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Motor Learning Guided Treatment for Acquired Apraxia of Speech: Factors That Influence Treatment Outcomes

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Motor learning guided treatment for acquired apraxia of speech: a case study investigating factors that influence treatment outcomes

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ABSTRACT

Purpose: The purpose of this study was to examine factors that might influence the treatment effectiveness of motor learning guided (MLG) treatment approach for apraxia of speech (AOS). Specifically, this study examined the effects home practice and the stimuli selection on speech production.

Method: This is a case study across two treatment cycles involving a 52 year-old male five months post left CVA (due to a carotid artery dissection). Each treatment cycle used three conditions of practice to investigate the influence of practice frequency on treatment outcomes. The personal relevance of stimuli within and across treatment conditions differed in the treatment cycles to investigate stimuli selection influence on treatment outcomes.

Results: Changes in speech motor learning occurred in all conditions of practice only after therapy began. Phrases practiced in therapy and at home met criterion for mastery in fewer sessions than therapy only and untrained phrases. The content of the stimuli did not appear to have a direct influence on speech motor learning.

Conclusion: This case study contributes to the growing evidence on the effectiveness of MLG treatment for acquired AOS. Future studies using an experimental design are needed to advance and strengthen the evidence for MLG.

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Introduction

Apraxia of speech (AOS) is a sensorimotor impairment in the planning and programing for speech. The prevalence of acquired AOS is unknown due to the challenges with common co-occurrence of aphasia and dysarthria (Duffy, 2013; Duffy, Strand, & Josephs, 2014). There are several treatment approaches for acquired AOS however; the evidence base is not efficient to make a recommendation for a single treatment approach that works for the vast majority of persons with AOS (Ballard et al., 2015; Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006a, 2006b). The majority of the research studies use an articulatory-kinematic approach based on the framework first introduced by Rosenbek, Lemme, Ahern, Harris, and Wertz (1973). These protocols use serial repeated practice, integral stimulation, high frequency of clinician modeling and feedback for accurate articulatory gestures. Over the past decade, the theoretical framework has broadened to incorporate the principles of motor learning (PML) from limb motor learning research (Bislick, Weir, Spencer, Kendall, & Yorkston, 2012; Maas et al., 2008; Schmidt & Lee, 2011).

The PML are conditions for the structure of practice and augmented feedback that foster the acquisition and learning of a motor skill. To better understand how the PML influence outcomes for individuals with motor speech disorders receiving speech treatment, researchers have compared specific conditions of practice and augmented feedback to existing treatment protocols (e.g., Austermann Hula, Robin, Maas, Ballard, & Schmidt, 2008; Katz, McNeil, & Garst, 2010; Knock, Ballard, Robin, & Schmidt, 2000; Maas, Barlow, Robin, & Shapiro, 2002; Wambaugh, Nessler, Cameron, & Mauszycki, 2013; Wambaugh, Nessler, Wright, & Mauszycki, 2014; Wambaugh, Nessler, Wright, Mauszycki, & DeLong, 2016). Hageman and colleagues (2002) developed a hierarchical treatment protocol, Motor Learning Guided (MLG), based on the conditions of practice and augmented feedback found to be most influential for long-term retention in limb motor learning (Schmidt & Lee, 2011). They reported positive outcomes in the initial study using MLG in an individual with aphasia and acquired AOS.

The framework and structure of the MLG protocol addresses the impaired sensorimotor system. The factors of PML used in the protocol are random practice of personally relevant and meaningful words or phrases in varying contexts. It uses multiple practice

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opportunities of the complex stimuli with an integrated 2–4 s delay between each production. The individual is instructed to use the delay to identify if the outcome of their production was the intended outcome and make appropriate adjustments for their next attempt. The clinician provides delayed knowledge of results (KR) feedback at a reduced frequency (i.e., after every third production). KR feedback provides information on the outcome of the production (e.g., 'I heard changes with each attempt', 'the last one was closest', 'how do you think you did?'). The structure of the practice permits the individual to increase self-awareness of their speech production and facilitates the development of internal strategies to correct any errors produced.

