CAS. Motor Learning Guided Treatment (MLG) has been used successfully to treat acquired apraxia of speech (AOS), an adult disorder with similarities in speech characteristics; but MLG has not yet been applied to the treatment of CAS (Austermann Hula, Robin, Maas, Ballard, & Schmidt, 2008)

Childhood Apraxia of Speech

ASHA (2007) defined CAS as “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.” CAS presents itself as an “impairment in planning and/or programming spatiotemporal parameters of movement sequences” which results in speech sound production errors (ASHA, 2007). The ASHA technical report (2007) also identified three features consistent with the CAS diagnosis, or speech sound disorders with deficits in motor planning, in order to aid researchers in distinguishing children with CAS from children with

other motor speech disorders. The three features include “(1) inconsistent errors on consonants and vowels in repeated productions of syllables or words, (2) lengthened and disrupted coarticulatory transitions between sounds and syllables, and (3) inappropriate prosody, especially in the realization of lexical or phrasal stress” (ASHA, 2007).

Previously, researchers used a variety of characteristics to qualify children with a diagnosis of CAS for research studies. Forrest (2003) reported results from a survey of speech-language pathologists (SLPs) asked to describe diagnostic criteria they used to identify children with CAS. The SLPs most commonly reported the following characteristics for the diagnosis of CAS: inconsistent productions, general oral-motor difficulties, groping (e.g., searching for accurate tongue placement for speech production), inability to imitate sounds, increased errors with increased utterance length, and poor sequencing of sounds. Other characteristics often reported included vowel errors, motor programming problems, slow progress in therapy, and reduced intelligibility (Forrest, 2003). The ASHA technical report on CAS (2007) confirmed that there was no single validated list of diagnostic characteristics of CAS to differentiate it from other childhood speech sound disorders. However, the characteristics used to select children with CAS for this study were derived using guidelines from that report. They included the presence of one or more features from the following categories: motor speech behavior (impaired production of trisyllabic DDK sequences, impaired nonword repetition, impaired multisyllabic word repetition), speech sounds and structures (vowel errors, inconsistent speech errors, articulatory regression, improved performance on automatic vs. volitional productions, errors on production order), and prosody (prolonged sounds, prolonged pauses, syllable segregation, excess equal stress).

Treatment Approaches

Previous researchers targeted definitions of CAS to meet the needs of individual studies, thus making it difficult to determine how children with CAS learn speech sound targets (Austerman Hula, Robin, Maas, Ballard, & Schmidt, 2008; Moriarty and Gillon, 2006; Strand, Stoeckel, & Baas, 2006; Maassan, Nijland, & Van Der Meulen, 2001; Hayden 2006). Numerous treatment strategies have previously been applied to CAS consisting of both non-motor (Hayden, 2006; Moriarty and Gillon, 2006; McNeill, Gillon, & Dodd, 2009) and motor approaches (Austermann Hula et al., 2008; Fountain, Lasker, & Stierwalt, 2007; Strand et al., 2006).

Non-motor strategies applied to CAS include phonetic or phonological approaches (Hayden, 2006; Moriarty and Gillon, 2006; McNeill et al., 2009). A phonological awareness approach to CAS involves simultaneous treatment of speech intelligibility, phonological awareness, and reading development (Moriarty & Gillon, 2006). Moriarty and Gillon (2006) implemented a phonological awareness approach to treatment of CAS and results of their research suggested that some children with CAS were able to generalize accurate speech production of target words to untreated targets. McNeil, Gillon, and Dodd (2009) applied the same phonological awareness approach to treatment of CAS with a larger sample size than Moriarty and Gillon (2006). McNeil et al. (2009) determined that nine out of 12 participants increased speech production accuracy of trained targets, but only half generalized accurate production to untreated targets.

Motor strategies previously applied for treatment incorporated principles of motor learning theory to the treatment of children with CAS (Strand et al., 2006) as well as adults with AOS (Austermann Hula et al., 2008; Fountain et al., 2007). Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT) is “a tactually grounded sensori-motor, cognitive-linguistic model and approach for speech production disorders” (Hayden, 2006).

Hayden (2006) presented a case study of a 7 year old male with a speech production disorder who was determined to have speech characterized by inconsistent errors and poor motor control. Structured PROMPT treatment was provided for his motor speech impairment and results suggested that tactile cues be used in treatment (Hayden, 2006). Freed, Marshall, and Frazier (1997) applied the PROMPT treatment model to one adult with AOS and aphasia and found that the approach resulted in improved speech production accuracy of most targets.

Dynamic temporal and tactile cueing (DTTC) “is a treatment approach based on integral stimulation, which emphasizes the shaping of movement gestures for speech production and continued practice of those gestures, in the context of speech” (Strand et al., 2006). Strand et al. (2006) investigated the effects of this approach among four participants with CAS and found that three of the four children’s speech production skills changed rapidly, but all still exhibited compromised intelligibility.

Principles of motor learning theory feedback have been applied to treatment for adult Apraxia of Speech (AOS). Success has been shown in speech movement learning with delayed and reduced frequency feedback (Austermann Hula et al., 2008). Austermann Hula et al. (2008) found that high frequency feedback helped in the initial phase of therapy, but low frequency feedback resulted in better long-term retention and generalization to different contexts. They found similar results when immediate versus delayed feedback was studied. Immediate feedback was beneficial during the initial phase of therapy; however, delayed feedback resulted in greater retention and transfer of trained speech skills to different contexts (Austermann Hula et al., 2008). This research applying motor learning treatments to AOS demonstrated positive outcomes, therefore suggesting potential for success when applied to CAS.

The ASHA (2007) definition of CAS provides consensus among researchers for inclusion/exclusion criteria that was previously unavailable. Motor learning treatments have proven successful with individuals with motor disabilities and adults with AOS. This suggests that a motor learning approach to the intervention of CAS may prove beneficial. The extensive review published by ASHA (2007) supports the application of principles of motor learning theory for treatment of CAS and indicated that principles of motor learning provide optimal treatment.

Motor Learning Theory

Motor Learning Theory has been applied to numerous intact, nonspeech motor systems in the past, but it is uncertain whether the same principles apply to impaired speech motor systems (Maas, Robin, Austermann Hula, Freedman, Wulf, Ballard, & Schmidt, 2008). Maas et al. (2008) hypothesized that applying a motor learning approach to the treatment of motor speech disorders should be beneficial because speech production is a motor act and should therefore be governed by the principles of motor learning.

Application of motor learning theory typically begins with a pre-practice period followed by application of practice with two principle considerations. The two main principles of motor learning consist of the structure of practice and the nature of augmented feedback. Structurally, practice is divided into amount, distribution, variability, schedule, attentional focus, and movement complexity. Structure of augmented feedback is described by type, frequency, and timing (Maas et al., 2008).

The pre-practice period is included to ensure that the learner fully understands the task instructions and is able to perform the task; thus it facilitates learning. The main goals for pre-practice are motivation, understanding, and stimulability. Stimulability is tested to determine

an individual's ability to produce incorrect speech targets after receiving cues and or models (Bauman-Waengler, 2008). Each of these goals tend to work together to facilitate learning. During prepractice, the clinician provides feedback to the participant by acknowledging correct productions and explaining how to correct incorrect productions (Maas et al., 2008).

