A Comparison of Motor Learning Guided and Sound Production Treatment Approaches for Training Novel Speech in Healthy Adults

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A COMPARISON OF MOTOR LEARNING GUIDED AND SOUND PRODUCTION TREATMENT APPROACHES FOR TRAINING NOVEL SPEECH IN HEALTHY ADULTS

By

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A Dissertation submitted to the School of Communication Science and Disorders in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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To my Mom, with Love
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There are many wonderful individuals whom I would like to recognize for their contribution to the success of this journey. Words cannot express how much the love and support of my parents; Leo and Arlena Hauck has meant to me through the years. My driving force has stemmed from your trust and belief that no matter the challenge the goal is reachable as long you pursue it.

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ABSTRACT

Purpose: There is evidence to support the Motor Learning Guided (MLG) approach as a feasible and effective treatment for speech production impairments. To achieve the next step in providing a solid evidence base, the current study compares the more recently developed MLG with an established treatment (Sound Production Treatment; SPT) in a randomized study of training novel speech in healthy adults.

Methods: Twenty native English speakers between the ages of 18-30 with no history of neurological, speech, or hearing disorder with less than 2 years of Spanish more than 2 years ago participated in this study. Participants were randomly assigned to receive training of novel speech phrases using the MLG training protocol or the SPT training protocol. Target stimuli consisted of five Spanish “tongue twister” phrases. A control set of five Spanish “tongue twisters” balanced for syllable length and target sounds were used to identify generalization of learning. Three baseline measures were collected followed by four training sessions, a 1-week and 2-week follow-up. Baseline, 1-week and 2-weeks post-training measures also included the control phrases to assess generalization.

Results: Two-way repeated measure ANOVA’s were performed to examine treatment affects both within and between groups. There were statistically significant treatment effects for each training group and the pattern of learning for the novel speech targets was virtually equivalent between the MLG training group and the SPT training group. The training effect was maintained, with no significant decline across the two post treatment measures. Generalization, identified by performance on control set of phrases at baseline, 1 week and 2 weeks post measures was noted. Specifically, there was a significant improvement over time however, the speech gains were not as great as the trained phrases and there was no statistically significant difference between groups.

Conclusion: These two methods were effective in training novel speech utterances to our participants. This further validates MLG as a treatment protocol offering good concurrent validity with an established treatment protocol (SPT). The primary purpose for comparing these two methods was to establish that both methods are effective treatments for individuals with motor speech impairment. This preliminary investigation has provided an important step in that direction.
CHAPTER ONE
INTRODUCTION

Overview of Treatment of Apraxia of Speech

Evidence based practice takes into consideration current evidence, clinical expertise, and client/patient values. In an effort to improve the quality of services and clinician decisions regarding management of specific populations, the Academy of Neurologic Communication Disorders and Sciences (ANCDS) has been charged to comprise and disseminate evidence-based guidelines for a range of neurological conditions (Helm-Estabrooks et al., 2004). Consequently, a number of researchers in the realm of neurogenic communication disorders have conducted comprehensive analyses to study treatment effectiveness. According to a meta-analysis performed by Wambaugh, Duffy, McNeil, Robin, and Rogers (2006a, 2006b) and a follow-up meta-analysis by Ballard et al. (2013) the research with regard to treatment approaches for apraxia of speech (AOS) is promising but lacking in evidence to support any one treatment approach. Information from the meta-analysis indicated that articulatory kinematic treatment approaches make up the majority of the studies. Of these, Sound Production Treatment (SPT) has received the most systematic study. Since Wambaugh and colleagues conducted their initial meta-analysis there has been a growing interest in applying components of the Principles of Motor Learning (PML) to existing AOS treatment protocols (Hula, Robin, Maas, Ballard, & Schmidt, 2008; Katz, McNeil, & Garst, 2010; Maas, Barlow, Robin, & Shapiro, 2002; Wambaugh, Nessler, Cameron, & Mauszycki, 2013).

The PML are a compilation of strategies employed during practice to foster change in the acquisition and learning of a motor skill. While the theoretical rationale for these principles is well grounded in exercise science and kinesiology (Schmidt & Lee, 2011; Wulf & Shea, 2002), application to speech production is relatively new. The primary elements of the PML are applied in conditions of practice and augmented feedback (Table 1). Hageman and colleagues (2002) were the first to introduce the application of PML for the treatment of AOS, referred to as the motor learning guided (MLG) approach. Since this time there has been growing evidence to support the effectiveness of MLG (Johnson, Lasker, Stierwalt, MacPherson, & LaPointe, in preparation; Lasker, Stierwalt, Hageman, & LaPaoonte, 2008; Lasker, Stierwalt, Spence, & Cavin-Root, 2010). Like the MLG approach, SPT incorporates elements of PML, however, there are distinct differences between SPT and MLG’s hierarchical structure and application of the
PML. For example, in the MLG treatment hierarchy target elicitations begin with a clinician model, but clinician support fades through the treatment session, regardless of production accuracy. The SPT hierarchy calls for increasing clinician support when errors in sound production occur.

Table 1. Principles for motor learning

<table>
<thead>
<tr>
<th>Conditions of Practice</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distribution</strong></td>
<td>Distributed: practice is ≤ amount of rest</td>
</tr>
<tr>
<td><strong>Schedule</strong></td>
<td>Random: unpredictable</td>
</tr>
<tr>
<td><strong>Practice</strong></td>
<td>Variable: different targets in different context</td>
</tr>
<tr>
<td><strong>Variability</strong></td>
<td>Variable: different targets in different context</td>
</tr>
<tr>
<td><strong>Coordinating</strong></td>
<td>Whole: task is practiced in its entirety</td>
</tr>
</tbody>
</table>

**Augmented Feedback**

<table>
<thead>
<tr>
<th>Knowledge of Results:</th>
<th>related to the outcome of the movement</th>
<th>Knowledge of Performance:</th>
<th>related to the movement pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate:</td>
<td>immediately following the target action</td>
<td>Delayed:</td>
<td>delayed in time following the target action</td>
</tr>
<tr>
<td>Verbal:</td>
<td>spoken</td>
<td>Nonverbal:</td>
<td>unspoken-visual, biofeedback, etc.</td>
</tr>
<tr>
<td>Concurrent:</td>
<td>during the movement</td>
<td>Terminal:</td>
<td>post movement</td>
</tr>
<tr>
<td>Accumulated:</td>
<td>summary of past performance</td>
<td>Distinct:</td>
<td>each performance individually</td>
</tr>
</tbody>
</table>


To establish a sound evidence base, a treatment should be carefully evaluated for elements that contribute to its effectiveness (ClinicalTrials.gov, 2012). In addition, investigations that compare a novel treatment to a more established protocol are warranted. Such comparison studies serve several purposes to include lending support to previous treatment research and may expand treatment options. Consequently, an investigation of the effectiveness of these two approaches in a randomized study would further guide the development of evidenced-based practice for AOS treatment.

