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Motor learning guided treatment for acquired apraxia of speech

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ABSTRACT

Purpose: The purpose of this study was to expand the evidence on the effectiveness of motor learning guided approach for the treatment of acquired apraxia of speech. This study investigated the influence of practice frequency and number of targets per practice set on transfer of speech motor learning.

Method: This is a multiple baseline single-case study across two treatment cycles involving two individuals with chronic acquired apraxia of speech. Treatment Cycle 1 investigated the influence of self-controlled practice on speech motor learning through two conditions of practice. Treatment Cycle 2 investigated the influence of number of targets on transfer of learning.

Results: There was a treatment effect for both participants in both treatment cycles. In Treatment Cycle 1, both participants demonstrated speech motor learning on treated stimuli in all practice conditions and no transfer of learning to untrained phrases. In Treatment Cycle 2, the number of targets was reduced. A change in speech motor learning was demonstrated by both participants on the trained phrases as well as a transfer of learning as measured by performance on untrained set of phrases.

Conclusion: The outcomes of this study contribute to the growing evidence supporting the effectiveness of motor learning guided treatment for acquired apraxia of speech.

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Speech motor learning; apraxia of speech; motor learning guided; intervention; treatment; aphasia

Introduction

Apraxia of speech (AOS) is a motor speech disorder affecting the spatial and temporal programing and planning for speech production resulting in articulation and prosodic errors. Treatment studies for AOS date back to the 1950s. However, evidence to support a single treatment for AOS remains insufficient (Ballard et al., 2015; Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006a, 2006b). The majority of the research includes case studies and single-case experimental design studies using an articulatory kinematic approach (Ballard et al., 2015; Wambaugh et al., 2006a, 2006b). Traditional articulatory kinematic treatment protocols use serial repeated practice, integral stimulation, high frequency of clinician modeling, visual, and verbal feedback and articulatory placement cues to guide individuals to correct articulatory targets.

Of recent interest is how the different factors of principles of motor learning (PML) influence outcomes of individuals with motor speech disorders taking part in speech treatment (Bislick, Weir, Spencer, Kendall, & Yorkston, 2012; Maas et al., 2008). Among the PML are aspects of practice schedule and augmented feedback that foster the acquisition and learning of a motor skill (Schmidt & Bjork, 1992; Schmidt & Lee, 2011). Hageman, Simon, Backer, and Burda (2002) first introduced a treatment approach based on the PML called Motor Learning Guided (MLG) approach to treat an individual with acquired AOS.

The Motor Learning Guided (MLG) approach differs from traditional articulatory kinematic treatment protocols in the practice schedule and the nature of clinician feedback. The primary differences include the use of an imposed 2–3 s pause-time between productions rather than serial repeated production as used in traditional articulatory treatment protocols. During this pause-time, the participant is given instructions to analyze their production prior to making their next production. Another distinct difference in the treatment protocol is the type and amount of augmented feedback. Traditional treatment approaches, use a high level of clinician support consisting of high frequency of knowledge of performance feedback. Depending on the patient's performance, this feedback may include modeling, biofeedback, integral stimulation, and/or placement cues (e.g., Sound Production Treatment, Phonetic Placement Treatment, Eight Step Continuum). In MLG, the type and amount of feedback the clinician provides is at a reduced frequency (approximately 20%) following the series of productions. The clinician provides knowledge of results feedback, which consists of information related to the outcome of the production (e.g., the second production was closest) rather than knowledge of performance such as specific

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articulatory placement cues (e.g., round your lips more). The rationale for these distinct differences is to allow the participant to develop or rehabilitate their intrinsic feedback system, which is typically compromised due to the sensory motor feedback impairment, assumed to underlie AOS (Bohland, Bullock, & Guenther, 2010; Duffy, 2013; Maas, Mailend, & Guenther, 2015).

Multiple case studies have reported positive outcomes using MLG in patients with chronic severe AOS (Johnson, Lasker, Stierwalt, MacPherson, & LaPointe, 2014; Kim & Seo, 2011; Lasker, Stierwalt, Hageman, & LaPointe, 2008; Lasker, Stierwalt, Spence, & Cavin-Root, 2010). In addition to changes in speech production of trained words/phrases, two of these case studies reported transfer of learning to untrained phrases (Kim & Seo, 2011; Lasker et al., 2008).

In an exploratory case study using two treatment cycles, Johnson and colleagues (2014) investigated parameters that may influence the effectiveness of speech motor learning using MLG. The first treatment cycle of this study, investigated practice frequency using three sets of phrases at different levels of practice opportunity. Practice on one set of phrases occurred in therapy and at home, practice on the second set occurred in therapy only, and the third set served as a control (probed every five sessions). In the second treatment cycle, they investigated if the influence of the semantic relationship of the phrases influenced the rate of acquisition while keeping the practice schedule the same as the first treatment cycle. They reported that changes in speech production occurred only after practice of target phrases occurred, independent of their linguistic relationship. Phrases practiced outside of therapy appeared to improve at a faster acquisition rate compared to phrases practiced only in therapy. However, due to the change in the number of targets per practice set as criterion was met (45; 30; 15), it is unclear if the practice frequency influenced the difference in acquisition or if it was due to the decrease in the number of targets in the practice set.