When applying motor learning theory to speech treatment, the structure of practice has a major impact on the outcome of intervention. Mass et al. (2008) looked at previous research on non-speech, gross motor movements, as well as motoric speech movements to determine the effects of the following: amount of practice, practice distribution, practice variability, practice schedule, attentional focus, and movement complexity. When studying speech treatment, Maas et al. (2008) found that many treatment programs (Chumpelik, 1984; Fox, Morrison, Ramig, & Sapir, 2002; Rosenbek, Lemme, Ahern, Harris, & Wertz, 1973; Van Riper & Irwin, 1958; Wambaugh, Kalinyak-Rliszar) recommend giving a large number of trials, but there is no evidence supporting that more trials create better results. In non-speech studies (Baddeley & Longman, 1978; Shea, Lai, Black, & Park, 2000), it was found that distributed practice, as opposed to massed practice, facilitates short and long-term learning. Maas et al. (2008) also found that learning occurs best when it begins with constant practice and then switches to variable practice. Blocked practice facilitates learning early in treatment, but random practice results in greater retention of speech sounds (Knock, Ballard, Robin, & Schmidt, 2000). Maas et al. (2008) also looked at research on the effects of attentional focus. He found that these effects have not been studied in the area of speech motor learning, but external focus aids learning for non-speech motor tasks (Hodges & Franks, 2001; Vance, Wulf, McNevin, Tollner, & Mercer, 2004; Wulf, McNevin, & Shea, 2001). Evidence also supports using more complex targets to facilitate generalization to less complex targets (Maas et al., 2008).

Augmented feedback is “feedback that is given in addition to the individual’s own intrinsic feedback” (Maas et al., 2008). The structure (i.e., type, frequency, timing) of augmented feedback is a key aspect of motor learning. The researcher can provide two types of feedback to clients, which include knowledge of results (KR) and knowledge of performance (KP). KR is information that is provided about the movement outcome in relation to the goal, and is provided after the completion of a movement (Maas et al., 2008) (e.g., “I heard you say pish instead of fish”). In contrast, KP refers information that is provided regarding the nature or quality of the movement pattern (Maas et al., 2008) (e.g., correct/incorrect). The effects of each of these types of feedback have rarely been applied to speech motor learning interventions.

Feedback frequency can be provided at high or low levels based on the individual’s learning skills or level of task difficulty. Austermann Hula et al. (2008) described low frequency feedback as that feedback presented after 60% of productions; whereas high frequency feedback was defined as that presented after 100% of productions. Recent research indicates that low frequency feedback enhances motor learning of speech sounds by facilitating retention and transfer (Austermann Hula et al., 2008).

Feedback timing can also be altered in treatment. It may be provided immediately following a production, after a brief delay of a specified amount, or in summary form following all productions. Mass et al. (2008) found minimal research regarding feedback timing for speech tasks, making it difficult to determine which type of feedback timing enhances speech motor learning.

Fountain et al. (2007) applied a Motor Learning Guided Approach (MLG) in combination with augmentative and alternative communication to the treatment of adults with severe apraxia of speech. They found that by reducing the amount of feedback provided by the clinician, subjects were more successful with speech treatment targets. The researchers posited that this

might have been due to the subjects' development of self-evaluation skills facilitated by repetitive practice and limited feedback from the clinician (Fountain et al., 2007). Reduction of the amount of feedback provided by clinicians' may have potential benefits for children with CAS.

Summary and Rationale

As is apparent in the literature, selected principles of motor learning theory may be applicable in the treatment of CAS. Application of selected principles of motor learning would determine if aspects of the treatment aid participants in increasing accuracy of speech sound targets. Maas et al. (2008) report that studies regarding the treatment for individuals (re)learning motor skills may offer valuable information that could assist in the treatment of speech impairments in individuals with motor speech disorders. Speech is ultimately a motor skill that has to be relearned in adults and learned in children (Maas et al., 2008).

The goals of this research are to determine (1) if children with CAS respond with improved speech production to motor learning guided (MLG) treatment strategies, (2) the type of cueing and feedback needed to increase accuracy of production, and (3) if MLG treatment results in increased accuracy of production during the subsequent treatment session, thus serving as an indicator of motor learning. The benefit of this research would be the provision of evidenced based practice regarding treatment of CAS to SLPs.

Research Questions

1. Does level of cueing support (i.e., verbal model) influence accuracy of production during treatment sessions (i.e., improve motor performance)?
2. Does feedback type (i.e., KP or KR) influence accuracy of production during motor learning focused speech treatment?

Chapter 2: Method

Participants

Five children, chronological ages 4;8 to 5;10 years, with suspected CAS were recruited from the East Carolina University Speech-Language and Hearing Clinic and surrounding areas to participate in this research study. In order to be included in the study, each participant demonstrated the following characteristics: (1) hearing within normal limits on audiometric screening, (2) normal/corrected visual acuity, (3) native speakers of American English, and (4) diagnosis of CAS as determined during pre-testing for study.

After being included in the study, one parent revealed that one participant had bilateral myringotomy with tube insertion immediately prior to beginning the study. Still, this participant was included in the study because she had passed the hearing screening and the speech sound errors made during pretreatment testing were not consistent with error patterns of children with hearing loss (Shriberg & McSweeny, 2002).

Pre-testing. Prior to beginning the study each potential participant was evaluated in a quiet, well-lighted room at the East Carolina University Speech-Language and Hearing Clinic for approximately 1.5 hours to determine if they met the characteristics of CAS as defined by the ASHA technical report (2007). Tests administered included: *Clinical Assessment of Articulation and Phonology* (CAAP, Secord & Donohue, 2002), *Kaufman Speech Praxis Test for Children* (KSPT, Kaufman, 1995), *Primary Test of Nonverbal Intelligence* (PTONI, Ehrlert & McGhee, 2008), *Test of Auditory Comprehension of Language, 3rd Edition* (TACL-3, Carrow-Woolfolk, 1999). The CAAP was administered to measure articulation skills by having the participants independently name pictures. The KSPT was administered to measure each participant's imitative abilities and determine the level at which the speech system breaks down. The PTONI was administered to assess nonverbal intelligence, aptitude, abstract reasoning, and problem

solving abilities. The TACL-3 was administered to assess receptive vocabulary knowledge, meaning of grammatical morphemes, and syntactic understanding of elaborated phrases and sentences. The results of these tests for each participant with CAS can be found in Table 1.

Methods implemented to determine participant inclusion. Specific inclusion factors consisted of (a) syllable repetitions [e.g., maximum repetition rate, alternating repetition rate, diadochokinesis]; (b) challenging speech production tasks designed to elicit error patterns (Shriberg, Green, Campbell, McSweeny, & Scheer, 2003) including nonsense word repetition (Lewis, 2004). Percentage of vowels correct, percentage of consonants correct, and single word intelligibility were calculated (Dowden, 1999). Children found to have at least one feature from a checklist of behaviors derived from the ASHA technical report (2007) were diagnosed with CAS and included in the study. The CAS Inclusions Checklist appears in Table 2.