There have been a number of case studies reporting the effectiveness of MLG in acquired AOS (Kim & Seo, 2011; Lasker, Stierwalt, Hageman, & LaPointe, 2008; Lasker, Stierwalt, Spence, & Cavin-Root, 2010). In the first study (Lasker et al., 2008), MLG treatment was provided once a week across three treatment cycles in a patient with profound chronic AOS. The stimuli were programed into the patient's speech-generating device (SGD) for additional practice between therapy sessions. Treatment targeted personally meaningful stimuli, increasing in complexity and length with each treatment cycle. Transfer of speech motor learning (SML) was measured using untreated stimuli, matched for length and phonetic structure. Retention measures rated on an 11-point multidimensional rating scale were used as an index of SML. The authors reported a positive outcome identified by changes in speech production for treated items in each treatment cycle and transfer of SML in two of the three treatment cycles.

Kim and Seo (2011) replicated these findings in a case study of two patients with chronic AOS and Broca's aphasia without home practice. They report SML occurred for treated stimuli during 12 treatment sessions using MLG. Index of SML was based on retention measures using a similar version of the 11-point multidimensional rating scale. They also reported transfer of SML to untreated stimuli.

The effectiveness of MLG was further investigated in Lasker and colleagues' second case study (2010). Treatment sessions occurred twice weekly delivered face-to-face and via telehealth. Stimuli were matched for linguistic complexity and syllable length across treated and untreated stimuli as well as across treatment settings. The authors reported positive changes in SML for treated stimuli across treatment settings and no evidence of transfer to untreated items as measured in retention productions using a multi-dimensional rating scale.

Current study

We wanted to further explore the effectiveness of MLG in a patient that presented with aphasia and AOS following a stroke from a carotid dissection. We sought to investigate factors that may have influenced the outcomes in the previous case studies: home practice and the personal relevance of stimuli. In daily practice, clinicians frequently make decisions about creating specific treatment stimuli that are motivating and functional; clinicians also typically make recommendations about daily practice. However, little is known on the direct impact these recommendations have on patient outcomes.

This study was completed in two treatment cycles investigating influence of self-controlled home practice and the implications of stimuli selection. Advantages of self-controlled practice are discussed in vocational and limb motor learning (Wulf, Shea, & Lewthwaite, 2010). In self-controlled practice, the learner has control over practice conditions such as which items are practiced, amount of practice completed, and timing and frequency of feedback. This type of practice has a positive influence on motivation and engages the learner in different information processing resulting in enhanced outcomes (Lewthwaite & Wulf, 2012; Wulf et al., 2010). Despite the interest to use home practice programs for AOS, little is known about the implications home practice has on treatment outcomes. To investigate the influence of self-controlled practice in SML, we developed three sets of phrases across three practice conditions. One set of phrases was practiced in therapy and was available for practice outside of therapy (high dose); one set was practiced in therapy only (low dose) and one set was probed periodically (untreated). We used the same conditions of practice in both treatment cycles while manipulating the stimuli within and across conditions.

Decisions on stimuli selection and complexity for treatment of AOS are typically based on phonemic and articulatory repertoire and stimulability as it pertains to frequency or meaningfulness to the patient. Guidelines for target selection have been suggested (Odell, 2002), however the implications of stimuli selection for SML are grossly unknown. We wanted to explore if the rate of change of SML would differ based on the functionality of the stimuli across treatment conditions. Stimuli in Treatment Cycle 1 shared similar theme but were phrased differently and practiced differently. Treatment Cycle 2 stimuli were personally relevant but, did not share a themed topic. The topic of the stimuli across conditions was independent of the other to identify potential influence of motivating factors for SML.

Based on limb motor learning research, we hypothesized that the rate of SML would coincide with the amount of practice (Keetch & Lee, 2007). Based on prior research in aphasia, we also hypothesized that the functionality of the phrases would influence the rate of SML (Cherney, Kaye, Lee, & van Vuuren, 2015; Leonard et al., 2014). These outcomes have the potential to guide clinicians in decisions for home practice recommendations and factors to consider when creating treatment stimuli.

Method

Participant

BP was a 52-year-old, left-handed male Information Technology consultant who had a left cerebral vascular accident (CVA) due to a dissection of the carotid artery five months prior to intervention. Computerized Tomography (CT) identified a moderately large isolated infarct in the left parietal lobe. He was independent with his activities of daily living and ambulation. He lived at home with his wife and 17-year-old daughter. Following his stroke, BP received three months of inpatient and outpatient rehabilitation focusing on single word production until his insurance benefits were exhausted.