**Literature Review**

**Sound Production Treatment (SPT)**

As the more established treatment, SPT is an articulatory kinematic treatment for AOS that utilizes cuing strategies through a systematic process in which clinician support increases as
the individual demonstrates errors in sound production (Wambaugh, Kalinyak-Fliszar, West, & Doyle, 1998). The premise of SPT is to facilitate improvement on articulation of specific sounds that are consistently problematic for an individual. This is achieved by targeting the sound production in the context of words, phrases, or sentences. The protocol calls for a systematic cuing hierarchy for elicited productions following a clinician model. If there is an error in the production of the target sound, a model production of a minimal contrast pair is used to facilitate an accurate production of the target sound. If the individual remains unable to produce an accurate target sound, the clinician provides integral stimulation of ‘watch me, listen to me, and say it with me’. If the error in production of the target sound continues, the clinician provides specific cuing for articulatory placement beginning with a model coupled with verbal instructions (Wambaugh, Kalinyak-Fliszar, et al., 1998). Inherent in the protocol, SPT incorporates components of PML such as random practice, multiple practice opportunities, and a reduced feedback schedule. Experimental stimuli are created based on a pretreatment assessment of sound production on a full range of English mono- and multisyllabic words with multiple exemplars. The index of motor learning, or participant performance, is based on the perceptual accuracy of targets, which are elicited with a verbal model provided at the beginning of each treatment session. The perceptual judgments are scored according to a binary system, which indicates if the production of the target sound was correct or incorrect.

**Evidence for Sound Production Treatment**

Wambaugh and colleagues studied SPT through a series of single case design studies spanning more than 15 years. These investigations focused on acquisition and response generalization of trained sounds as a part of a systematic process to evaluate optimal treatment targets. The process included investigations applying SPT following changes in the selection of treatment targets (i.e. sound groups, isolated sounds, in context of words and phrases) and modifications in the treatment protocol. Positive changes in articulation when sound groups were trained following a verbal model (Wambaugh & Nessler, 2004; Wambaugh, West, & Doyle, 1998), carrier phrase (Wambaugh & Nessler, 2004) and story completion (Wambaugh, 2004) have been reported. In contrast, Wambaugh, Martinez, McNeil, and Rogers (1999) reported that when a sound was trained in isolation, the individual’s performance on that sound deteriorated when a different sound was introduced. The authors proposed that when novel sound was targeted, maintenance production of the previously trained sound was substituted by
the current trained sound. They attributed this phenomenon to overgeneralization of the target sound. Generalization to novel sounds for some participants was reported across several studies when sound groups were trained in individuals with moderate-severe, moderate, moderate-mild, and severe AOS, respectively (Wambaugh & Mauszycki, 2010; Wambaugh & Nessler, 2004) however the researchers reported poor maintenance of treatment effects for all individuals.

The application of SPT in the treatment of AOS has also been utilized to target rate and rhythm aspects in lieu of the sound production. Interestingly, positive change in sound production was reported when rate and rhythm of the productions were targeted in therapy. However, no significant change in rate and rhythm aspects of the production was achieved (Mauszycki & Wambaugh, 2008; Wambaugh & Martinez, 2000). The authors inferred that the improvements obtained on sound production, when the focus was on rate and rhythm, may have been secondary to practice effects of the treatment.

Currently, SPT is the most comprehensively studied and established treatment approach for AOS. Positive changes in articulation of targeted sounds have been reported through the performance measure, which rated accuracy of targets following a verbal model. These positive outcomes have been reported across multiple single case studies involving fifteen participants with varying levels of severity of AOS. There have been no group studies reported. Changes in speech production were consistently noted in trained sounds in the context of words; however, maintenance of trained sounds and generalization of trained sounds to untrained sounds has been inconsistent across participants and contexts.

Evidence for the MLG Approach

Applying the PML has demonstrated effectiveness for long-term retention and transfer of novel physical movements or movement sequences (Bjork, 1999; Schmidt & Lee, 2011). Evidence to support the application of the PML includes positive outcomes for limb motor learning and other vocational/educational training in healthy systems (Backstein, Brydges, Carnahan, & Dubrowski, 2007; Moulton et al., 2006; Wulf, Shea, & Lewthwaite, 2010) as well as in systems that have been damaged and are going through a rehabilitative process. Since the first introduction of PML for the treatment of AOS (Schmidt & Bjork, 1992), salient features have been applied to existing treatment protocols (Hula et al., 2008; Maas et al., 2002; McNeil et al., 2010). While there are elements of PML in SPT treatment, one treatment, referred to as MLG by Hageman and colleagues (2002), was specifically designed from the PML. The MLG
approach combines multiple practice opportunities, in various contexts, using meaningful stimuli, practiced in random order, with clinician provided summary knowledge of results (KR) feedback at approximately 20% schedule. Since its introduction, there has been emerging evidence to support the MLG approach as a therapeutic intervention for AOS (Johnson et al., in preparation; Lasker et al., 2008, 2010). Like the studies of SPT, the investigation of treatment using MLG has involved case study research. In their first case study, Lasker and colleagues (2008) reported on treatment results across three treatment cycles. Each treatment cycle consisted of trained and untrained items matched for syllable length and phonetic structure, which increased in complexity with each cycle. Performance accuracy was measured according to an 11-point multidimensional rating scale, applied to the target items elicited at the beginning of each session. This method of eliciting target items without the influence of a verbal model or practice (treatment) provides an index of learning. The authors reported positive outcomes, identified by changes in speech production for trained items in each treatment cycle and transfer of speech motor learning in the later two of the three cycles.

In a second study (Lasker et al., 2010), the effectiveness of MLG across treatment modalities was investigated. Treatment sessions occurred twice a week face-to-face and twice a week via telehealth. Stimuli were matched for linguistic complexity and syllable length (4-11 syllables) across each modality and control set. The authors reported positive changes in speech motor learning for trained stimuli only following the initiation of training across treatment delivery methods. They reported no evidence of transfer to untrained items. This is another case study reporting positive changes in speech motor learning in which the rate and extent of change was parallel across modalities.

Johnson et al. (in preparation) investigated parameters that might further enhance treatment effectiveness with PML in the framework of MLG in a single case multiple baseline design study across two phases. The first phase targeted treatment dosage comparing semantically related phrases across three practice conditions: 1) high dosage (twice a week with therapist plus home practice) 2) low dosage (twice a week with therapist only) and 3) a probe of untreated targets every 5 sessions. Phase two compared linguistically unrelated phrases across the same practice conditions to investigate the semantic influence on speech motor learning that may have occurred in the first phase. The authors reported a direct relationship between practice and speech improvement. The trend of improvement was observed in both semantically related
and unrelated phrases using the MLG treatment protocol. As in the Lasker et al. (2010) study, improvement in speech production did not occur until the phrases were practiced in treatment. This study provided additional evidence for MLG as an effective treatment approach for AOS.

Current Study

With regard to the treatment of AOS, SPT and MLG both report positive outcomes on changes in speech production. Both of these treatment approaches incorporate elements of the PML, however, they are implemented using different methodologies. Specifically, both SPT and MLG incorporate random order presentation, provide multiple practice opportunities, and provide feedback at a reduced schedule. However, the hierarchy of clinician support increases in SPT to facilitate the individual’s ability to accurately produce the target sound; while in MLG the clinician support fades with each treatment phase to facilitate the individual’s self-awareness and independent cuing system. In addition, while feedback is provided at a reduced frequency schedule in both SPT and MLG, MLG only utilizes KR feedback while SPT uses both KR and knowledge of performance (KP) feedback. Another distinct difference between the two treatment approaches is the index of motor learning. At the initiation of each treatment, SPT uses a binary rating to judge the articulation accuracy of the individual’s productions, each of which are elicited following a verbal model. Similarly, MLG measures performance prior to initiating treatment. However, MLG measures an independent (no model) production using a multi-dimensional rating scale to measure the articulation accuracy, immediacy and naturalness of the whole message (Lasker et al., 2008). Application of the PML in the framework of MLG for individuals with acquired AOS has demonstrated gains with improvements during treatment as well as in social contexts, per patient report. Social validity has not been reported in SPT studies. Both MLG and SPT have reported improvement related to practice effects while MLG has identified a specific relationship between practice and change in productions. For both of these treatment methods, these benefits have been revealed in single case studies; no group findings have been reported.