Stimuli

Participants comprised a heterogeneous group and therefore required individualized selection of speech sound targets for the study. Stimuli selected ranged in complexity from simple single consonant-vowel words to more motorically complex word combinations based on number of errors made during pre-test assessment and high functionality of the participant (e.g., egg, animals, zip your coat). High functionality was determined by the level at which the participant demonstrated breakdown in speech production. The stimuli consisted of symbols, photos, drawings paired with text. Participant's targets (i.e., speech sounds, utterance complexity) were selected based on errors produced during pre-testing; 80 stimuli were created for each participant in this manner. Additionally, target selection was based on the participant's literacy level and personal preferences. Once selected, the stimuli were then randomly ordered by an online random number generator (StatTrek.com, 2010) and were placed into two groups: 20

Participant	Age	Sex	PTONI	TACL	CAAP (SS, RS)	KSPT- OM	KSPT- S	KSPT- C
101	5; 1	F	107	121	71, 13	108	<49	45
102	5; 10	F	81	76	<55, 28	108	<49	19
103	4; 11	M	69	76	59, 23	106	<49	52
104	4; 8	F	113	121	<55, 36	108	<49	65
105	4; 10	M	103	96	<55, 33	106	<49	52

Table 1. Characteristics of participants with CAS. SS = standard score; RS = raw score; OM = oral movement; S = simple phonemic/syllabic level; C = complex phonemic/syllabic level; PTONI = *Primary Test of Nonverbal Intelligence*; TACL = *Test of Auditory Comprehension of Language*; CAAP = *Clinical Assessment of Articulation and Phonology*; KSPT = *Kaufman Speech Praxis Test for Children*.

	Participants				
	101	102	103	104	105
Motor Speech Behavior					
(1 or more feature)					
Impaired production of trisyllabic DDK sequences		X	X		X
Impaired nonword repetition	X	X	X	X	
Impaired multisyllabic word repetition	X	X	X	X	
Speech Sound & Structures					
(2 or more features)					
Vowel errors	X	X	X	X	X
Inconsistent speech errors	X	X	X	X	X
Improve automatic vs. volitional productions	X	X	X	X	X
Errors on production order	X				
Sounds	X	X	X	X	X
Morphemes					X
Words	X	X	X	X	X
Intelligibility of speech <90%		X	X	X	X

Table 2. CAS Inclusion Checklist

untreated probes and 60 treated stimuli. During all sessions, stimuli were presented visually on a 15.1 inch laptop computer screen via Microsoft PowerPoint.

Untreated probes. Untreated probes consisted of 20 stimuli that were used to evaluate initial baseline performance and improvements suggestive of generalization of treatment to untreated stimuli. Probes were administered at the beginning of every other treatment session (i.e., Sessions 1, 3, 5, 7). They produced each probe in succession without cues or feedback.

Treated stimuli. The 60 treated stimuli consisted of the remaining items from the original 80 stimuli. These stimuli were practiced during the treatment sessions and randomly assigned to each cueing/feedback treatment type. Thus, 20 stimuli were practiced during each of three treatment types where cueing/feedback were manipulated.

Treatment

Participants received treatment to determine the effectiveness of cueing and feedback techniques on MLG intervention for participants with CAS. Participants received six total weeks of three treatment types. Each treatment included eight treatment sessions over a two-week period. The five participants were randomly assigned to each of three treatment groups. The groups were counter balanced for treatment using a Latin square as depicted in Table 3. Two participants were placed into the first two groups, and the third group included one participant. Prior to each session, the presentation order of stimuli was randomized. All sessions were digitally audio-video recorded for later scoring of responses and analysis. The treatment rooms were equipped with Canon VC-C50i cameras and Crown PZM-10 ceiling mounted microphones. The control room had camera controls, pan/tilt and zoom, Marshall Electronics V-LCD20 monitors. Video and audio were captured with a Pinnacle Video Transfer device using H.264 video compression on a USB flash memory stick.

Group #	Treatment Order		
1 (n=2)	VMKP	VMKR	KR
2 (n=2)	VMKR	KR	VMKP
3 (n=1)	KR	VMKP	VMKR

Table 3. Treatment order by group. VMKP = Verbal Model with Knowledge of Performance Feedback; VMKR = Verbal Model with Knowledge of Results Feedback; KR = Knowledge of Results Feedback.

Verbal model with knowledge of performance (VMKP). The researcher provided a verbal model of each stimulus followed by 3 seconds of silence. Next, the participant was visually cued to imitate the stimulus 4 additional times (with a 3 second silent delay interval between each production). Participants received knowledge of performance feedback (e.g., “I heard you say...”) in summary form following the 5 productions. Figure 1 illustrates the procedures used for VMKP treatment.

Verbal model with knowledge of results (VMKR). The researcher provided a verbal model of each stimulus followed by 3 seconds of silence. Next, the participant was visually cued to imitate the stimulus 4 additional times (with a 3 second silent delay interval between each production). Participants received knowledge of results feedback (e.g., correct or incorrect) in summary form following all 5 productions. Figure 2 illustrates the procedures used for VMKR treatment.

Knowledge of results (KR). The researcher provided a visual cue (pointing) of each stimulus item followed by 3 seconds of silence. Next, the participant produced the stimulus item and the researcher visually cued the participant to produce the stimulus 4 additional times (with 3 second delay intervals of silence between each production). Participants received knowledge of results feedback (e.g., correct) in summary form following all 5 productions. Figure 3 illustrates the procedures used for KR treatment.

Structure of Sessions

Each participant attended a total of 24 individual sessions, lasting approximately 15 minutes each for a total of 360 treatment minutes. Participants were seated comfortably in a child-sized chair at a small table and asked to refrain from talking or asking questions (other than producing stimuli), particularly during the 3-second delay intervals. At Session 1 and at every