Informed written consent was obtained before initiating testing and treatment procedures. BP was characterized as having Broca's aphasia secondary to agrammatic and telegraphic speech productions. Initial testing results (Table 1) indicated a moderate aphasia and functional reading competency at the sentence level according to the Western Aphasia Battery (WAB-R; Kertesz, 2006). BP's score on the reading comprehension and reading command tasks are reflective of his speech impairment. All responses for reading comprehension and performance on the written direction tasks were accurate and precise. There were no indications for the presence of alexia. Performance on the Apraxia Battery of Adults (ABA-2; Dabul, 2000) indicated a moderate to severe AOS. Confirmation of the presence of AOS was determined using the Apraxia of Speech Rating Scale (ASRS; Strand, Duffy, Clark, & Josephs, 2014) completed by an ASHA certified speech-language pathologist. On the ASRS 'frequent but not pervasive (2)' and 'nearly always evident but not marked in severity (3)' ratings were assigned on five of the six primary distinguishing features for AOS (one or more must be present for diagnosis of AOS). BP's speech was characterized as having the following features: distorted sound substitutions increasing with increased utterance length; sequential motion rate (SMR) that was deliberate and distorted compared to alternate motion rate (AMR); speech initiation difficulty; and false starts and restarts. BP independently utilized a strategy of writing (primarily single words) to facilitate communication. This strategy was successful in situations of known context and limited response possibilities.

Materials and apparatus

Setting and apparatus

Treatment sessions were delivered using Skype webcam technology two times per week. Prior to initiating the intervention, the clinician performed a home visit to install, set-up, and conduct a test Skype Internet call. Retention measures were recorded using Call Recorder™, an add-on program for Skype. Employing Skype allowed for an increased number of treatment sessions and has been established as effective as face-to-face treatment (Hill, Theodoros, Russell, & Ward, 2009). Self-controlled home practice was completed using a speech-generating device (SGD). The high dose phrases were programed into the device with a single target item stored under a single button identified by the written target. When the button was pressed the target utterance was 'spoken' aloud by the device. BP was provided written instructions to follow during the self-controlled practice of the targets using the MLG steps. BP used a paper calendar to document the amount of time spent practicing outside of the therapy sessions. Education on the purpose of the research study including the methods and procedures was provided to BP's spouse. She was available to assist with the home practice if needed.

Stimulus item selection

In each treatment cycle, three sets of 15 phrases matched in syllable length with the primary emphasis

Table 1. Pre-treatment and serial post-treatment aphasia, apraxia of speech assessment scores and content unit analysis from picture description tasks.

	Pre-Treatment	Post- Treatment Cycle 1	Post-Treatment Cycle 2	3 Months Post- Treatment
WAB-R				
Aphasia Quotient (100)	61.9	74.6	84.2	90.2
Spontaneous (20)	12	15	19	19
Auditory Verbal Comprehension (10)	9.65	9.7	10	10
Repetition Score (10)	4.1	6.7	6.3	8.2
Naming and Word Finding Score (10)	2.6	5.9	6.8	7.9
Reading (100)	86	dnt	dnt	dnt
ABA-2				
Diadochokinetic	Mild	Mild	Mild	Mild
Increase word length - part a	Severe	Mild	Normal	Normal
Increase word length - part b	Severe	Mod	Mod	Mild
Content Unit Analysis				
Index of Lexical Efficiency	5.8	3.9	3.0	3.6
Index of Grammatical Support	2.6	2.8	2.2	3.4

Note: dnt = did not test.

of functionality were created (Table 2). The content of the phrases were identified in a structured interview with BP and his spouse. The complexity of the stimuli was determined based on language samples taking into consideration the ease of speech production and length of the utterance. The stimuli selected were not based purely on a 'motor speech' perspective (i.e., identifying impaired speech sounds). Rather an overall complexity representative of similar number of singletons and blends and syllable length was used. One set of phrases was clinician treated and available for self-controlled practice at home (high dose); one set of phrases was clinician treated only (low dose) and one set of phrases was untreated (untreated).