There is evidence to support the feasibility of both MLG and SPT in the treatment of AOS. The next step to provide a solid evidence-base is to compare the effectiveness of these two treatment approaches in a randomized study. Unfortunately, investigating the effectiveness of treatment protocols in a disordered system can be difficult secondary to differences across participants in lesion location, severity of impairments, and comorbid language impairments.
These issues are compounded when attempting to make comparisons with a larger sample of individuals. One alternative is to study the treatment protocol in a healthy system. The use of healthy adults to investigate novel speech motor learning has been used previously by Kim and colleagues (2012) who identified better retention of novel utterances using KR feedback at a reduced frequency rate. Incorporating the two treatment methodologies while training novel speech targets in a larger sample would allow for a more direct comparison. While training a healthy system a novel speech behavior, such as a foreign language, is not a direct parallel to rehabilitating speech production following neurologic damage, it would provide an approximation of speech change that might occur in an impaired system. Therefore, in an attempt to make a more direct comparison, this study proposes to investigate the two treatment approaches in healthy motor systems. This study aimed to identify the effectiveness of MLG and SPT when training novel speech to healthy adults. To achieve this the following questions were investigated: 1) Is the motor learning of novel speech in a healthy speech motor system influenced by the treatment protocol? 2) Is the long-term retention of novel speech influenced by the treatment protocol?
CHAPTER TWO

METHODS

Participants and Procedures

This investigation was conducted upon receiving approval from the Institutional Review Board (IRB) at Florida State University. The approved informed consent form and the IRB approval letter are provided in the appendices of this document.

Participants

Twenty healthy adults between 18 and 30 years of age participated in this study. Inclusion criteria included (a) no known history of neurological, speech, language, or hearing disorders, (b) native English speaker and (c) 2 years or less of introductory Spanish coursework more than two years prior to the study. According to University course descriptions, the first two years of language instruction are considered introductory, with a focus primarily on vocabulary and verb conjugation. The additional requirement of at least two years without language instruction was imposed to limit an ongoing familiarity/mastery of Spanish. A language learning aptitude screening assessment based on the Modern Language Aptitude Test (MLAT; https://hiddentalent.channel4.com/c4/tests/language) was administered to identify individuals who may have a better than average inherent skill for learning foreign language that could influence novel speech acquisition. Participant demographics and performance on MLAT are provided in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Participant demographics and performance on MLAT</th>
</tr>
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<tbody>
<tr>
<td><strong>MLAT Screen Mean Scores</strong></td>
</tr>
<tr>
<td>Number Learning</td>
</tr>
<tr>
<td>Score (max = 4)</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>MLG 22.4</td>
</tr>
<tr>
<td>SPT 22.5</td>
</tr>
</tbody>
</table>

Stimulus Items

The novel speech targets used for training and control measures consisted of two sets of five Spanish phrases (10 total), with similar motoric and phonetic complexity and matched for syllable length and target sounds. The selected targets were considered Spanish tongue twisters, which would present a challenge for an individual even with some familiarity with the Spanish
language. Targets sounds/sound groups were chosen based on their novel phonemic production compared to English. The Spanish targets were ‘b’, ‘g’, ‘ll’, ‘j’, and ‘rr’. The length of the phrases ranged from 11-15 syllables. An example of a matched set is as follows (see Appendix C for a complete list):

Trained set: Ese bobo vino nunca beber debe.
Control set: Yo baja Busco al vasco bizco brusco.

Experimental Design

This is a quantitative experimental design study. Participants were randomly assigned to a training group. A graduate clinician or the first author guided each participant through a specific protocol to practice and learn the appropriate sound production for each target phrase. Group A received training of novel speech phrases using the MLG training protocol (Appendix D). The MLG training protocol was used as previously outlined in Lasker et al. (2010). Group B received training on the novel speech phrases using the SPT training protocol (Appendix E). The SPT training protocol utilizes a random practice schedule, multiple opportunities of practice, with an increase in modeling and cuing with inaccurate production of targets.

Procedure

Investigator Training

Two trained graduate clinicians in the FSU Communication Science and Disorders program along with the first author conducted experimental treatment sessions. Prior to performing any training sessions, the graduate clinicians were introduced to concepts involving the principles of motor learning, the motor learning guided approach and sound production treatment protocols. The graduate clinicians assisted with data collection, each was trained in a specific method, which was the only method they administered. The primary investigator provided 2-3 training sessions to the graduate clinicians for their respective treatment protocol. To demonstrate competency, the graduate clinicians needed to provide training to the primary investigators on the Spanish target phrases using the respective protocol.

Retention Measure

Each treatment session began with a retention measure, which acted as the index of motor learning. Ratings of retention measure the persistence of an acquired behavior in the absence of practice. This measure consisted of elicitation of each of the phrases included in the training presented in written form and random order. For the baseline, final, and long-term measures, the
control set (untreated phrases) was also included to assess transfer of motor learning to novel, nontreated phrases. Prior to treatment, three baseline measures were collected. The baseline, retention, and transfer measures were the only portion of the training session recorded and rated by the primary investigator. The measures were recorded using Audacity software via a Logitech h390 headset microphone. These elicited productions were evaluated using a multidimensional rating scale (Appendix F).

A 10-point multidimensional rating scale was used to identify speech motor changes based on two dimensions; articulatory accuracy and pausing. The first dimension was articulation accuracy which consisted of the following speech characteristics: accurate articulation (9-10 rating); <25% articulation errors (7-8 rating); <50% articulation errors (5-6 rating); self-correction (4 rating); >50% articulation errors (2-3 rating); and unintelligible (1 rating). Speech errors were identified according to the accuracy of production for each syllable in the phrase. Any error within the syllable was counted as one error. The percentage of articulation errors in a phrase was calculated by dividing the number of syllables that contained an error by the total number of syllables in a phrase. The second dimension of the scale took into consideration the pausing during the production. For each articulation-paired rating (i.e. 9-10 rating), the productions were rated according to appropriate pausing for all elements or inappropriate pausing for one or more elements in the phrase. For example, a rating of 10 would indicate fully accurate articulation throughout the phrase with appropriate pausing. A rating of 9 would represent accurate articulation with less appropriate pausing (i.e. hesitations, vowel prolongation).

**Treatment Protocol**

Following the retention measures, training began using either the MLG treatment protocol or the SPT treatment protocol. To maintain consistent KR feedback across participants, the graduate clinicians were provided feedback and cuing according to a pre-determined list of acceptable feedback responses developed specifically for the treatment protocol. For example, for the SPT protocol a list of specific instructions for the articulatory placement cues was used to standardize feedback across participants. Each training session lasted up to 30 minutes. The training sessions occurred for four sessions in one week (5 day period). This treatment duration was employed based on a pilot study, which revealed marked changes in speech production.
following four training sessions. Consequently that training period was employed for the study. Long-term retention measures were obtained at 1 week and 2 weeks post training.