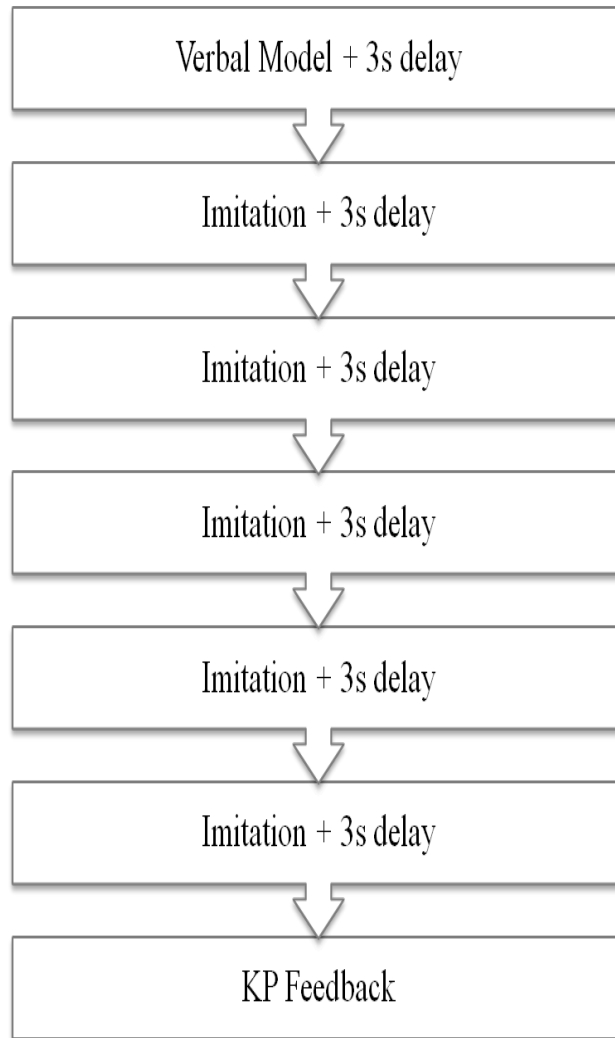


Figure 1. Verbal Model with Knowledge of Performance Schedule

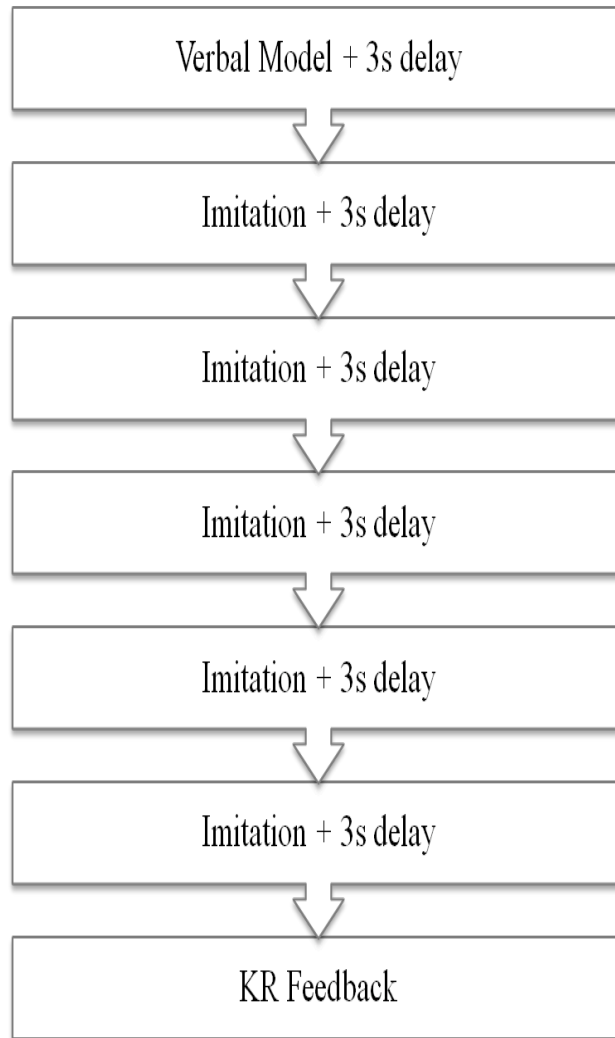


Figure 2. Verbal Model with Knowledge of Results Schedule

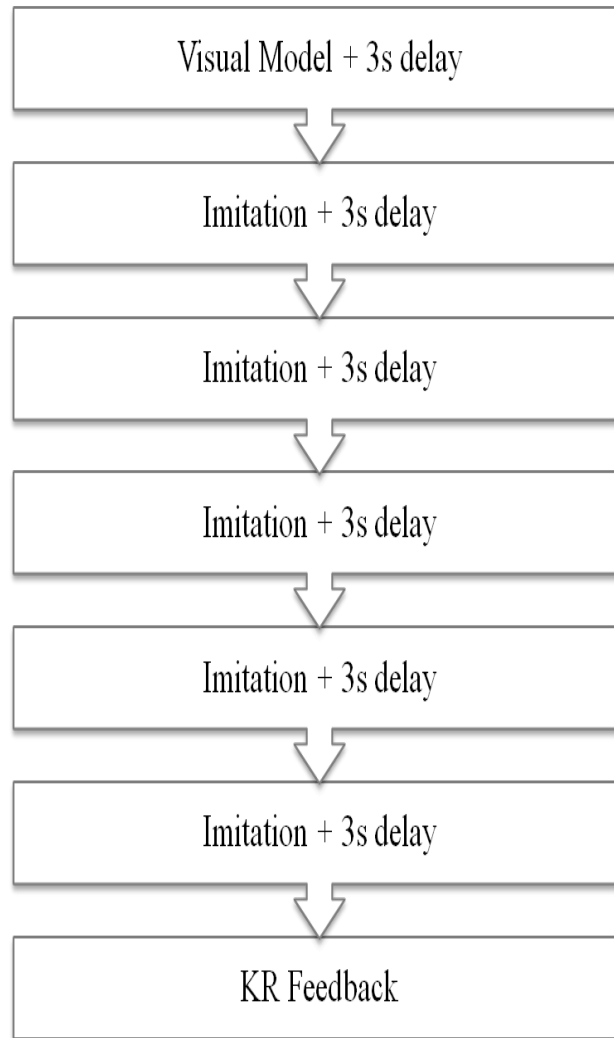


Figure 3. Visual Model with Knowledge of Results Schedule

other subsequent session (e.g., Sessions 3, 5, 7), the untreated probes were administered prior to the treatment practice. Each probe was presented once visually and the participant was asked to produce the item without a cued model or feedback. After probes were completed (i.e., on designated sessions), the researcher presented the 20 treated stimuli and produced a spoken model to cue the participant. Participants then produced the stimulus according to the cueing and feedback guidelines for the three treatment types. After all 20 treated stimuli were produced and practiced five times each, the session was complete.

Chapter 3: Results

Results for this study include descriptive statistics and some preliminary analyses for all three treatment types. The mean change for all participants within each treatment is illustrated in Figure 4. Following VMKP treatment, participants' accuracy of productions increased by an average of 13.4%. Following VMKR treatment, participants' accuracy of productions increased by an average of 4.8%. Finally, following KR treatment, participants' accuracy of productions increased by an average of 16%.

Figure 5 presents the percent of change with each treatment type for each participant; it illustrates the positive progress made for all participants when provided KR treatment. During both VMKP and VMKR treatments one participant displayed a negative response to treatment.

Verbal Model with Knowledge of Performance (VMKP)

When given a verbal model and knowledge of performance, participants presented a positive trend in accurate productions from 51.4% to 64.8% correct. Data from Session 1 and Session 8 for all participants is shown in Table 4. Figure 6 presents the percent correct of treated stimuli from Session 1 to Session 8 during VMKP treatment for each participant. Even though overall trends were positive for this treatment type VMKP, only four participants showed a positive trend on treated stimuli. The trend for one participant decreased from 80% to 74% correct.

With respect to untreated probes, three participants improved from Session 1 to Session 8. Two participants accuracy of untreated probes decreased from Pre Treatment (Session 1) to Post Treatment (Session 8). Data from Session 1 and Session 8 for all participants is shown in Table 5. Figure 7 presents the percent correct of untreated probes from Session 1 to Session 8 during VMKP treatment for each participant.

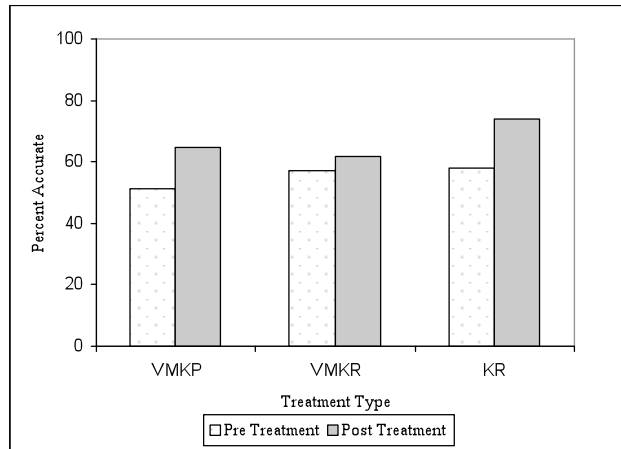


Figure 4. Group Mean Accuracy. This figure illustrates mean change for treated stimuli by treatment.