This single-case multiple baseline design study used two treatment cycles to further investigate the influence of practice frequency and number of targets per practice set on speech motor learning. The first treatment cycle investigated practice frequency on speech motor learning comparing two practice conditions using three sets of phrases: one set of phrases practiced in therapy and accessed outside of therapy (high dose), one set practiced in therapy only (low dose), and one untreated set as in the Johnson et al. (2014) study. The home practice used in the Johnson et al. (2014) study was structured as a self-controlled practice condition. That is, the participant was provided written instructions for the MLG protocol however, they had control over certain practice conditions such as what targets they wanted to practice and the timing and frequency of feedback (provided via the speech output on a speech-generating device). According to limb motor learning, the benefit of self-controlled practice is attributed to motivation and engagement in different information processing activity during the learning activity (Wulf, Shea, & Lewthwaite, 2010). Therefore, it is hypothesized that phrases accessed outside of the therapy session for self-controlled practice would result in a faster rate of change in speech motor learning compared to phrases practiced with the clinician only.

There have been mixed results regarding transfer of learning using MLG, therefore, the aim of the second treatment cycle was to investigate if a reduction in the number of targets would result in transfer of learning. A reduction in the number of targets would decrease the amount of contextual interference. Although it is well established that high contextual interference situations result in positive transfer of learning in a healthy system (Battig, 1979; MaGill & Hall, 1990; Shea & Morgan, 1979) more research is needed to identify the optimal balance of contextual interference to facilitate learning following a brain injury (Skidmore, 2015). Prior MLG studies ranged from 15 to 30 items trained at one time. For this study, the number of targets was reduced to 10 items per set in the second treatment cycle following the number of functional phrase targets used in an evidence based treatment for motor speech disorders (Sapir, Ramig, & Fox, 2011). To balance the stimulus selection while maintaining the personalization of the content, we used a template for the phrase structure and balanced the syllable length between trained and untrained stimuli. The phrases were completed with personal content as per

Table 1. Pre-treatment measures.

Measure	P1	P2
Apraxia Battery for Adults (Dabul, 2000)	Mod-Severe	Mod-Severe
AOS Characteristics (Apraxia of Speech Rating Scale ASRS-VI; Strand et al., 2014)	Score (0–4)*	
Distorted sound substitutions	4	4
Distorted sound additions (not including intrusive schwa)	0	0
Increased sound distortions or distorted sound substitutions with increased utterance length or increased syllable/word articulatory complexity	3	4
Increased sound distortions or distorted sound substitutions with increased speech rate	2	4
Inaccurate (off-target in place or manner) speech AMR's (alternating motion rates, as in rapid repetition of 'puh puh puh')	4	1
Reduced words per breath group relative to maximum vowel duration	0	0
Western Aphasia Battery-Revised (Kertesz, 2006)		
Aphasia Quotient	57.6	54.2
Aphasia Classification	Broca	Broca
Spontaneous speech	10	9
Auditory Verbal Comprehension	9.1	9.8
Repetition	4.6	1.9
Naming	5.1	5.4
Reading	11.8	16

*Note: ASRS –VI rating: 0 = not present; 1 = detectable but infrequent; 2 = frequent but not pervasive; 3 = nearly always evident but not marked in severity; 4 = nearly always evident and marked in severity.

preference of the participant. We hypothesized that the reduction of number of targets would decrease the cognitive load, therefore increasing the likelihood of transfer of learning to untrained stimuli.

Method

Participants

The participants in this study were a 61 year-old male (P1) who was 19 months post onset of a left hemisphere stroke and a 55 year-old male (P2) who was 28 months post onset bilateral embolic stroke. Consent was obtained before pre-treatment assessment, which occurred across two sessions.

Table 2. Example of stimulus phrases for P1 and P2 in Treatment Cycle 1 and Treatment Cycle 2.

P1	P2
Treatment Cycle 1	
High Phrases	
How was Xxx's day?	Email me.
I would like to make an appointment.	I had a stroke.
My arm is feeling tight right now.	Let's go sailing.
I look forward to going fishing next year.	I have 3 kids.
XX and I bought some supplies from Lowe's.	I went to UVA.
We like to travel to new places.	My daughter XX.
Do you need anything from the grocery store?	I had a great time.
Low Phrases	
I need to refill my prescription.	How are you?
What are we having for dinner.	Go Cavaliers.
We went to the festival on Saturday.	Call me XX.
Xx, how was work today?	I like summer.
I have an appointment at XXX.	What time does it start?
Are you going to the festival this weekend?	My brother Xx.
Tell me about your fish outing?	X is my nephew.
Untreated Phrases	
I looked up and noticed two old men.	Can you go?
The dolphins swam around our boat.	Night after night.
After I hit the ball, I dashed to first base.	I was worried.
The store serves meals every day.	We just sat there.
He said he was too old to travel.	It is not that rare.
Being close to people is important to me.	We bought a brown chair.
The wait for work can be very long.	We know we can score.
Treatment Cycle 2	
Treated Phrases	
Would you like to visit Terry later?	Would you like to get a sandwich later?
The Denver Broncos is my favorite team.	UVA Cavs are my favorite team.
We walked around the mall last weekend.	Sailing is a hobby of mine.
Untreated Phrases	
I would like to give X.X. X a call.	Would you like to go get some Mexican food later?
Bizarre Foods is my favorite TV show.	The beach is my favorite place to surf.
We drove to Dover Downs last weekend.	Xx, Xx, and X.X., I love you.