**Motor Learning Guided Treatment**

Following the retention measures, the treatment session consisted of either the MLG hierarchical treatment protocol or the SPT Protocol. Briefly, the MLG treatment protocol provided three stages of target elicitation with a level of support reduced in each successive stage. For each stage, the targets were presented in random order. The first stage began with a model production of the written target followed by the participant’s immediate production and a 4 second pause. The participant then produced the target item three additional times pausing 4 seconds between each production. The pause between each attempt allowed the participant to perform a self-assessment of the production and to make adjustments, as needed. A model of the production followed the completion of the participant’s productions and then a brief verbal KR was provided. These steps were repeated until all five-target items were attempted. The second stage was performed in the same manner with the exception of no initial model production of the target. After the five targets had been attempted, the third stage was performed. The third stage was performed in the same manner as the second stage with a modification of a 10 second pause between each production. This imposed 10 second pause required participants to listen to the target and hold it in short-term memory while the motor plan for their own utterance was programmed and then executed. The synthesized verbal models and pause time between productions were embedded in a PowerPoint presentation. Once the PowerPoint file was launched, the training was administered in a consistent sequence across participants

**Sound Production Treatment**

The SPT protocol used for this study was derived from Wambaugh et al. (2013). Following the retention measures, the treatment hierarchy was initiated. The first step in the hierarchy was a verbal model of the phrase followed by the participant’s production. If the production was accurate, KR feedback was provided and the participant was asked to produce the phrase for an additional five repetitions. If the production of the target word(s) in the phrase was inaccurate, the investigator provided KR feedback and proceeded to step two in the hierarchy. In step two the trainer presented the target phrase and underlined the sound(s) that were produced incorrectly, provided a verbal model of the target word(s), followed by the participant’s production. The trainer provided KR feedback. If correct, the participant provided
five successive productions. If incorrect, the trainer proceeds to step 3 in which the trainer instructed the participant to “watch me, listen to me, and say it with me” and the participant and trainer simultaneously produced the target phrase. This was attempted up to three times to elicit an accurate production. If correct, the participant provided five successive productions. If an accurate production was not produced, the trainer provided articulatory placement cues to correct the sound production errors and then repeated the procedures in Step 3. This sequence was followed for each of the target phrases until they had all been completed.

**Reliability**

**Inter-rater**

A native English speaker naïve to the study was trained on the multidimensional rating scale and rated a random selection of 10% of the 1300 retention measures. Krippendorff’s alpha was used for its robust statistical measure for quantifying the extent of agreement among raters. The point-by-point reliability using Krippendorff’s alpha an interval scale was found to have an acceptable level of agreement at $\alpha=0.75$.

**Intra-rater**

A random selection of 10% of the 1300 retention measures was re-rated by the investigator to identify reliability of their retention ratings. Krippendorff’s alpha on an interval scale was found to have an acceptable level of agreement at $\alpha=0.83$. 
CHAPTER THREE

RESULTS

Perceptual Ratings

Perceptual ratings for the baseline, retention, and post-training productions were documented according to participant code. Statistical analysis using SPSS Version 21 was used to perform one-way and two-way repeated-measure analyses of variance (RM ANOVA) to examine treatment effects within and between groups. A criterion alpha level of 0.05 was used for interpreting all statistical tests, including post hoc testing.

Distribution Characteristics

A series of exploratory analyses were performed to determine if measures were normally distributed. Results from normality plots, histograms and the Shapiro-Wilks test revealed a normal distribution for each dependent measure for both MLG and SPT groups. The Kolmogorov-Smirnov test revealed a significant deviation from normal distribution, but only for the first follow up measure gathered one week following training for the SPT group. Those data were included in the analysis to represent the heterogeneity of normal performance. Details of the descriptive statistics are provided in Tables 3 and 4.

Baseline Measures

A RM ANOVA was performed on the three baseline measures for trained phrases and control phrases for each group to examine the potential for practice effects. Mauchly’s test indicated that the assumption of sphericity was not violated for MLG trained phrases, $\chi^2(2) = 0.629$, $p=0.730$, nor for the SPT trained phrases, $\chi^2(2) = 0.855$, $p=0.652$. For the within subject comparison, there was no significant main effect for the trained phrases, $F(2,18)=2.507$, $p=0.110$, $\eta^2 = 0.218$ for the MLG group or the SPT group, $F(2,18)=0.797$, $p=0.466$, $\eta^2 = 0.081$. Similar results were found for the control set of phrases. Mauchly’s test indicated that the assumption of sphericity was not violated for MLG control phrases, $\chi^2(2) = 2.291$, $p=0.318$, and SPT control phrases, $\chi^2(2) = 3.878$, $p=0.144$. There was no significant main effect for the control set of phrases within subjects comparison for the MLG group, $F(2,18)=0.636$, $p=0.541$, $\eta^2 = 0.066$ or the SPT group, $F(2,18)=2.378$, $p=0.121$, $\eta^2 = 0.209$. Given that the analyses indicated a stable baseline, subsequent statistics used the computed mean baseline for treated phrases and control phrases for each respective group.
Table 3. Descriptive statistics and measures of distribution for each retention measure for the MLG group.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>KS p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLG (n=10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline Treated Combined</td>
<td>4.49 (0.69)</td>
<td>0.448</td>
<td>1.131</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 1 - Trained Phrases</td>
<td>4.22 (0.64)</td>
<td>-0.328</td>
<td>-1.90</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 2 - Trained Phrases</td>
<td>4.66 (0.85)</td>
<td>-0.066</td>
<td>0.498</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 3 - Trained Phrases</td>
<td>4.60 (0.86)</td>
<td>0.486</td>
<td>-0.589</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline Control Combined</td>
<td>4.54 (1.07)</td>
<td>0.413</td>
<td>0.687</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 1 – Control Phrases</td>
<td>4.66 (1.19)</td>
<td>0.446</td>
<td>-0.978</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 2 – Control Phrases</td>
<td>4.44 (1.19)</td>
<td>0.139</td>
<td>-1.778</td>
<td>0.07</td>
</tr>
<tr>
<td>Baseline 3 – Control Phrases</td>
<td>4.52 (0.99)</td>
<td>0.287</td>
<td>-1.779</td>
<td>0.04</td>
</tr>
<tr>
<td>Training Day 1</td>
<td>5.82 (1.50)</td>
<td>-1.139</td>
<td>1.292</td>
<td>0.20</td>
</tr>
<tr>
<td>Training Day 2</td>
<td>6.84 (1.57)</td>
<td>-0.404</td>
<td>0.433</td>
<td>0.20</td>
</tr>
<tr>
<td>Training Day 3</td>
<td>7.42 (1.55)</td>
<td>-0.500</td>
<td>1.416</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 1 week – Trained Phrases</td>
<td>7.26 (1.56)</td>
<td>-0.316</td>
<td>-0.839</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 2 week – Trained Phrases</td>
<td>7.04 (1.41)</td>
<td>-1.053</td>
<td>1.176</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 1 week – Control Phrases</td>
<td>6.02 (1.20)</td>
<td>-0.236</td>
<td>-0.953</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 2 week – Control Phrases</td>
<td>5.74 (1.42)</td>
<td>-0.75</td>
<td>-1.086</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Table 4. Descriptive statistics and measures of distribution for each retention measure for the SPT group