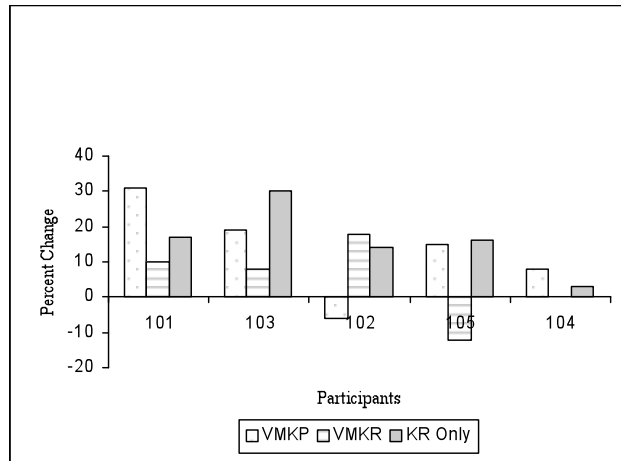


Figure 5. Percent change across treatment and severity. This figure illustrates percent change for treated stimuli in order of increasing severity from left to right.

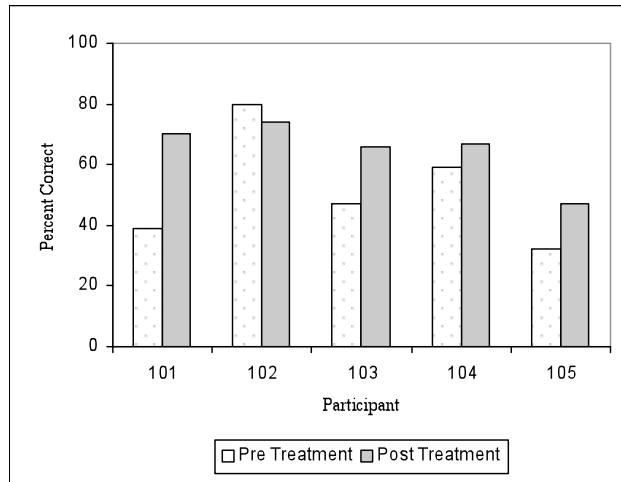


Figure 6. VMKP treated stimuli. This figure is a comparison of percent correct of treated stimuli from Session 1 to Session 8 during VMKP treatment for each participant.

Participant	VMKP Treated Stimuli	
	Pre Treatment	Post Treatment
101	39	70
102	80	74
103	47	66
104	59	67
105	32	47

Table 4. Data for VMKP treated stimuli

VMKP Untreated Probes		
Participant	Pre Treatment	Post Treatment
101	65	85
102	75	65
103	55	65
104	75	90
105	45	40

Table 5. Data for VMKP untreated probes

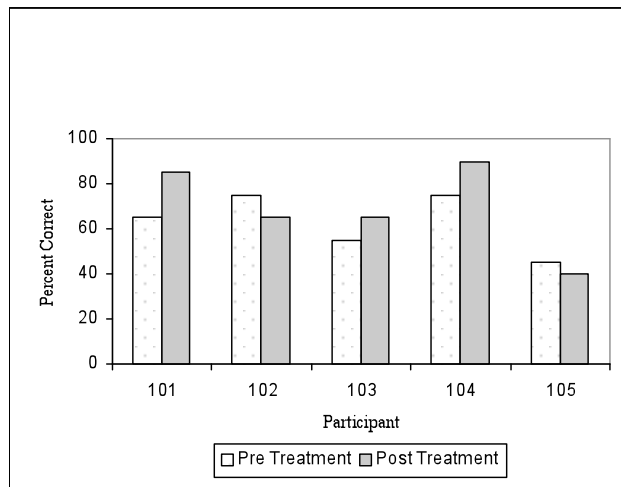


Figure 7. VMKP probe stimuli. This figure is a comparison of percent correct of untreated probes from Session 1 to Session 8 during VMKP treatment for each participant.

Verbal Model with Knowledge of Results (VMKR)

The percent correct from Session 1 to Session 8 during VMKR treatment for each participant is presented in Figure 8. Data from Session 1 and Session 8 for all participants is shown in Table 6. When provided a verbal model and knowledge of results, most participants had a positive trend with a mean accuracy increasing from 57% to 61.8%. Even though mean improvement was positive for this VMKR, only three of five participants showed positive change on treated stimuli. One participant maintained equal performance at 61% correct, while another participant demonstrated poorer performance, moving from 26% correct to 14% correct.

The percent correct of untreated probes from Pre Test (Session 1) to Post Test (Session 8) during VMKR treatment for each participant is illustrated in Figure 9. Data from Session 1 and Session 8 for all participants is shown in Table 7. The only participant who demonstrated a positive trend of performance to untreated probes was the participant who maintained their pretreatment performance on treated stimuli. Two participants maintained their performance and two others presented negative change, with poorer performance from Session 1 to Session 8.

Knowledge of Results (KR)

The percent correct on Session 1 and Session 8 for treated stimuli during KR treatment for each participant is presented in Figure 10. Data from Session 1 and Session 8 for all participants is shown in Table 8. When given no verbal model and knowledge of results feedback, all participants presented positive change with mean performance accuracy moving from 57.8% at Session 1 to 73.8% at Session 8.

The percent correct on untreated probe stimuli for Session 1 and Session 8 during the KR treatment phase is illustrated in Figure 11 for each participant. Data from Session 1 and Session 8 for all participants is shown in Table 9. Three participants demonstrated a positive change on

performance accuracy to untreated probes, and two participants maintained their performance from Session 1 to Session 8.

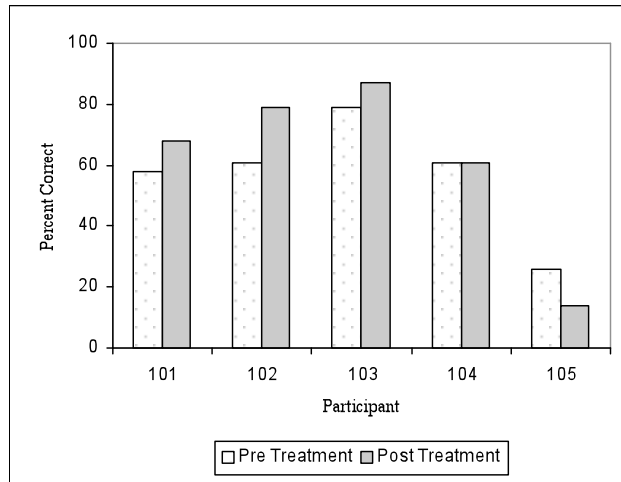


Figure 8. VMKR treated stimuli. This figure is a comparison of percent correct of treated stimuli from Session 1 to Session 8 during VMKR treatment for each participant.

Participant	VMKR Treated Probes	
	Pre Treatment	Post Treatment
101	58	68
102	61	79
103	79	87
104	61	61
105	26	14

Table 6. Data for VMKR treated stimuli

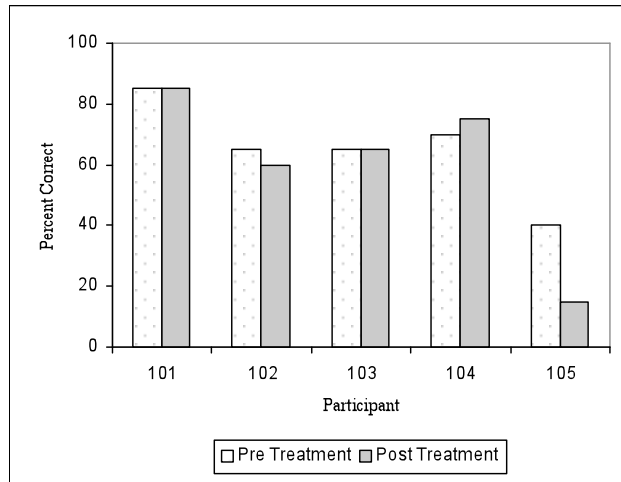


Figure 9. VMKR probe stimuli. This figure is a comparison of percent correct of untreated probes from Session 1 to Session 8 during VMKR treatment for each participant.