In Treatment Cycle 1, for a given topic, three phrases were created for each condition of practice. All topics were personal and professional interests and activities. The phrases within each condition were unrelated however; the content of the phrases was related to the topic across conditions. The phrases across conditions were matched by syllable count ranging from 6 to 13 syllables. In Treatment Cycle 2, the phrases within the condition of practice were related to the same topic. The topic was unrelated across conditions of practice but matched by syllable count (8–13 syllables). The content for the phrases in the high dose condition of practice consisted of technical jargon based on BP's continued impairment in verbalizing written numbers and interest in returning to his previous vocation. The low dose set of phrases were taken from the Sentence Intelligibility Test (Yorkston, Beukelman, & Hakel, 1996) and the untreated set were functional phrases that differed in content from phrases in Treatment Cycle 1.

Procedures

Experimental design

This is an exploratory case study across two treatment cycles investigating factors that influence SML. Three conditions of practice in each treatment cycle were used to investigate the influence of self-controlled practice on SML. The stimuli selection was manipulated to investigate the implications of functionality of the stimuli on SML.

A retention measure obtained at the beginning of each treatment session prior to initiating the MLG protocol was used as the measure of SML. An oral reading task (no model) was used to elicit independent speech production. The use of a reading probe is a means to elicit speech production in the absence of a model for a measure of SML rather than a measure of repetition, as is the case if a model is provided. These productions were rated using an 11-point multidimensional rating scale based on articulation accuracy, intelligibility and immediacy of the speech productions (Table 3). Ratings were scored online and confirmed offline from the video recording as needed. A performance criterion was used to determine the length of treatment for each condition of

Table 2. Stimuli for three conditions of practice in Treatment Cycle 1 and Treatment Cycle 2.

High dose	Low dose	Untreated
Treatment Cycle 1		
I go to the gym everyday.	Every morning I go swimming	I enjoy my daily workout
My insurance is CHP and Aetna.	Do you need my personal information?	I have two healthcare benefit policies.
We need to make a grocery list.	Let's write down what we need for the week	What time are we going to the store?
I have a Sprint meeting every morning.	When will we see each other tomorrow?	I need to prepare for my appointment.
We talked about the backlog today.	We discussed the data collected.	The meeting was very productive.
We gave a product report to the owner today.	I gave a presentation of our work to the group.	Is everything completed for the meeting?
Insure the artifacts for service.	Thank you for all of your assistance.	What should I prepare for our next session?
What are good exercises for core training?	I lift weights to rebuild muscle strength.	Can you show me how to use this machine?
I had my stroke in October.	Last year, I had a CVA.	My brain event occurred last year.
I attend speech treatment at FSU.	I have a hard time getting my words out.	My therapy is given via Skype.
I will type my message	Please give me one moment.	I need pen and paper.
Do you have any errands for me to do?	I can stop by the drug store later today.	I have time for chores tomorrow afternoon.
I need to refill my prescription.	My medication is running low.	I plan to go to the pharmacy.
I am going to walk Xx at Phipps.	I took the dog around the trail today.	Xx and I jogged in the neighborhood.
I had a sandwich for lunch after my swim.	I had something to eat after I got home.	I had a late meal because I made a stop.
Treatment Cycle 2		
64-bit Windows 7	I tell you it was wonderful.	We spent the day at Tom Brown park.
There are 6 GB of RAM	The girls cut lacy valentines.	I'm a UWF alumnus.
Core i3 has 4 MB cache.	It's a grace that must be developed.	We spent the weekend at a beach house.
7200-rpm	I've had one unusual request.	I live at 1512 Xx Xx.
3.3 GHz 6-core Xeon	I don't know how I managed to get here.	Xx starts FSU in the fall.
Seagate 7200.11	The process works in other ways as well.	I see the neurologist on Monday.
It's a 7.1 channel audio	Fill the pan about half full of gravel.	Mountain biking is one of my hobbies.
$3,699.00	Well, religion made me what I am today.	It took 6 months to process the paperwork.
Serial ATA-300 models	I hope you have time and energy to spare.	In August, I see the vascular surgeon.
Core i7-2600 PC	I've stopped trying to eat all my troubles away.	Someday, I would like to return to the workforce.
Operating systems are $6000	It can lead to any number of adventures.	Today, I focused on my breaststroke at the pool.
Windows 7 Ultimate is 150 more.	People often work in their offices at night.	Xxx rides her bike to work when it is nice.
2.4 GHz Core 2 Duo processor	What the badger gains from the partnership is not clear.	I am a business process improvement specialist.
150 to $250	It still has to be taken to where it can be used.	I decided to upgrade to an Android cell phone.
Core i7 965x-quad core CPU	Adding extra sugar didn't increase the sweetness.	My bachelor's degree is in Marine biology.