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>KS p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPT (n=10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline Treated Combined</td>
<td>4.44 (0.98)</td>
<td>0.032</td>
<td>-1.673</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 1 - Trained Phrases</td>
<td>4.52 (1.06)</td>
<td>-0.658</td>
<td>-0.717</td>
<td>0.11</td>
</tr>
<tr>
<td>Baseline 2 - Trained Phrases</td>
<td>4.26 (0.86)</td>
<td>-0.163</td>
<td>-1.719</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 3 - Trained Phrases</td>
<td>4.54 (1.28)</td>
<td>0.389</td>
<td>0.171</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline Control Combined</td>
<td>4.43(1.10)</td>
<td>-0.082</td>
<td>-1.168</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 1 – Control Phrases</td>
<td>4.22 (1.02)</td>
<td>-0.004</td>
<td>-0.420</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 2 – Control Phrases</td>
<td>4.44(1.13)</td>
<td>0.244</td>
<td>-0.897</td>
<td>0.20</td>
</tr>
<tr>
<td>Baseline 3 – Control Phrases</td>
<td>4.62 (1.30)</td>
<td>0.018</td>
<td>-1.104</td>
<td>0.20</td>
</tr>
<tr>
<td>Training Day 1</td>
<td>5.78 (1.36)</td>
<td>-0.523</td>
<td>-1.283</td>
<td>0.18</td>
</tr>
<tr>
<td>Training Day 2</td>
<td>6.86 (2.02)</td>
<td>-0.023</td>
<td>-1.594</td>
<td>0.20</td>
</tr>
<tr>
<td>Training Day 3</td>
<td>7.46 (1.16)</td>
<td>-0.187</td>
<td>-0.226</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 1 week – Trained Phrases</td>
<td>7.84 (1.51)</td>
<td>-1.230</td>
<td>1.070</td>
<td>0.01</td>
</tr>
<tr>
<td>Post 2 week – Trained Phrases</td>
<td>7.46 (1.58)</td>
<td>-0.393</td>
<td>-1.154</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 1 week – Control Phrases</td>
<td>5.58 (1.55)</td>
<td>-0.348</td>
<td>-0.318</td>
<td>0.20</td>
</tr>
<tr>
<td>Post 2 week – Control Phrases</td>
<td>5.60 (1.42)</td>
<td>-0.284</td>
<td>-0.500</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*Note.* *=Indicates significant deviation from normal distribution at significance level of p=0.05.
Inferential Statistics

Motor learning

To investigate the primary research question regarding the influence of the training model on motor learning of novel speech in a healthy motor system, a two-way RM ANOVA was conducted. Mauchly’s test indicated that the assumption of sphericity was not violated for the main effect of time, $\chi^2(5) = 5.116$, $p = 0.403$. Table 5 summarizes the results of the repeated measure ANOVA. There was a significant change in speech motor learning across time, $F(3,54) = 62.474$, $p < 0.01$, $\eta^2 = 0.776$, however, there was no significant interaction effect between time and training group, $F(3,54) = 0.019$, $p = 0.996$, $\eta^2 = 0.001$. Figure 5 illustrates the performance of the MLG group and SPT group regarding pattern of learning, $F(1,18) = 0$, $p = 0.988$, $\eta^2 = 0.0$

![Figure 1](chart.png)

*Figure 1.* Pattern of learning novel speech targets by treatment groups, measured by average retention ratings (1-10) across four treatment sessions.
Table 5. The results of a two-way repeated measures of analysis of variance, which examined the effect of time and training protocol on target phrases.

<table>
<thead>
<tr>
<th>Effect</th>
<th>MS</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>34.07</td>
<td>3</td>
<td>62.474</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Time * Training Group</td>
<td>0.010</td>
<td>3</td>
<td>0.019</td>
<td>0.996</td>
</tr>
<tr>
<td>Error</td>
<td>0.545</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Long-Term Retention of Learning Novel Speech Movements

A two-way RM ANOVA was also performed to assess the effect of training method on follow-up measures of learning for the novel speech targets. Comparison among the mean baseline measures on the trained phrases, the last training session, one-week post-training and two-weeks post-training was conducted. Table 6 summarizes the results of the RM ANOVA. There were no significant main effects of time at one week, $F(1,18) = 0.367, p=0.552$, $\eta^2 = 0.020$, and two weeks post training, $F(1,18) = 2.840, p=0.109$, $\eta^2 = 0.136$.

Figure 2. Follow up measures by training groups at 1 week post training.
Table 6. Results of a two-way repeated measure ANOVA, which examined the effect of time and training protocol on retention measures of target phrases at 1 week and 2 weeks post training.

<table>
<thead>
<tr>
<th>Effect</th>
<th>MS</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post 1-week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>0.121</td>
<td>1</td>
<td>0.367</td>
<td>0.552</td>
</tr>
<tr>
<td>Time * Training Group</td>
<td>0.729</td>
<td>1</td>
<td>2.213</td>
<td>0.154</td>
</tr>
<tr>
<td>Error</td>
<td>0.329</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post 2-week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>0.841</td>
<td>1</td>
<td>2.840</td>
<td>0.109</td>
</tr>
<tr>
<td>Time * Training Group</td>
<td>0.169</td>
<td>1</td>
<td>0.571</td>
<td>0.460</td>
</tr>
<tr>
<td>Error</td>
<td>0.297</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As illustrated in Figure 2, the SPT group’s post 1-week retention ratings were slightly higher than the MLG group post 1–week retention ratings. However, this difference was not statistically significant $F(1,18)=0.246$, $p=0.646$, $\eta^2=0.013$. At 2 weeks post training, both the MLG and SPT groups demonstrated a decrease in the retention ratings compared to retention ratings at last training day (Figure 3). Again, the decrease between the MLG group and the SPT group was not statistically significant, $F(1,18) = 0.080$, $p = 0.780$, $\eta^2 = 0.004$.

Figure 3. Follow up measures by training groups at 2 weeks post treatment.
An investigation of generalization of speech motor learning to nonpracticed target phrases was conducted using a two-way RM ANOVA for mean baseline ratings of control phrases and retention ratings of control phrases at 1 week and 2 weeks post training. Table 7 summarizes the results of that analysis. Mauchley’s test indicated that the assumption of sphericity was not violated for the main effect of time, $\chi^2(2) = 3.739, \eta^2 = 0.154$. There was a significant main effect of time on the change in retention ratings post training, $F(2,36) = 24.188, p < 0.01, \eta^2 = 0.573$. However, there was no significant interaction effect between time and training group across all three points (mean baseline, 1 week post, 2 weeks post), $F(2,36) = 0.371, p = 0.693, \eta^2 = 0.020$. As illustrated in Figure 4, the difference between the MLG group and the SPT group was not significant at each of the follow up measures (1-week $F(1,18)=0.287, p=0.599, \eta^2=0.016$; 2-weeks $F(1,18)=0.033, p=0.858, \eta^2=0.002$).

![Figure 4](image-url)

*Figure 4.* Generalization of speech motor learning by training group at post 1 week and post 2 weeks.
Table 7. Results of a two-way repeated measure ANOVA which examined the effect time and training protocol on generalization of motor learning to nontrained speech targets at 1 week and 2 weeks post training.