Participant	VMKR Untreated Probes	
	Pre Treatment	Post Treatment
101	85	85
102	65	60
103	65	65
104	70	75
105	40	15

Table 7. Data for VMKR untreated probes

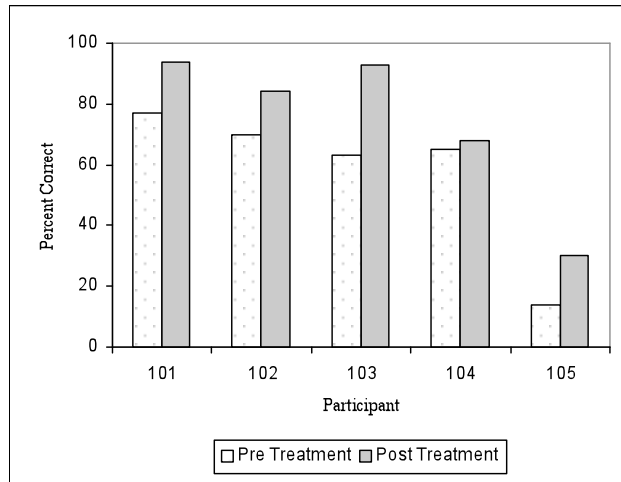


Figure 10. KR treated stimuli. This figure is a comparison of percent correct of treated stimuli from Session 1 to Session 8 during KR treatment for each participant.

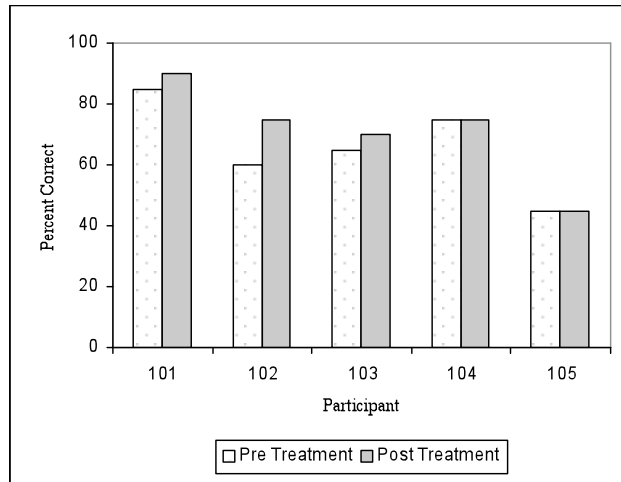


Figure 11. KR probe stimuli. This figure is a comparison of percent correct of untreated probes from Session 1 to Session 8 during KR treatment for each participant.

Participant	KR Treated Probes	
	Pre Treatment	Post Treatment
101	77	94
102	70	84
103	63	93
104	65	68
105	14	30

Table 8. Data for KR treated stimuli

Participant	KR Untreated Probes	
	Pre Treatment	Post Treatment
101	85	90
102	60	75
103	65	70
104	75	75
105	45	45

Table 9. Data for KR untreated probes

Chapter 4: Discussion

The data support the hypothesis that productions resulting from no verbal cue and limited feedback provided in summary form result in increased accuracy of speech production among children with CAS. Overall, all three treatment types implemented during this study presented positive outcomes; however, KR treatment yielded the strongest positive outcome, with a mean increase of 16% from Pre Treatment (Session 1) to Post Treatment (Session 8). MLG treatment also resulted in improved productions on untreated probes with the majority (60%) of participants increasing performance. Although these results should be interpreted cautiously due to the small sample size and brief duration of treatment, the brief duration of this study and the generally positive results indicate excellent potential for treatment benefits. These results suggest that treatment for children with CAS may indeed benefit from practice. This is the case particularly when stimuli are presented in a manner consistent with the procedures utilized in this study. The most successful procedure employed a visual cue but no verbal model of randomized stimuli followed by a 3-second delay prior to the next practice, and then summary knowledge of results feedback following 5 productions.

Participants received each treatment (i.e., VMKP, VMKR, KR) for a two-week period only during the conduct of this study. Although participants demonstrated progress during this brief duration of treatment, the optimal duration of treatments to maximize outcome remains uncertain. However, it is important to consider that one diagnostic feature of CAS that has been anecdotally mentioned on a recurring basis by clinicians, is that CAS is resistant to therapeutic modifications. Notable, all participants in this study demonstrated progress during even a very brief two-week treatment addressed motor learning processes.

Verbal Model with Knowledge of Performance (VMKP)

Following VMKP treatment, participants presented a positive trend in accurate productions of treated stimuli as compared to pre treatment data. Increases in accuracy may have been limited during VMKP treatment due to the distraction resulting from both the verbal model and knowledge of performance feedback. The researcher provided the model and detailed feedback regarding each production, which may not have allowed participants the opportunity to plan and process each production. Motor learning theory subscribes to the premise that learning increased when distractions, particularly those occurring immediately preceding and following task production, are minimized. Still, 3 participants demonstrated improved accuracy of production on untreated probes following VMKP treatment, suggesting a potential generalization of skills obtained during treatment to other contexts. Two participants, however, showed no signs of generalization; in fact, their performance decreased from Pre Treatment (Session 1) to Post Treatment (Session 8) on untreated probes.

Verbal Model with Knowledge of Results (VMKR)

Following VMKR treatment, participants presented a positive trend in accurate productions of treated stimuli as compared to pre treatment data. Increases in accuracy may have been limited during VMKR treatment due to the distraction of the verbal model. The researcher provided the model and gave limited feedback regarding their productions which may have interfered with participants planning and processing of productions. Only one participant demonstrated improved accuracy of untreated probes following VMKR treatment, suggesting a potential generalization of skills obtained during treatment. The other four participants, however, showed no signs of generalization; in fact, two maintained their Pre Treatment performance and two demonstrated decreased performance from Pre Treatment (Session 1) to Post Treatment (Session 8).

Knowledge of Results (KR)

Following KR treatment, all participants presented a positive trend in accurate productions of treated stimuli as compared to pre treatment data. During VMKR treatment the distraction of both the verbal model and knowledge of performance were removed. The researcher did not provide a verbal model and gave limited feedback allowing participants time for planning and processing productions without distractions. Three participants demonstrated improved accuracy of untreated probes following KR treatment, suggesting a potential generalization of skills obtained during treatment. The other two participants showed no signs of generalization, however, they maintained their Pre Treatment performance from Pre Treatment (Session 1) to Post Treatment (Session 8).

Potential Limitations

Potential limitations of this study included the following: attention, motivation tools and strategies (e.g., tokens), and small number of participants.

Three of the five participants demonstrated difficulty attending to treatment tasks; however, their behaviors did not prevent them from completing all treatment tasks. The participants were required to sit quietly at a table for 15 minutes and produce stimulus items in a drill type format. This was a long period of time for young children ($M = 60.8$ months, $SD = 5.45$) with short attention spans to sit quietly and attend to tasks, but with motivational incentives (e.g., varying prosody, volume, rate, giving them control over stimulus presentation) they successfully completed treatment.