Underline indicates common phrase elements. Xx are used to replace any identifying information

Both participants demonstrated chronic AOS and aphasia (Table 1). P1 and P2 demonstrated moderate to severe AOS as evidenced by ratings on the Apraxia Battery of Adults-2, (ABA-2; Dabul, 2000), with speech behaviors consistent with the characteristics of AOS as identified using Apraxia of Speech Rating Scale (ASRS-VI; Strand, Duffy, Clark, & Josephs, 2014). Specifically, both participants demonstrated distorted sound substitutions that increased with articulatory complexity and increased speech rate and inaccurate speech AMRs. Both participants were characterized as having Broca's aphasia according to the classification system of the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006). Reading competency was determined functional at the sentence length per performance on the reading subtests from the WAB-R. During the course of this investigation, both participants received language therapy targeting only receptive and nonverbal language skills under the direction of the same university clinical supervisor. Both participants agreed to participate in a treatment study to address their considerable AOS.

Materials and apparatus

Setting and apparatus

Treatment sessions were conducted in a university clinic twice a week for 60 min sessions. All oral reading retention measures were videotaped and recorded using a Panasonic HC-V750 video recorder. Both participants had access to a voice output augmentative and alternative communication system. In Treatment Cycle 1, 15 of the phrases were programed into their system with a single target item stored under a single button. When the participant pressed a specific area on the system, identified by the written target item, a target utterance was 'spoken' aloud by the device for the participant to practice independently at home on non-therapy days. The participants were provided written instructions to follow for the self-controlled practice of the targets at home using the MLG steps (minus augmented feedback). In place of the clinician's modeled productions the instructions were to press the button on the device to hear the target phrase. The number of productions and pause-time between productions remained the same. Participants were asked to record the amount of time spent practicing daily on a paper calendar. Additionally, the number of 'hits' per phrase was recorded on the speech-generating device.

Stimulus item selection

For Treatment Cycle 1, three sets of sentence stimuli were identified – 15 stimuli for treatment in therapy two times a week and available for home practice (high), 15 for treatment in therapy only two times a week (low) and 15 untreated (Table 2). The high and low stimuli were used for the daily oral reading retention measure (no model provided). The untreated set of stimuli was included in every fifth retention measure. Researchers attempted to create lists of treated and untreated stimuli that were similar in terms of length and phonetic structure. However, the primary emphasis was functionality of the target phrases with the exception of the untreated set of phrases. The high and low dose stimuli included two phrases with the same beginning (e.g., I have, I would like, What time) with the rationale to increase the variability and avoid recurrent or overlearned utterances. The untreated set of phrases were obtained from the Sentence Intelligibility Test (Yorkston, Beukelman, & Hakel, 1996) to reduce the familiarity element. For P1, each set of stimuli ranged from 5 to 13 syllable phrases, with an average of eight syllable items for each list. For P2, each set of stimuli ranged from 2 to 6 syllable words/phrase with an average of 4.3 syllable items for each list. Although both participants had a similar severity, intelligibility of communication intent was patient specific. P1 demonstrated the use of a recurrent utterance 'I want' to initiate speech. It was unclear if this recurrent utterance was directly related to his aphasia, or if it was 'overlearned' from his previous speech-language therapy intervention. The stimuli created used alternate wording to reflect similar meaning for his recurrent utterance. P2 demonstrated considerable distortions in vowel production, which affected intelligibility. Therefore, the stimuli created used a variety of cvc, cvcc, and ccvc combinations in various contexts.

For Treatment Cycle 2, two new sets of stimuli were identified – 10 stimuli for treating in therapy two times a week and 10 as untreated probes (Table 2). Each set was created using a sentence template that was completed with personal information to maintain the primary emphasis of functionality. One phrase was used for both participants. Three phrases had the same beginning structure, three had the same middle structure and three had the same end phrase structure. As in Treatment Cycle 1, the researchers attempted to create lists of treated and untreated stimuli that were similar in terms of length and phonetic structure with the primary emphasis of functionality. For P1, each set of stimuli ranged from 8 to 13 syllables, with an average of 10.1 syllable items for each list. For P2, each set of stimuli ranged from 8 to 15 syllables, with an average of 11.2 syllable items for each list.

Table 3. Multidimensional Rating Scale.

Rating	Articulation accuracy	Intelligible	Immediacy
11	Accurate articulation	Intelligible	Immediate production of all elements
10			Delayed production of some element
9	Distortion, sound addition or deletion	Intelligible	Immediate
8			Delayed
7	Incomplete articulation	Missing elements of production but does not interfere with general message	Immediate
6			Delayed
5	Self correction was successful		
4	Incomplete articulation	Missing crucial elements of production so that utterance is not intelligible	Immediate
3			Delayed
2	Perseverative or wrong target		Immediate
1			Delayed

Procedures

Experimental design

A multiple baseline design across participants, behaviors (oral reading) and conditions was employed. The daily retention measure across sessions was an oral reading task without a model prior to beginning the treatment protocol. Changes in speech production performance in the oral reading tasks during the retention measure were rated using an 11-point multidimensional rating scale (Table 3). Productions were rated based on articulation accuracy, intelligibility, and immediacy. Items were scored both online and from videotaped recordings. Two treatment cycles took place in which different sentence stimuli were targeted. Treatment Cycle 2 was initiated 3 months following the termination of the first treatment cycle. Follow-up measures were obtained for both treatment cycles at ten months post-treatment.