<table>
<thead>
<tr>
<th>Effect</th>
<th>MS</th>
<th>Df</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post 1-week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>17.336</td>
<td>1</td>
<td>39.987</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Time * Training Group</td>
<td>0.267</td>
<td>1</td>
<td>0.615</td>
<td>0.443</td>
</tr>
<tr>
<td>Error</td>
<td>0.434</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post 2-weeks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>8.22</td>
<td>1</td>
<td>23.615</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Time * Training Group</td>
<td>0.007</td>
<td>1</td>
<td>0.20</td>
<td>0.888</td>
</tr>
<tr>
<td>Error</td>
<td>0.348</td>
<td>18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER FOUR

DISCUSSION

The purpose of this study was to compare the effectiveness of MLG and SPT when training novel speech to healthy adults using a randomized control study design. MLG and SPT each incorporate salient elements of the PML such as multiple practice opportunities, random order presentation, and a reduced feedback schedule. The main difference between the two training methods is the level of support provided to identify the error in the production as well as instruction on how to repair the error. SPT provides specific instructions for the movement of the articulators for accurate sound production incorporating both KP and KR feedback. This differs from MLG, which incorporates a structured pause time to allow the trainee to compare their production to that of the model. The imposed evaluation time allows the individual to make adjustments for their next practice attempt, all while receiving general KR feedback at a reduced schedule. Consequently, while there are similarities between the two treatments regarding the inclusion of PML, there are also differences in how PML are incorporated. Because MLG is a relatively new treatment method, it is an important step in establishing a strong evidence base to compare it to treatment protocols, which have been carefully studied and established, in this case SPT.

The findings from this study indicate that both the MLG and SPT training protocols were effective for training novel speech in healthy adults. In addition, the pattern of learning, acquisition of learning and the rate of change between the MLG training protocol and the SPT training protocol were virtually equivalent. Positive speech change only occurred after the training was initiated following stable performance during the baseline measures. Mean performance at baseline measures was perceptually judged to contain more than 50% articulation errors and inappropriate pausing for one or more elements. Mean performance at the end of the training was perceptually judged to contain less than 25% articulation errors and appropriate pausing. The clear treatment effect replicates previous research by Wambaugh and colleagues (Wambaugh & Nessler, 2004; Wambaugh, West, et al., 1998) and Lasker and colleagues (2008, 2010). Across the duration of training, motor learning for unique speech targets was similar based on these perceptual measures, regardless of the treatment method employed.

The similar treatment effects may indicate that for this sample important elements for learning novel speech were random order presentation, multiple practice opportunities, and
reduced feedback schedule. It was noted during the participant training that KP feedback was beneficial in order to identify the subtle differences between the model and their production (e.g. the Spanish pronunciation of /b/) as well as specific instruction of the movement for isolated sound production (e.g. Spanish trill), which were elements of SPT. While for other production differences limited KR feedback was adequate for the participants to identify and modify their productions to the model, elements related to MLG. The range of performance within groups likely reflects a normal range of variation. In both groups, some participants demonstrated learning quickly while the rate of change was in smaller increments for others in which additional training may have led to accurate articulation for all elements of the phrase. It was also observed that subtle differences in production were difficult to identify by participants. In a number of these cases additional instruction was clearly an added benefit to modify the production to the model. For example, the /b/ sound in Spanish is produced without the lips touching compared to the plosive production in English.

Performance on the speech targets was measured at 1 and 2 weeks post training to examine the strength of motor retention. Performance by the SPT group was slightly better than the MLG group on the trained phrases at 1 week and 2 weeks post training, however the difference was not statistically significant. Mean productions at both of the time periods consisted of less than 25% articulation errors and appropriate pausing. Of interest to note was that both training groups demonstrated a declining trend in performance across follow up measures when compared to the end of training. This coincides with previous SPT studies reporting poor maintenance of treatment effects in individuals with AOS (Wambaugh & Mauszycki, 2010; Wambaugh & Nessler, 2004). However, it is contradictory to MLG studies in which stable maintenance of treatment gain has been reported several months post treatment (Johnson et al., in progress; Lasker et al., 2008, 2010).

This decline in performance on long-term retention measures may be related to the stability of performance proficiency before the termination of training. Specifically, the participants in both groups were demonstrating performance improvements from one session to the next indicating that their level of performance had not plateaued. Previous MLG studies report an established level of stable performance proficiency prior to ending a treatment cycle followed by stable maintenance effects (Johnson, et al., in preparation; Lasker et al., 2008; Lasker et al., 2010). Previous SPT studies have reported declining maintenance effects observed
for sounds that have not reached high consistent level of production during training despite the long length of training (Wambaugh & Mauszycki, 2010; Wambaugh & Nessler, 2004). All prior studies for both MLG and SPT report motor learning occurred over a much longer time period than four sessions. For the purpose of this investigation in healthy adults, the time frame was not as long as a typical treatment cycle. It is possible that performance with the two methods may have diverged over a longer period of time. The four training days in this study limited the opportunity for the participants to reach a stable level of proficiency in the learned speech movement. It would be reasonable to suggest that a longer training period would allow individuals to achieve stability in performance at a higher accuracy level, which may be an indicator of a change in behavior that would be reflected in the long-term retention productions. Such an assumption certainly warrants further investigation.

While not a direct question in this study, generalization of trained speech movements to non-trained speech movements was investigated by comparing retention ratings of productions at the mean baseline of the control phrases to retention ratings of productions of the control phrases at 1 week and 2 weeks post training. A slight improvement in the untreated speech targets was indicated on the 1 week and 2 week follow-up measures. Productions at mean baseline consisted of 50% or more articulation errors and inappropriate pausing. At 1 week and 2 weeks post training, productions were rated to have less than 50% articulation errors. This trend was identified for both the MLG and SPT group with the MLG group demonstrating a slightly higher retention rating. However, none of these changes were statistically significant. Prior research looking at generalization to untrained stimuli for both MLG and SPT has been identified in some but not all case studies (Lasker et al., 2008; Wambaugh & Mauszycki, 2010; Wambaugh & Nessler, 2004). For MLG, generalization was reported in one prior case study after the second cycle of treatment targets (Lasker et al., 2008) as well as through reported social validity measures however, not observed in the retention measures of untrained stimuli (Johnson, et al., in preparation; Lasker et al., 2008, 2010). For SPT, generalization to different stimulus contexts has been limited (Wambaugh & Mauszycki, 2010; Wambaugh & Nessler, 2004) with no generalization across stimulus sounds (Wambaugh, Kalinyak-Fliszar, et al., 1998; Wambaugh & Mauszycki, 2010; Wambaugh & Nessler, 2004). The theory previously discussed regarding motor stability holds true for generalization of the learned behavior to untrained phrases even
though we do not see the degree of change in the control phrases compared to the trained phrases.

The results of this study provide evidence for the effectiveness of both the MLG and SPT training protocols for speech motor learning. This study was designed specifically to investigate the effectiveness of the training protocols by maintaining consistent training and measurement elements across participants and groups. The training steps for each protocol were consistent with previous studies and applied to the same set of targets. The focus for SPT training remained on specific target sounds while MLG training focused on the message as a whole. The index of learning was based on a multidimensional rating scale to capture acquisition of learned speech movement independent of a model. This was important to ensure the measurement of learning was comparable while safeguarding the integrity of the theory behind the treatment method.