During individual sessions, some participants required motivation tools and strategies to remain engaged in treatment. Motivation tools, such as tokens and stickers, may have been a distraction for some participants. These strategies potentially interfered with the silent processing of their productions during the 3-second delay between productions. When participants were

given both VMKP and VMKR treatment, one participant demonstrated decreased accuracy for each treatment type. This decline may have been due to the distractions from the motivation tools and strategies provided. Data for these participants was included since many children at this age require some type of motivational aid to attend to the speech treatment.

This study involved a small sample size, including only five participants. In future research, this type of treatment should be studied in a larger sample involving a wider age range to more effectively determine effectiveness of treatment.

Implications of Research

The results of this study provide clinical implications for SLPs working with children with CAS. The ASHA technical report (2007) introduced a possible increased incidence of CAS in recent years. If this suggestion is accurate, SLPs will have an increasing number of children with CAS in their treatment caseloads. There is limited therapeutic research at this time supporting various treatments for children with CAS. Traditional therapeutic approaches have not shown significant efficacy for children with CAS, however, participants included in this study demonstrated progress in a brief six-week treatment period. Indeed, positive change was observed with each treatment of only two weeks duration. This indicates that if MLG, specifically KR, treatment is provided for a longer duration of time, children with CAS may show even greater progress. Additionally, when considering that children with CAS, a group traditionally resistant to therapeutic change, demonstrated progress with this type of treatment, may have potential implications for treatment of other speech sound disorders. With a motor learning basis, children with speech sound errors similar in nature may also benefit, including such impairments as persistent (i.e., residual) articulation errors (e.g., /r/, /l/), dysarthrias, or phonological disorders where questions exist regarding a motoric component to the impairment, that may also respond to this type of treatment.

The stimulus set for each participant may have influenced performance due to it being individualized for each participant. SLPs may typically use a consistent stimulus set for use across all children on their caseload; however, such a stimulus set may not meet specific intervention needs of individual participants. Stimulus selection is critical for SLPs when planning treatment. Stimuli for this study were selected based upon speech sounds that participants were feasibly able to produce, but were challenging for the participant to produce (i.e., able to produce speech sound in at least one context). To accomplish this, each stimulus item included one phoneme that was difficult for the child. All other phonemes in each stimulus were items produced accurately by the participant during pre-testing.

The structure of the KR treatment may have influenced performance of stimuli due to the type of cueing and feedback provided during these treatment sessions. When receiving this type of treatment, participants were provided a visual cue to produce stimulus items (i.e., pointing to stimuli). This removal of the verbal (i.e., sound) distraction from the stimulus presentation may have encouraged participants to process each item with greater independent focus on his/her productions. Similarly, the KR treatment provided only knowledge of results (i.e., correct or incorrect) feedback, which may have caused participants to process their own productions and determine what movements they had produced that caused them to be correct or incorrect.

All participants in this study demonstrated inconsistent productions of stimulus items across sessions, which is characteristic of CAS. However, mean accuracy increased for all participants across sessions during the KR treatment condition. It should be noted that this progress was made when participants were provided eight treatment sessions over a very brief two week period. Future research with MLG treatment should be implemented over a longer time period with a larger sample size to determine if progress would continue after a two-week period of treatment at an accelerated rate. Future researchers should also examine whether longer

periods of treatment or brief but concentrated periods of treatment provide more benefit to children with CAS.

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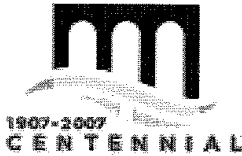
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APPENDIX: Institutional Review Board Approval



University and Medical Center Institutional Review Board
East Carolina University, 600 Moye Boulevard
1L-09 Brody Medical Sciences Bldg. • Greenville, NC 27834
Office 252-744-2914 • Fax 252-744-2284 • www.ecu.edu/irb
Chair and Director of Biomedical IRB: L. Wiley Nifong, MD
Chair and Director of Behavioral and Social Science IRB: Susan L. McCammon, PhD

TO: Sarah Williamson, BA, Dept. of CSDI, ECU
FROM: UMCIRB *gjs*
DATE: April 1, 2010
RE: Expedited Category Research Study
TITLE: "Motor Learning Guided Treatment with Childhood Apraxia of Speech: Cueing & Feedback"

UMCIRB #10-0145

This research study has undergone review and approval using expedited review on 3/17/10. This research study is eligible for review under an expedited category numbers 6 & 7: collection of data from voice, video, digital, or image recordings made for research purposes and research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. The Chairperson (or designee) deemed this **unfunded** study **no more than minimal risk** requiring a continuing review in **12 months**. Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

The above referenced research study has been given approval for the period of 3/17/10 to 3/16/11. The approval includes the following items:

- Internal Processing Form (dated 3/3/10)
- Advertisement Flyer (received 3/16/10)
- Informed consent (version 2/19/10)
- Minor Assent (received 3/3/10)

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

The UMCIRB applies 45 CFR 46, Subparts A-D, to all research reviewed by the UMCIRB regardless of the funding source. 21 CFR 50 and 21 CFR 56 are applied to all research studies under the Food and Drug Administration regulation. The UMCIRB follows applicable International Conference on Harmonisation Good Clinical Practice guidelines.



Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Motor Learning Guided Treatment with Childhood Apraxia of Speech: Cueing & Feedback

Principal Investigator: Sarah E. Williamson, B.A.

Institution/Department or Division: Communication Sciences & Disorders/College of Allied Health

Address: 3310U Allied Health Sciences, Mail Stop 668, Greenville, NC 27834

Telephone #: (252) 744-6147

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of people who are willing to take part in research.

The person who is in charge of this research is called the Principal Investigator. The Principal Investigator may have other research staff members who will perform some of the procedures. The person explaining the research to you may be someone other than the Principal Investigator. Laura Ball, Martha Smith, Skye Lewis, Rudi Carter, or Caitlin Webb may be asking you and your child to take part in this study.

You may have questions that this form does not answer. If you do, feel free to ask the person explaining the study, as you go along. You may have questions later and you should ask those questions, as you think of them. There is no time limit for asking questions about this research.

You do not have to consent to your child taking part in this research. Take your time and think about the information that is provided. If you want, have a friend or family member go over this form with you before you decide. It is up to you. If you choose to allow your child to be in the study, then you should sign the form when you are comfortable that you understand the information provided. If you do not want your child to take part in the study, you should not sign this form. That decision is yours and it is okay to decide not to volunteer your child.

Why is this research being done?

The purpose of this research is to measure the characteristics of Childhood Apraxia of Speech (CAS). We will also determine how the use of Motor Learning Guided cueing and feedback affects intervention. The decision for your child to take part in this research is yours to make. By doing this research, we hope to learn how to better characterize and treat CAS.

Why is my child being invited to take part in this research?

Your child is being invited to take part in this research because he/she has persistent sound substitutions errors consistent with a speech diagnosis of CAS. If you volunteer your child to take part in this research, he/she will be one of about 6 children to do so.

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TO 3-16-11

Are there reasons my child should not take part in this research?

I understand that if I will not be able to keep scheduled testing or treatment sessions, I should not volunteer my child for this research study.

What other choices do I have if my child does not take part in this research?