Probing schedule

Three baseline measures were obtained prior to initiating the treatment. Two baseline measures were obtained at the beginning and end of the second session of pre-treatment testing. The third baseline was obtained on the first day of treatment before treatment began. There was no upward trend in the performance therefore, treatment initiated following the third baseline measure. Baseline was not extended across participants, rather an untreated set of phrases served as the control.

Treatment protocol

Each treatment session began with random elicitation of the treatment phrases in the oral reading (no model) task as a measure of speech motor learning. The untreated target phrases were included in the oral reading task at the start of every fifth session. Following the retention oral reading task, treatment began using the MLG protocol previously described (Lasker et al., 2010). There are three stages to the MLG protocol; the clinician support was faded in each stage. For each stage, all targets were presented in random order.

The first stage of the treatment hierarchy began with the clinician randomly selecting a phrase for the participant to read silently while the clinician modeled the phrase. After the model, the participant read the phrase aloud followed by a 3-second delay. The participant then produced the phrase two more times with an imposed 3-second delay between each production. During this pause, the participant was instructed to analyze their production to make adjustments for their next attempt. After the third production, the clinician provided a verbal model of the phrase followed by verbal knowledge of results feedback (e.g., you had it on that second one, how do you think you did? I heard changes with each try). These steps were completed in sets of five phrases with a 1-minute break between each set until all phrases were practiced. The second stage was performed in the same manner without the initial clinician model of the phrase. The third stage was performed in the same manner as the second stage (no initial clinician model), with the difference of successive presentation of all phrases rather than in sets of five. Clinicians provided knowledge of results feedback at approximately 20% schedule. The treatment duration reported across twenty-five treatment sessions is equivalent to three months of therapy at the traditional dosage of two sessions a week.

The graduate research clinicians received training on the treatment protocol by the author. In order to ensure that all steps of the treatment protocol were instituted for each target, treatment fidelity was maintained by the author's observation of at least 25% of therapy sessions for all clinicians. Any discrepancy, which was primarily in the feedback provided, was corrected directly. Graduate research clinicians and the author met weekly to review any issues related to treatment delivery and participant performance.

Data analysis

Data were analyzed with both visual inspection and effect size calculations. In addition, the mean treatment gain for each treatment cycle was calculated by subtracting the mean of the last three treatment retention measures from the mean of the three baseline measures. The mean rating for each stimulus set was calculated for each session and effect sizes were computed using the Tau-U metric to determine changes in trend across phases of the experiment (Parker, Vannest, Davis, & Sauber, 2011). The analysis of the overall omnibus Tau-U was calculated using the online calculator available at http://www.singlecaseresearch.org/calculators/tau-u Tau-U of 0.93 and higher is considered very effective; 0.66–0.92 is effective and below 0.65 is questionable (Rakap, 2015). The standard mean difference (d) as described in Beeson and Robey (2006) is also reported as a conservative estimation of effect size to compliment Tau-U. Treatment effect sizes and follow-up effect sizes were calculated using excel according to guidelines provided in Bailey, Eatchel, and Wambaugh (2015). The Tau-U effect size was calculated for each cycle as well as the standard mean difference effect sizes (d).

Reliability

Clinicians scored the utterances on the oral reading retention measure at the start of each session. The author viewed the first few sessions in each cycle to establish reliability on the scoring system. Discrepancies were resolved immediately after the session and by viewing the session recording. Clinicians scored online and then viewed the videos to correct any transcription or scoring errors. Clinicians randomly re-rated a blind 20% of their retention recordings for intrarater reliability. Interrater reliability was obtained by random rating of a blind 20% of the recorded retention measures by the author after the completion of the study. Krippendorf's alpha on an interval scale was used to determine rater reliability. Interrater reliability was α at 0.80 and intrarater reliability was α at 0.88, indicating good reliability for the multidimensional scale.

Social validity

Social validity measures were obtained through modified survey of communication effectiveness (Ball, Beukelman, & Pattee, 2004) administered before and after the treatment cycles. The scales identify the communicator's success in communication across different situations as indicated using a 7-point Likert scale of 1 – not effective at all to 7 – very effective.

Results

Treatment Cycle 1

Figure 1 illustrates the mean retention rating for each set of stimulus items in Treatment Cycle 1 (maximum score is 11). The mean baseline rating for P1 was approximately 3.49 for high dose, 3.29 for low dose and 1.67 for untreated set of phrases. The mean baseline rating for P2 was 4.38 for high dose, 3.67 for low dose and 2.69 for untreated sets of phrases. These ratings indicate speech productions described as missing crucial elements making the utterance unintelligible. A rating of 2 or below indicates speech productions that are perseverative or the wrong target.