An element that was omitted from this study that has been hypothesized to be a high contributing factor to the positive outcomes with MLG was the meaningfulness of the target phrases. The phrases chosen for this study were based on motoric complexity resulting in phrases that had little meaningfulness to apply to real life situations. In fact, the participants were never informed of the English translation of these phrases. The elimination of this factor reduced the likelihood of practice outside of the training sessions in proper context and removed a potential emotional connection and motivation to learning. While this offered strong experimental control for the purposes of this study, it is a departure from our objective in terms of treatment outcomes when the treatment has been applied for disordered populations (AOS). It would be reasonable to hypothesize that meaningfulness may be an important element to maintenance and even generalization of speech motor learning. That element may also have explained the maintenance of speech targets previously seen in studies using MLG.

The treatment duration was a limitation to this study. Most of the participants did not demonstrate a consistent level of proficiency in motor learning given the limited number of training sessions when compared to training as they would have if they were trained to a level of criterion. This limitation may have contributed to masking the differences between the two treatment methods pertaining to long-term retention and generalization. Future studies should include criterion-based mastery as an outcome rather than an apriori treatment duration.

In conclusion, results indicate these two methods were equally effective in training novel speech utterances to our participants based on the perceptual ratings. This provides further
support for MLG as a treatment protocol and demonstrates good concurrent validity with an established treatment protocol (SPT). Such validation is necessary in order to establish a sound evidence base. Future research should expand the investigation to include the influence of meaningful target selection to speech motor learning for a more accurate comparison of treatment method using MLG and SPT. Finally, the primary purpose of testing these two methods is to create effective treatments for individuals with motor speech impairment. This preliminary investigation has provided an important step in that direction.
APPENDIX A
INFORMED CONSENT

INFORMED CONSENT FORM FOR AN ADULT RESEARCH PARTICIPANT

TITLE: Effectiveness of a training approach to learning novel speech in healthy adults: An acoustic and perceptual study

PRIMARY INVESTIGATOR:
Rachel K. Johnson, M.S., CCC-SLP
Doctoral Candidate
School of Communication Science and Disorders
Florida State University
201 W Bloxham
Tallahassee, FL 32303-1200
(850) 644-2238

INVITATION TO PARTICIPATE: You, [participant's name], are invited to participate in a research study that focuses on learning novel speech. The following information is provided to help you to make an informed decision regarding whether or not you should participate. If you have any questions please do not hesitate to ask.

You are a candidate for the study because you have (1) no known history of acquired or degenerative neurological disorders, (2) no speech, language, or hearing disorders, (3) native English speaker and (4) score at the novice-low or novice-mild level on the Modern Language Aptitude Test (MLAT, Carroll & Sapoun, 2002). You were recruited by the Principal Investigator in an announcement provided in one of your undergraduate courses at Florida State University.

PURPOSE OF THE STUDY
You are being asked to participate in a research project that will systematically evaluate the effectiveness of a training approach to learn novel speech. At the start of the project, your ability to learn a foreign language will be assessed using a standardized assessment tool. You will be randomly assigned to a training group that will meet four times a week for one week with me and/or a trained graduate student for sessions at the FSU Neurolinguistic-Neurocognitive Rehabilitation lab. During the training session you will practice saying phrases in a foreign language. Training sessions will last between 15 and 45 minutes. You will meet for up to two follow-up sessions scheduled 1-4 weeks after the last session for a final 5-10 minute session. You will meet with me and/or a trained graduate student for a total of 6-7 visits.

The experiment will be conducted in a quiet setting in the Neurolinguistic – Neurocognitive Rehabilitation lab located at the Warren Building at Florida State University. All sessions will be audio recorded and analyzed at a later time by the primary investigator or a trained research assistant.

RISKS AND BENEFITS
There are no potential risks associated with this study. You will be in no physical discomfort during the experiment. The sessions will be held during a time of day that you judge to be most convenient. This research may benefit the field of speech-language pathology, however, there is no direct benefit to the participant.

Participants Initials: [participant's initials]                                      Page 1 of 2
Date: [date]


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COMPENSATION AND COSTS
There is no cost to you for participating in this study. In addition, compensation will be provided for participating in this study.

ASSURANCE OF CONFIDENTIALITY
Your identity will be kept strictly confidential to the extent permitted by law through a coding system. All data collected during this study will be identified through a coding system, not directly linked to any identifying information. All digital audio recordings will be kept on a secured server that is password protected for 5 years. Research records will be stored securely and only researchers will have access to the records. The digital audio recording will contain no personally identifiable information and will be kept completely confidential. The audio recordings may be presented during scientific meetings with no personally identifiable information. The information obtained in this study may be published in scientific journals or presented at scientific meetings, but your identity will be kept strictly confidential.

RIGHT TO WITHDRAW
You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators, Florida State University, or the L.L. Schendel Speech and Hearing Clinic at Florida State University.

SUMMARY OF RESULTS
No information will be withheld from you. The results of the study will be reviewed with you if you express an interest in this information. A written summary of this research will be supplied to you, at no cost, upon request.

VOLUNTARY CONSENT
The researchers conducting this study are Rachel Johnson and Dr. Julie Stierwalt. You may ask any question you have now. If you have a question later, you are encouraged to contact them at 201 W. Bloxham, 850-644-3952, [contact information].

Your rights as a research participant have been explained to you. If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the FSU IRB at 2010 Levy Street, Research Building B, Suite 276, Tallahassee, FL 32306-2742, or 850-644-7900, or by email at humansubjects@magnet.fsu.edu.

You will be given a copy of this information to keep for your records.

YOU ARE VOLUNTARILY MAKING A DECISION REGARDING YOUR PARTICIPATION IN THIS RESEARCH STUDY. YOUR SIGNATURE CERTIFIES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ AND UNDERSTOOD THE INFORMATION PRESENTED.

Signature of Adult Participant

Date

Participants Initials: ____________

Date: ____________

APPENDIX B

IRB APPROVAL LETTER

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673  FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 1/8/2014

To: Rachel Johnson

Address: 201 W Blocham
Dept.: COMMUNICATION DISORDERS

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Effectiveness of a training approach to learning novel speech in healthy adults: An acoustic and perceptual study

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and one member of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 1/6/2015 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA0000168/IRB number IRB00004446.

Cc: Julie Stierwalt, Advisor
HSC No. 2013.11873
APPENDIX C
LIST OF PHRASES TRAINED

<table>
<thead>
<tr>
<th>Trained Phrases</th>
<th>Control Phrases</th>
<th>Target sounds for SPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ese bobo vino nunca beber debe</td>
<td>Yo baja Busco al vasco bizco brusco.</td>
<td>b</td>
</tr>
<tr>
<td>El gente acogiendo seguir de gimnasia</td>
<td>Gigante las generaciones se degeneran</td>
<td>g</td>
</tr>
<tr>
<td>Ya llegó el día, y hoy es hoy.</td>
<td>¿Cómo me las maravillaría yo?</td>
<td>ll</td>
</tr>
<tr>
<td>Juan junta juncos junto a la zanja.</td>
<td>El cajas y cajitas y cajones.</td>
<td>j</td>
</tr>
<tr>
<td>Un perro en el barro con su rabo barre.</td>
<td>A los carros por los rieles del ferrocarril.</td>
<td>rr</td>
</tr>
</tbody>
</table>
APPENDIX D

MOTOR LEARNING GUIDED (MLG) PROTOCOL

Retention Measures
At the start of each MLG treatment session
1. Randomize and present in succession to the client.
2. The client immediately attempts to say the stimulus after each presentation
3. The clinician analyzes the production using a multidimensional rating scale designed for aspects of articulation accuracy and pausing.
4. Repeat steps 1-3 until all stimulus items are attempted.
   • Record these productions.
   • Baseline, final, and long-term retention productions will include the control set of phrases.
   • Inter-rater reliability performed on 10% of the sample.
   • Following these measures, the remainder of the therapy session consisted of MLG training.