Table 3. Multidimensional Rating Scale.

Rating	Accuracy	Immediacy
11	Accurate articulation, intelligible	Immediate production of all elements
10		Delayed production of some elements of production (searching, groping)
9	Distortion; sound addition or deletion	Immediate production of all elements
8		Delayed production of some elements of production (searching, groping)
7	Incomplete articulation (missing elements of production does not interfere with general message)	Immediate production of all elements
6		Delayed production of some elements of production (searching, groping)
5	Successful Self Correction	
4	Incomplete articulation (missing crucial elements of production so that utterance is not intelligible)	Immediate production of all elements
3		Delayed production of all or some elements of utterance (searching, groping)
2	Perseverative error – wrong target	Immediate production of all or some elements
1		Delayed production of all or some elements of utterance (searching, groping)

practice in both treatment cycles. Criterion for mastery was a retention rating of 11 or 10 (intelligible and accurate production) in 13 of the 15 phrases across three consecutive sessions. Treatment Cycle 1 was completed in 10 weeks. Treatment Cycle 2 began after a four week break and was completed in seven weeks.

Each treatment cycle used three conditions of practice: high dose (clinician trained + self-controlled practice), low dose (clinician trained only) and untreated (untreated). Once the high dose set reached criterion for mastery, training and self-controlled practice of these phrases concluded and the treatment focus turned to training with the low dose set (no self-controlled practice) only. Once the low dose set reached criterion for mastery, training of this set of phrases concluded. Finally, treatment of the untreated phrases began until criterion for mastery was met. The phrases that met the criterion for mastery (high and low dose sets of phrases) were included in the retention measures collected at the beginning of each session.

Probing schedule

Two baseline measurements preceded the initiation of treatment for all three sets of phrases. The treatment protocol immediately ensued after the second baseline measure. While obtaining two baseline measurements limited the number of exposures to each phrase to better identify the relationship between practice and changes in speech production, a stable baseline in Treatment Cycle 1 was not obtained prior to initiation of treatment. To account for the researcher error, the inclusion of an untreated set of phrases served as an extended baseline.

Treatment protocol

Treatment sessions occurred two-days per week beginning with the random elicitation of the high dose and low dose treatment phrases in an oral reading (no model) probe. At the beginning of every fifth session, all three sets (high dose, low dose, and untreated) were included to yield the retention and a transfer measure. Following the retention measure, the remainder of the treatment session consisted of the MLG hierarchical treatment protocol (Appendix) modified from Hageman *et al.* (2002) and adapted from Lasker et al. (2010).

Data analysis

Post-testing and follow-up measures

Reassessment of language and speech measures using WAB-R (Kertesz, 2006) and ABA-2 (Dabul, 2000) occurred at the end of each treatment cycle. Maintenance of SML was determined using performance on retention measures obtained at one month and six months post Treatment Cycle 1 and 3 months post Treatment Cycle 2. Social validation measures were obtained through the modified Communication Effectiveness survey (mCETI; Ball, Beukelman, & Pattee, 2004) completed by the participant (pre, post Treatment Cycle 2 and 16 months post-treatment) and spouse (post Treatment Cycle 2 and 16 months post). The success of communication across different settings is rated using a Likert scale indicated by a 1 (not at all effective) to 7 (very effective).

Reliability

Reliability was determined on a random selection of 20% of the total number of retention measures across both treatment cycles using Krippendorff's alpha on an interval scale. A research clinician unfamiliar with this client was trained on the 11-point multidimensional rating scale on a sample of retention recordings before completing independent ratings. Interrater reliability was acceptable level of agreement at $\alpha = 0.93$. Intrarater reliability was determined following the last maintenance measure with an acceptable level of agreement at $\alpha = 0.95$.