After training was instituted, both high dose phrases (therapy + home) and low dose phases (therapy online) showed gains in both participants (Figure 1). The high dose phrases showed a slightly higher mean retention rating for the duration of the treatment program than low dose phrases. For P1 ratings indicated speech productions that contained distortions, sound addition/

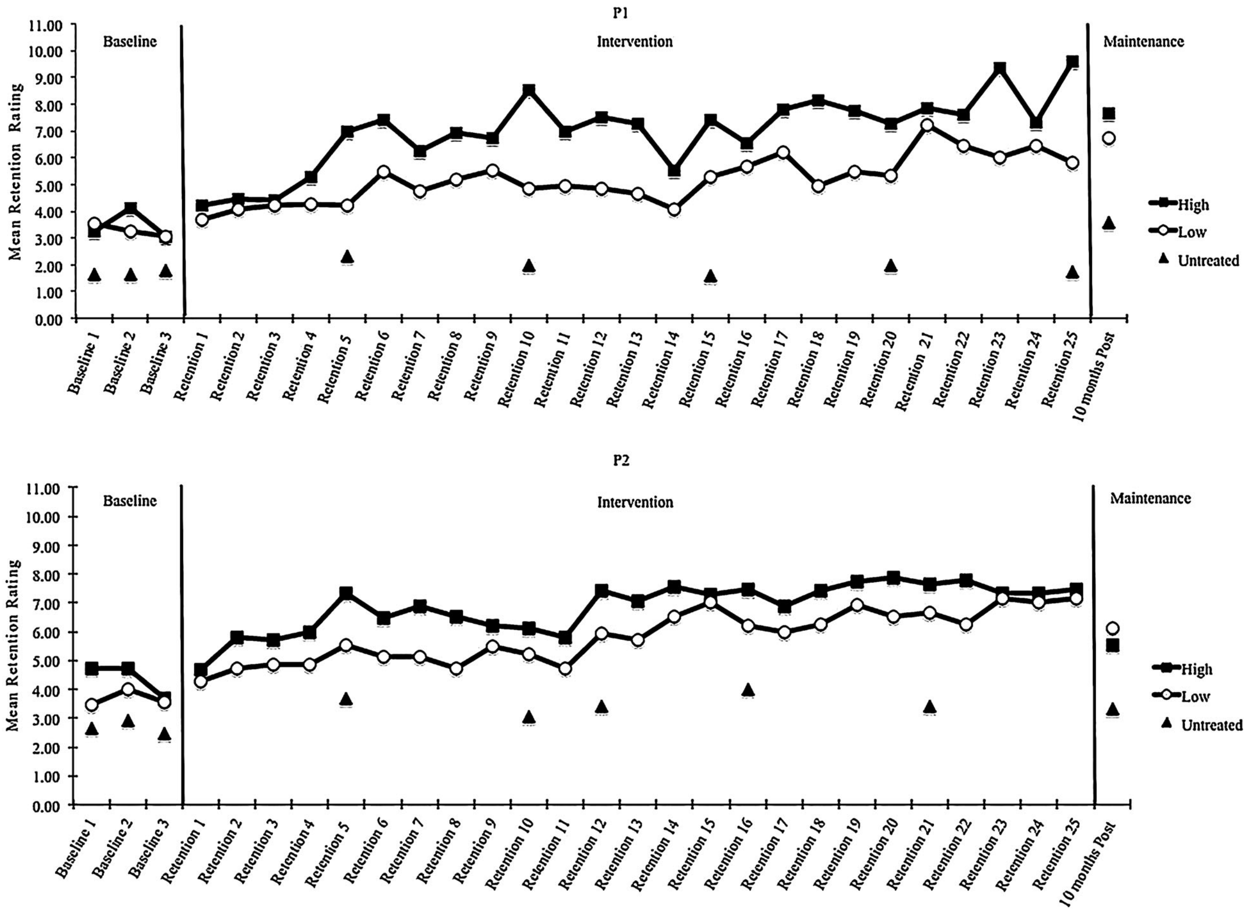

Figure 1. Treatment Cycle 1 mean retention ratings across treatment conditions for P1 and P2.

deletions, however maintained their intelligibility. P2 speech productions were delayed and contained distortions (primarily vowels). The therapist led practice set of phrases (low dose) followed the same trend of change, however, the mean retention rating threshold remained lower than the high dose phrases. For P1, this indicates that more of those phrases contained sound distortions, additions/deletions than the high dose phrases. For P2, the distortions resulted in more phrases that were unintelligible. The untreated phrases minimally changed for both participants during this treatment cycle, however some gain was noted on untrained phrases for P1 at the follow-up maintenance measure. Mean treatment gain for P1 was 5.27 (high) and 2.80 (low); P2 was 3.0 (high), 3.42 (low).

Results from Tau-U suggest large effect sizes for speech motor learning during Treatment Cycle 1. The Tau-U across treatment conditions for high dose condition was 0.97 with 90% confidence intervals between 0.56 and 1. This result indicates that 97% of the data showed improvement between baseline and intervention phase. For the low dose condition, Tau-U was 1.0 with 90% confidence interval between 0.58 and 1.0. This result indicates 100% of the data showed improvement between baseline and intervention. For the within treatment condition, Tau-U was 0.99 indicating that 99% of the data showed improvement with a 90% confidence interval of 0.69 to 1.

The standard mean difference (d) as described in Beeson and Robey (2006) is also reported. According to effect size guidelines from Bailey et al. (2015), there was a large treatment effect size for P1 ($d =$ 11.96) and P2 ($d = 11.78$) in the low phrases. A medium effect size was seen for P1 in the high ($d =$ 9.29) phrases and P2 in the untreated ($d = 4.32$) phrases. Follow-up effect size was large for P1 in the low ($d = 14.71$) and untreated ($d = 24.54$) phrases. The large effect size in the untreated phrases reflects the stable performance on the baseline productions resulting in a small standard deviation. A medium effect size was seen for P1 in the high ($d = 7.32$) phrases and P2 for the low ($d = 8.49$) phrases. A small effect size was seen in P2 for the untreated ($d = 2.75$) phrases.