MLG Training
   • Feedback provided consists of Knowledge of Results (KR) only. KR feedback is a general acknowledgement of the correctness of the client’s productions. For example: “you had it on the second one”, “you were very close”, and “that was perfect”
   • KR should not exceed a 20% rate.
   • There are three stages to the therapy target set of phrases.

Stage 1: Present the stimulus items in random order.
1. Provide the written presentation of the stimulus accompanied by a verbal model.
2. The participant will immediately attempt to say the stimulus,
3. Followed by a 4 second pause to allow the client to self-analyze his response and attempt to make corrections as appropriate
4. 3 more attempts are made with a 4 second pause in between each attempt
5. Provide the verbal model of the stimulus
7. Repeat Steps 1-7 until all of the stimulus items are attempted.

Stage 2: Present the stimulus items in random order.
1. Provides written presentation of the stimulus without a verbal model.
2. Participant produces the utterance.
3. The participant attempts to say the stimulus three times with a 4 second pause between each attempt to allow for self-corrections, as needed.
4. Provide a verbal model of the stimulus item and brief verbal KR feedback.
5. Repeat Steps 1-4 until all of the stimulus items are attempted.

Stage 3: Present the stimulus items in a random order.
1. Provides written presentation of the stimulus without a verbal model.
2. The participant attempts to say the stimulus three times with a 10 second pause between each attempt to allow for self-corrections, as needed.
3. The clinician says the stimulus item and provides brief verbal KR feedback.
4. Repeat Steps 1-4 until all of the stimulus items are attempted.
APPENDIX E

SOUND PRODUCTION TREATMENT (SPT) PROTOCOL

Retention Measures
At the start of each training session
1. Randomize and present in succession to the participant.
2. The participant immediately attempts to say the stimulus after each presentation
3. The trainer analyzes the production using a multidimensional rating scale designed for aspects of articulation accuracy and pausing.
4. Repeat steps 1-3 until all stimulus items are attempted.
   - Record these productions.
   - Baseline, final, and long-term retention productions include the control set of phrases.
   - Inter-rater reliability performed on 10% of the sample.
   - Following these measures, the remainder of the therapy session consists of the SPT training.

SPT Training
Step 1: Model of target phrase provided followed by production of phrase by participant.
   a. If correct, the trainer provides feedback concerning accuracy and the phrase is produced an additional five times. Then the next item is presented.
   b. If incorrect, the trainer provides feedback concerning accuracy, and the next step in the hierarchy is attempted.

Step 2: The trainer provides the target phrase in printed form and underlines the target sound(s) that were produced incorrectly. The trainer indicates the problem sounds; a model of the target phrase is provided, followed by the participant’s production.
   c. If correct, the trainer provides feedback concerning accuracy, and the phrase is produced an additional five times. Then the next item is presented.
   d. If incorrect, the trainer provides feedback concerning accuracy, and the next step in the hierarchy is attempted.

Step 3: The trainer says, “Watch me, listen to me, say it with me” (i.e., integral stimulation) and the target word is produced simultaneously with the participant. This procedure is attempted for three times in the hope of eliciting a correct production.
   e. If correct, the trainer provides feedback concerning accuracy, and the phrase is produced an additional five times. Then the next item is presented.
   f. If incorrect, the trainer provides feedback concerning accuracy, and the next step in the hierarchy is attempted.

Step 4: The trainer provides articulatory placement cues appropriate to the sound production errors and then repeats the procedures in Step 3.
   g. If correct, the trainer provides feedback concerning accuracy, and the phrase is produced an additional five times. Then the next item is presented.
   h. If incorrect, the trainer provides feedback concerning accuracy, and the next item is presented.
## APPENDIX F

### RETENTION MEASURE RATING SCALE

<table>
<thead>
<tr>
<th>Rating</th>
<th>Accuracy</th>
<th>Pausing</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Accurate articulation, intelligible</td>
<td>Appropriate pausing</td>
</tr>
<tr>
<td>9</td>
<td>Accurate articulation, intelligible</td>
<td>Inappropriate pausing for one or more elements</td>
</tr>
<tr>
<td>8</td>
<td>&lt;25% articulation errors</td>
<td>Appropriate pausing</td>
</tr>
<tr>
<td>7</td>
<td>&lt;25% articulation errors</td>
<td>Inappropriate pausing for one or more elements</td>
</tr>
<tr>
<td>6</td>
<td>&lt;50% articulation errors</td>
<td>Appropriate pausing</td>
</tr>
<tr>
<td>5</td>
<td>&lt;50% articulation errors</td>
<td>Inappropriate pausing for one or more elements</td>
</tr>
<tr>
<td>4</td>
<td>Self correction</td>
<td>Inappropriate pausing for one or more elements</td>
</tr>
<tr>
<td>3</td>
<td>&gt;50% articulation errors</td>
<td>Appropriate pausing</td>
</tr>
<tr>
<td>2</td>
<td>&gt;50% articulation errors</td>
<td>Inappropriate pausing for one or more elements</td>
</tr>
<tr>
<td>1</td>
<td>Unintelligible</td>
<td>Pausing may be appropriate but likely inappropriate pausing for one or more elements</td>
</tr>
</tbody>
</table>
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BIOGRAPHICAL SKETCH

Rachel K. Johnson received her Bachelor of Arts degree in Biology from the University of North Carolina at Wilmington in 1999. She worked as a research technician at Duke University Medical Center before attending East Carolina University where she received her Master of Science degree in Communication Science and Disorders in 2006. While at East Carolina University she obtained an Assistive Technology Certificate and completed a Master’s thesis titled “Function Communication in Individuals with Chronic Severe Aphasia Using Augmentative Communication”. Upon receiving her Master’s degree, Rachel worked in various adult rehabilitation settings to include a traumatic brain injury rehabilitation center, acute hospital and acute rehabilitation, skilled nursing facility, outpatient clinic and home health in New York and Florida. She specialized in evaluation and treatment of dysphagia, acquired neurogenic communication disorders and augmentative and alternative communication. In 2011, she entered the Doctoral degree program in Communication Science and Disorders at Florida State University (FSU) under the mentorship of Dr. Joanne Lasker with a research focus of acquired neurogenic disorders and augmentative and alternative communication. After Dr. Lasker’s departure from FSU, Rachel continued the doctoral program at FSU under the mentorship of Dr. Julie Stierwalt. Her research focus has involved investigations for evidence based treatment methods for motor speech disorders specifically, Motor Learning Guided treatment approach for acquired apraxia of speech. In addition to her full time coursework, Rachel worked part-time as a clinical educator at the FSU Speech and Hearing Clinic for the last two years of her doctoral program. She received the 2014 FSU Graduate Student Research and Creativity Award for her research involving a creative treatment approach for apraxia of speech as well as the College of Communication Science and Disorders Doctoral Student of the Year. Rachel’s areas of interest in the field of speech-language pathology include investigating aspects of motor learning in individuals with acquired neurological impairment, specifically as it relates to speech production and exploring how the use of technology might influence treatment outcomes with respect to severity of the communication disorder and the individual’s support system. After earning her PhD from FSU, she will join the Communication Disorders and Special Education faculty at Old Dominion University where she will be teaching coursework and continuing her line of research.