Results

Treatment cycle 1

In Treatment Cycle 1 the stimuli consisted of content related by topic across treatment conditions. Figure 1 represents the number of stimuli rated as a 10 or 11 (intelligible and accurately articulated; may have a delay) on the retention measure. A steady trend in SML occurred only after initiation of training. The high dose set of phrases (clinician + self-controlled) met criterion (13 of 15 phrases receiving a 10 or 11 rating) following nine treatment sessions. Self-reported time spent practicing on the high dose phrases ranged from 10 to 50 min 4–7 days per week (Table 4). The low dose phrase set met criterion in 12 treatment sessions. The untreated set of phrases did not demonstrate change until targeted in treatment and met criterion after seven training sessions. Performance on retention measures remained steady at one and six months post-treatment.

Treatment cycle 2

The content of the phrases across treatment conditions were unrelated for Treatment Cycle 2. The trend in speech motor changes as measured using the multidimensional rating scale was similar to Treatment Cycle 1. However, the number of sessions needed to reach criterion was fewer for all conditions of practice. The high dose set of phrases met mastery following four treatment sessions compared to nine sessions Treatment Cycle 1. Self-reported time spent practicing on the high dose phrases ranged from 20 to 60 min 3–5 days per week (Table 4). The low dose phrase set met criterion in six treatment sessions compared to 12 sessions in Treatment Cycle 1. As with the untreated set in Treatment Cycle 1, a change on ratings on the retention measures was not indicated until treatment on the phrases began (Figure 2). As in Treatment Cycle 1, criterion was met in seven treatment sessions. Post-treatment retention measures obtained three months post-treatment remained steady.

Table 4. Self-controlled practiced on high dose phrases per treatment cycle as reported in minutes per day.

	Treatment Cycle 1							
	M	T	W	Th	F	S	S	Total
Week 1	50	40	35	35	35	25	20	240
Week 2	20		20	20		20		80
Week 3		20		20	20			60
Week 4	15	10		10	15			50
Week 5		10						10
Total Minutes for Treatment Cycle								440
	Treatment Cycle 2							
	M	T	W	Th	F	S	S	Total
Week 1	60		60	60		45	45	270
Week 2		60		60		30		150
Week 3	30			30			20	80
Total minutes for Treatment Cycle								500

Follow-up speech and language assessment

Speech and language performance were formally assessed at the end of each treatment cycle using the WAB-R (Kertesz, 2006) and ABA-2 (Dabul, 2000) (Table 1). Pre-treatment Aphasia Quotient of 61.9 improved to 90.2 at three months post-treatment. This is well beyond the average performance improvements reported over the course of recovery (Aftonomos, Appelbaum, & Steele, 1999; Basso, Capitani, & Vignolo, 1979). Improvement was seen in all areas with the most notable on naming and fluency tasks: 2.6 (pre) to 7.9 (post) out of 10.

Severity of AOS as measured by performance on the ABA-2 (Dabul, 2000) improved from a moderate-severe to a mild-normal severity of apraxia. There were noted changes in speech production on repeating words of increasing length – severe at pre-treatment (unable