Participants were asked to document the amount of time spent during home practice activity. P1 consistently documented the amount of time spent on the self-controlled practice. During Treatment Cycle 1, P1 reported practice on 115 days for a mean of 35 (15) minutes each day. P2 was inconsistent in documenting time spent on self-controlled practice. P2 documented 12 days of practice for a reported mean of 35 (2) minutes each practice day. Number of hits per phrase was recorded on P1's speech-generating device. P1 ranged from 0 to 22 hits with a mean of 11 (6) per phrase. P2 was provided a speech-generating device to use for self-controlled practice at home that would allow us to track the number of hits along with a time stamp. Unfortunately, P2 preferred to use the same iPad text to speech app used for communication. Therefore, we do not have data to report for P2's self-controlled practice activity.

Treatment Cycle 2

Figure 2 illustrates the mean rating for the treated and untreated set of stimulus items in Treatment Cycle 2. The mean baseline rating for P1 was approximately 3.0 for treated and 3.30 for untreated phrases. P2 mean baseline rating was 3.90 for treated and 4.40 for untreated phrases. These ratings indicate speech productions that are missing crucial elements of the production making the utterance unintelligible.

Once training in Treatment Cycle 2 was instituted, a steady trend of improvement in retention ratings occurred for both participants on the treated set of phrases. P1 demonstrated a mean retention rating of 8 by retention probe 9. This indicates his speech productions were described as delayed with sound distortions, deletions or additions, however the overall message was intelligible. P2 demonstrated a mean retention rating of 8 by retention day 14 and remained steady at this level of intelligibility for the remainder of the treatment cycle. Mean treatment gain was 5.20 for P1 and 4.57 for P2.

Transfer of speech motor learning was observed for both participants as evidenced by mean retention ratings on the untrained phrases. P1 had a mean retention rating of 6.8 and 7.1 on retention day 20 and 25. This indicates his speech productions were mostly immediate and intelligible despite incomplete articulation. Despite the improvement in P2's performance from baseline, his productions remained delayed, however productions were intelligible despite elements of incomplete articulation.

The Tau-U across treatment conditions of Cycle 2 was 0.94 with 90% confidence intervals between 0.52 and 1. This result indicates that 94% of the data showed improvement between baseline and