You have the choice of not permitting your child to part in this research study.

Where is the research going to take place and how long will it last?

The research procedures will be conducted in the Health Sciences Building at the East Carolina University Speech-Language and Hearing Clinic, as well as in another room (2310U) of the same building. You will need to bring your child to the ECU Speech-Language and Hearing Clinic 24 times during the study. Most visits will take approximately 10 minutes. The total amount of time you will be asked to volunteer your child for this study is approximately 1 hour of testing and 240 minutes of treatment over the next 2 months.

What will my child be asked to do?

Your child is being asked to do the following:

- Pre-experimental testing will be completed and will include a speech and language battery (i.e., oral mechanism examination, Test of Auditory Comprehension of Language, conversational speech sample, an articulation test, as well as a test of nonverbal intelligence). This will be done to measure your child's language and cognition. We will ensure that your child's speech mechanism is within functional limits. We will also determine whether your child's speech qualifies as CAS. The entire battery of tests will take approximately 1 hour to complete, not including breaks for your child.
- We will screen your child's hearing acuity throughout the speech frequencies at 1000, 2000, and 4000 Hz HL. This screening will take 5-10 minutes. This will ensure that your child's hearing is within limits appropriate for completing the study.
- We will screen your child's vision. This screening will take 5 minutes. It will ensure that your child's vision is within limits appropriate for completing this study.
- Your child will attend a total of 240 minutes of one-on-one therapy over the course of the study. The therapy will be divided into three blocks. Therapy sessions will occur 4 times weekly for 6 weeks. Each session will last approximately 10 minutes.

In addition, each session will be digitally audio- and video recorded. This procedure is integral for collection of data for the research study. Only the named researchers will have access to the audio/video data. The recordings will be kept for 5 years from the conclusion of the study. They will be kept on a hard drive in the Principal Investigator's locked lab.

What possible harms/discomforts might my child experience if he/she takes part in the research?

There are always risks (the chance of harm) when taking part in research. It has been determined that the risks associated with this research are no more than what you would experience in a normal life. However, some people react to things differently so it is important for you and your child to tell us as quickly as possible if he/she experiences any negative feelings, or feels sick.

UMCIRB Number: _____

Consent Version 2010.02.19A
UMCIRB Version 2009.08.15

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TO 3-16-11

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Participant's Initials

Are there any reasons you might take my child out of the research?

During the study, information about this research may become available that would be important to you. This includes information that, once learned, might cause you to change your mind about wanting your child to be in the study. We will tell you as soon as we can.

There may be reasons we will need to take your child out of the study, even if you want him/her to stay in. We may find that you are not or cannot come for your child's study visits as scheduled. If this is found to be true, we will need to take your child out of the study.

What are the possible benefits my child and I may experience from taking part in this research?

We do not know if you will get any benefits by taking part in this study. This research might help us learn more about CAS and how to best treat it. Besides free speech therapy services, there may be no personal benefit from your child's participation but the information gained by doing this research may help others in the future.

Will my child be paid for taking part in this research?

We will not pay your child for the time he/she volunteers while being in this study.

Who will know that my child took part in this research and learn personal information about him/her?

To do this research, ECU and the people and organizations listed below may know that your child took part in this research and may see information about him/her that is normally kept private. With your permission, these people may use your private information to do this research:

- Any agency of the federal, state, or local government that regulates human research. This includes the Department of Health and Human Services (DHHS), the Food and Drug Administration (FDA), the North Carolina Department of Health, and the Office for Human Research Protections.
- The University & Medical Center Institutional Review Board (UMCIRB) and its staff, who have responsibility for overseeing your welfare during this research, and other ECU staff who oversee this research.

How will you keep the information you collect about my child secure? How long will you keep it?

All data will be kept for 5 years from the completion of the research study. Digital audio and video recordings, as well as physical data (e.g., test protocols) will be kept in the Principal Investigator's locked lab.

What if I decide I do not want my child to continue in this research?

If you decide you no longer want your child to be in this research after it has already started, he/she may stop at any time. He/she will not be penalized or criticized for stopping. He/she will not lose any benefits that your child should normally receive.

What if my child gets sick or hurt while he/she is in this research?

This study does not involve any risk greater than what your child experiences in everyday life. Therefore, we do not expect your child to become sick or hurt as a result of being part of this research. However, people respond differently to things and sometimes accidents do happen. Therefore, if you need emergency care, call 911 for help. If possible, take a copy of this consent form with you when you go.

UMCIRB Number: _____

Consent Version 2010.02.19A
UMCIRB Version 2009.08.15

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TO 3-16-11

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Participant's Initials

Call the principal investigator as soon as you can. She needs to know that your child is hurt or ill. Call Dr. Laura J. Ball at (252) 744-6147, Dr. Martha Smith at (252) 744-6094, or Ms. Skye Lewis at (252) 744-6119.

If you believe you have been hurt or if you get sick because of something that is done during the study, you should call Dr. Laura J. Ball at (252) 744-6147 immediately. There are procedures in place to help provide care for your child. Costs associated with this care will be billed in the ordinary manner, to you or your insurance company. However, some insurance companies will not pay bills that are related to research costs. You should check with your insurance about this. Costs that result from research-related harm may also not qualify for payments through Medicare, or Medicaid. You should talk to the Principal Investigator about this, if you have concerns.

Research Participant Authorization to Use and Disclose Protected Health Information

The purpose of the information to be gathered for this research study is to better understand the effects of cueing and feedback in treatment of childhood apraxia of speech. The individuals who will use or disclose your identifiable health information for research purposes include Dr. Laura Ball, Dr. Martha Smith, Ms. Skye Lewis and Ms. Sarah Williamson. Individuals who will receive your identifiable health information for research purposes include Dr. Laura Ball, Dr. Martha Smith, Ms. Skye Lewis and Ms. Sarah Williamson. The type of information accessed for this research study includes videotaped recordings. The information will be used and disclosed in such a way as to protect your identity as much as possible; however, confidentiality cannot be absolutely guaranteed. Someone receiving information collected under this Authorization could potentially re-disclose it, and therefore it would no longer be protected under the HIPAA privacy rules (federal rules that govern the use and disclosure of your health information). There is not an expiration date for this Authorization.

You may not participate in this study if you do not sign this Authorization form. You may revoke (withdraw) this Authorization by submitting a request in writing to Dr. Laura Ball. However, the research team will be able to use any and all of the information collected prior to your request to withdraw your Authorization.

To authorize the use and disclosure of your health information for this study in the way that has been described in this form, please sign below and date when you signed this form. A signed copy of this Authorization will be given to you for your records.

Who should I contact if I have questions?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator, Dr. Laura J. Ball, at (252) 744-6147 (days, between 8:00 am-5:00 pm).

If you have questions about your rights as someone taking part in research, you may call the UMCIRB Office at phone number (252) 744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of UMCIRB Office, at (252) 744-1971.

I have decided I want my child to take part in this research. What should I do now?

The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.

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TO 3-16-11

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Participant's Initials

Title of Study: A Motor Learning Guided (MLG) Treatment of CAS: Kinematic & Perceptual Outcomes

- I understand that I can stop my child from taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.
- I understand that the researchers may contact me about future research opportunities.

Participant's Name (PRINT)	Signature	Date
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Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

Person Obtaining Consent (PRINT)	Signature	Date
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Principal Investigator (PRINT) (If other than person obtaining informed consent)	Signature	Date
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UMCIRB Number: _____

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