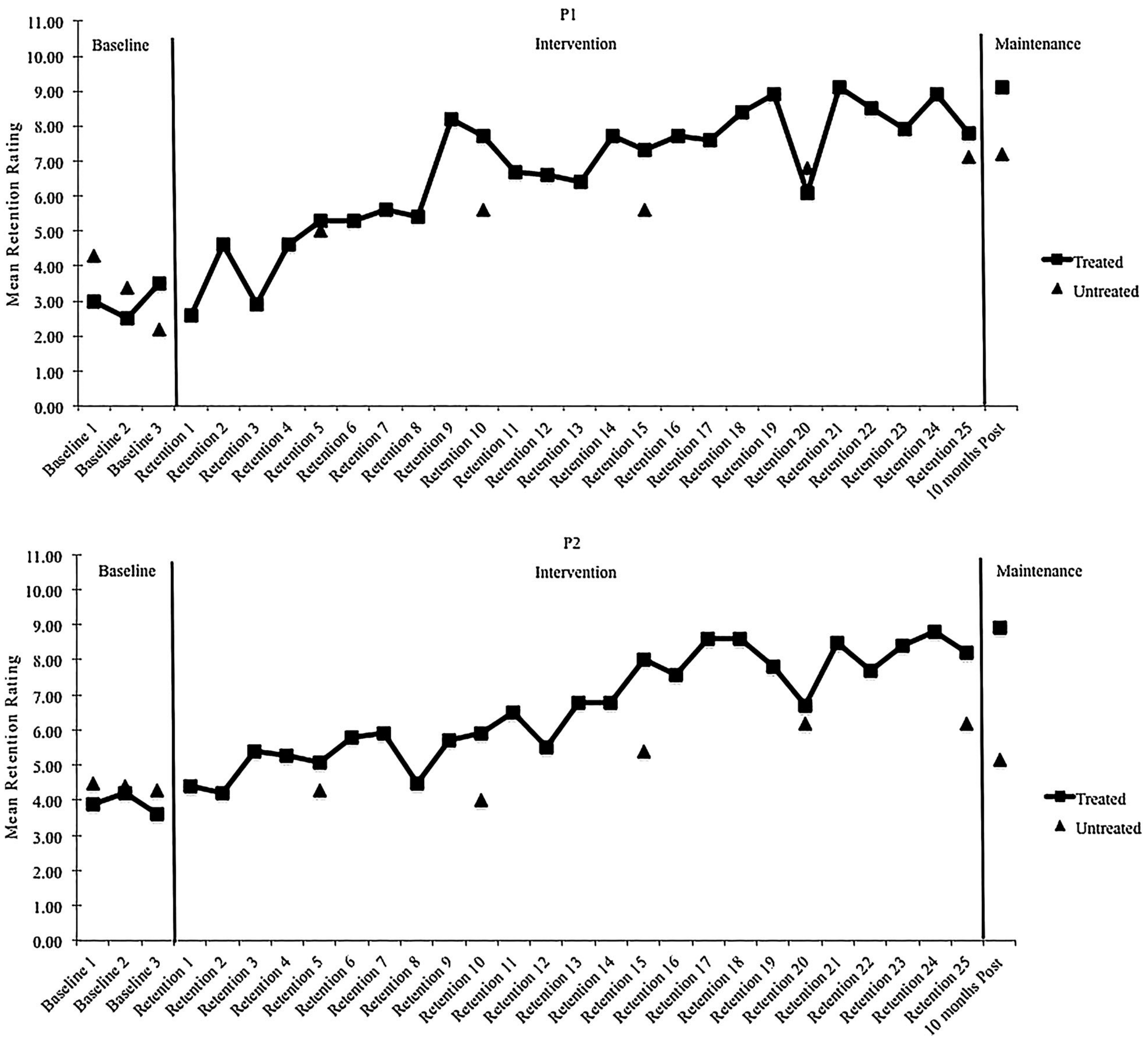

Figure 2. Treatment Cycle 2 mean retention ratings for treated and untreated conditions for P1 and P2.

intervention phase. For the within treatment condition, Tau-U was 1.0 indicating that 100% of the data showed improvement with a 90% confidence interval of 0.58 to 1. In addition, treatment effect sizes (d) were calculated as previously described. Large effect sizes were found for P1 treated ($d = 10.40$), P2 treated ($d = 15.22$) and untreated ($d = 15.33$). P1 untreated ($d = 3.04$) phrases had a small effect. Follow-up effect size was large for P1 ($d = 12.20$) and P2 ($d = 16.70$) in the treated phrases. A small effect size was seen for P1 in the untreated ($d = 3.70$) phrases and a medium effect size for P2 in the untreated ($d = 7.82$) phrases.

Social validity

Social validity measures were obtained through a modified survey of communication effectiveness (Ball et al., 2004). Pre-treatment and post-treatment ratings from the communicator and family member were obtained (Table 4). For P1, the biggest changes were in ratings by self and spouse on questions related to having a conversation on the phone, traveling in a car and before a group. For P2, both self and brother rated biggest changes on having a conversation with young children.

Discussion

The results of this investigation were widely consistent with previous results using MLG for the treatment of acquired AOS. The first treatment cycle investigated practice frequency in two conditions of practice: high (therapy and self-controlled home practice) compared to low (therapy only). Changes in speech motor learning occurred for both participants in both high and low conditions of practice (Johnson et al., 2014). As hypothesized, mean retention ratings on the high practice set of phrases were superior to low practice set of phrases, however the effect size for the low practice set of phrases was larger. This suggests that improvement from baseline was greater for low practice than high practice condition. In these two participants, having access to the phrases posed no clear advantage (nor disadvantage) to speech motor learning compared to not having access to the phrases for self-controlled practice. Both participants reported that they liked having the ability to practice at home, which indicates having access to the stimuli may have a positive influence on motivation.

Behavior changes in self-controlled practice are believed to be attributed to motivation (Lewthwaite & Wulf, 2012). There is great interest to facilitate self-controlled practice (i.e., home practice) (Johnson et al., 2014; Lasker et al., 2008, 2010) and/or self-controlled therapy using computer-based programs for acquired AOS (Varley et al., 2016). While home practice has been incorporated in multiple MLG treatment studies, the influence of the practice beyond treatment session with clinician is unknown (Ballard et al., 2015). In aphasia treatment, there are mixed reports for self-directed treatment (Palmer, Enderby, & Paterson, 2013) and computer-based treatment (Lavoie, Macoir, & Bier, 2017; Teasell et al., 2016; Zheng, Lynch, & Taylor, 2015). However, as was the case in this study, from a client perspective, there is a high level of satisfaction with computer-based programs with one study reporting clients had a perceived increase in autonomy (Wade, Mortley, & Enderby, 2003).

Under the self determination theory, motivation can be related to autonomy, competence, or relatedness (Deci & Ryan, 2011). However, there are few studies that have directly measured motivation to quantify its effectiveness on motor learning. There are multiple elements of motivation and various ways to facilitate motivating factors in self-controlled practice (see Sanli, Patterson, Bray, & Lee, 2012). Unfortunately, due to noncompliance by one of our participants, we have limited data to report on patterns of self-controlled practice. Of the data collected from P1, the number of hits per phrase indicated preferential practice on certain phrases throughout the treatment cycle. However, the preference changed from week to week. The number of hits did not directly translate to better performance on retention measures. Additionally, both participants seemed to dedicate a similar amount of time to the self-controlled practice and for P1 the time spent remained consistent throughout the treatment cycle. We are limited in our interpretation of the data collected for self-controlled

Table 4. Pre and post-treatment participant and family member social validity ratings as measured using the modified communication effectiveness index (Ball et al., 2004).

P1		P1 Spouse		P2		P2 Brother		
Pre	Post	Pre	Post	Pre	Post	Pre	Post	
2	5	3	7	3	4	1	5	Having a conversation with familiar persons in a quiet environment.
2	5	2	7	2	2	1	5	Having a conversation with strangers in a quiet environment.
2	7	2	7	1	1	1	1	Having a conversation with a familiar person over the phone.
2	7	3	7	2	5	1	5	Having a conversation with young children.
1	7	2	4	1	1	1	1	Having a conversation with a stranger over the phone.
2	7	2	7	2	4	1	5	Having a conversation while traveling in a car.
1	1	1	2	2	2	1	3	Having a conversation with someone at a distance.
1	1	2	4	1	3	1	4	Having a conversation with someone in a noisy environment.
3	7	3	7	1	1	1	2	Speaking or having a conversation before a group.
1	1	1	1	1	2	1	2	Having a long conversation with someone (over an hour).

practice due to the missing information of production frequency. However, it is apparent that there was a motivating factor to complete the self-controlled practice.

Perhaps, one of the ingredients missing in our quest to identify optimal treatment intensity is the influence of motivation. Currently, motivation is not one of the factors considered for optimal treatment intensity (Baker, 2012; Warren, Fey, & Yoder, 2007). However, it is reported that how much *and* what was practiced influenced treatment outcomes more than session dose and was identified as potentially one of the missing ingredients (Cherney, 2012; Togher, 2012). Having a better understanding of specific motivating factors of our clients, could guide our decision to use self-controlled practice and identify the best structure to meet our patient's needs (Varley et al., 2016). Investigations measuring motivating factors would be a welcome area of future research (Raymer & Rothi, in press) and may be one of the missing ingredients to maximize behavioral change for speech motor learning in our clients with acquired AOS.

The second treatment cycle aimed to explore the influence of number of targets on transfer of speech motor learning. Transfer of speech motor learning occurred by retention 10 for P1 and around retention 15 for P2. At ten months post-treatment, P1 maintained performance while P2 dropped slightly. It should be noted that P1 improved on the ten months post-treatment measures on the untreated phrases from Treatment Cycle 1. This response generalization suggests that the MLG approach was successful at internalizing the strategy or at least targeting the underlying process affecting the speech motor programing and planning system (Coppens & Patterson, 2018). The response generalization and maintenance, supports the hypothesis that decreasing the number of targets influences transfer of speech motor learning.

Changes in encoding, storage and retrieval processes of memory for verbal stimuli are affected following a stroke (Campos, Barroso, & de Lara Menezes, 2010). By decreasing the number of targets, participants practiced the same phrase with fewer items of interference between each phrase. This decrease in cognitive load resulted in successful transfer of speech motor learning not seen with more targets. Response generalization is reported in other studies using MLG (Friedman, Hancock, Schulz, & Bamdad, 2010; Kim & Seo, 2011; Lasker et al., 2008), the framework of PML (van der Merwe, 2011), as well as studies comparing factors of PML in existing treatment protocols (Austermann Hula, Robin, Maas, Ballard, & Schmidt, 2008; Ballard, Maas, & Robin, 2007; Wambaugh & Nessler, 2004). Guidelines for target selection have been reported (Odell, 2002) however, there is a lack of studies investigating the optimal number of targets on speech motor learning in acquired AOS. Further, the reported number of targets varies considerably across studies – anywhere from 5 to 48 items (e.g., Austermann Hula et al., 2008; Friedman et al., 2010; Kurland, Pulvermuller, Silva, Burke, & Andrianopoulos, 2012; Mauszycki, Wambaugh, & Cameron, 2012; Wambaugh, Nessler, Wright, & Mauszycki, 2014). The influence of the number of targets used during treatment is another area worthy of further investigation to optimize treatment outcomes and identify optimal treatment dosage.

A limitation of this study is the use of only three baseline measures in both participants. While three baseline measures fall within the 'meets standards with reservations' recommendations of What Works Clearing House (Kratochwill et al., 2013), the outcomes would be stronger if there were five baseline measurements or an extended baseline in the second participant. The untrained stimuli in Treatment Cycle 1 serve as a strong control, however. The untrained stimuli in Treatment Cycle 2 also serve as a strong control. Given the trend and consistency in data patterns across treatment cycles, there is strong evidence to support that the data represent speech motor learning rather than practice effects.

The variability in the stimuli across participants and conditions of practice may have been a contributing factor to outcomes in this study. Despite our efforts to balance phrases across practice conditions, the difference in baseline performance indicates that the untrained set of phrases in Treatment Cycle 1 may have been more complex than the high and low dose sets of phrases. However, the performance could also be due to the unfamiliarity of the phrases and/or there may be a motivation factor. The variability of the phrases in Treatment Cycle 1 was acknowledged. Therefore, in Treatment Cycle 2 a sentence template was used to better balance the stimuli while maintaining the integrity of personalizing the content. The mean baseline measures for the treated and untreated set of phrases in Treatment Cycle 2 were similar.

The outcomes from this study contribute to the growing evidence for the effectiveness of MLG treatment approach for the treatment of acquired AOS. The acquisition of speech motor learning is comparable to traditional treatment approaches. However, the uniqueness of the outcomes in this study pertain to the use of phrases as stimuli compared to limiting stimuli to single or multisyllable words as is frequented in traditional treatment studies. In addition, outcomes were measured on an oral reading task without a model, which differs from traditional approaches in which the outcomes are measured following a verbal clinician model. Future work includes expanding to connected speech samples and generalization to spontaneous communication in structured conversation. Future studies also include using a more rigorous research design to include more participants in a random assigned treatment condition.

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No potential conflict of interest was reported by the authors.

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