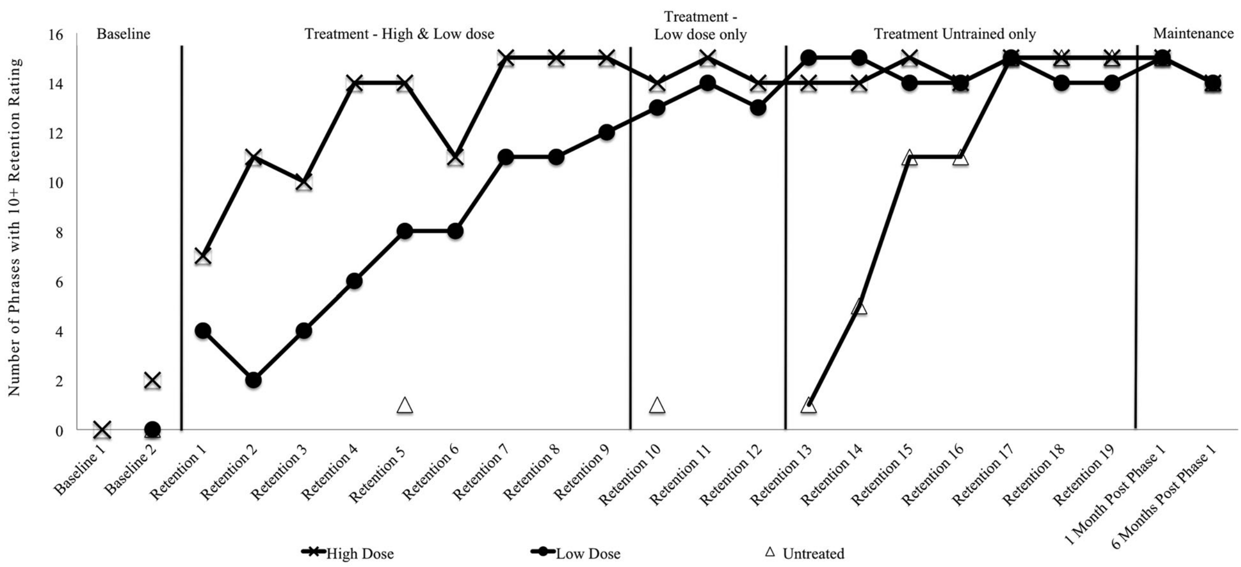

Figure 1. The total number of 10–11 ratings on retention measures for each condition of practice in Treatment Cycle 1.

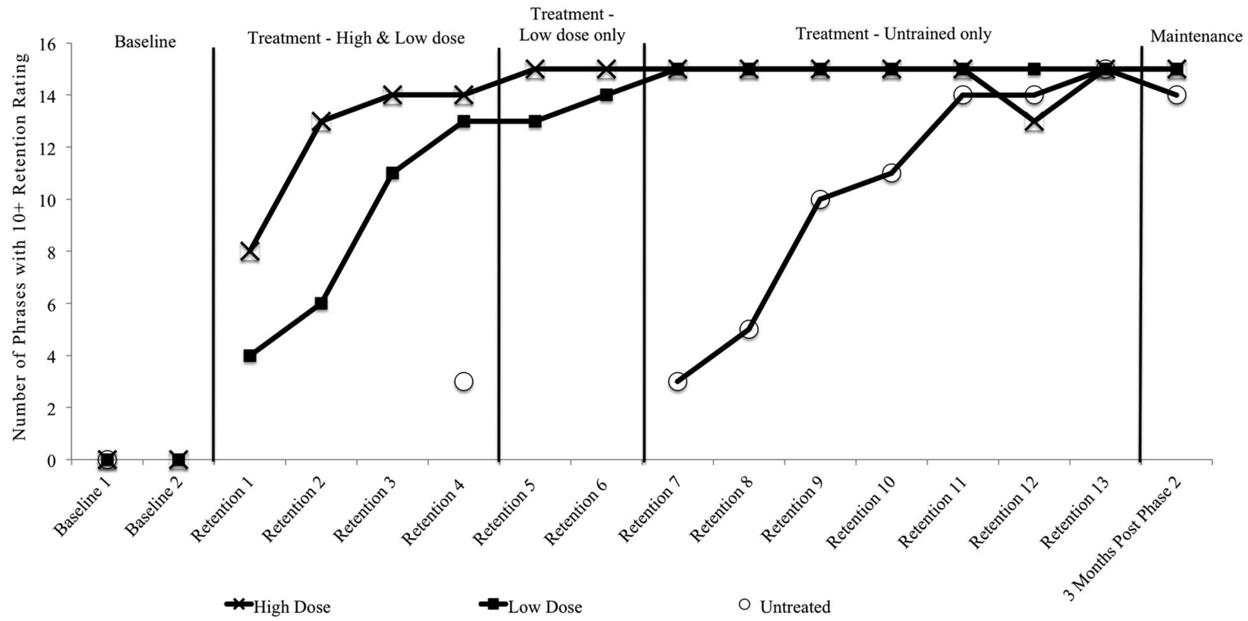

Figure 2. The total number of 10–11 ratings on retention measures for each condition of practice in Treatment Cycle 2.

to complete the most complex subtest) to mild at three months post-treatment (all subtests).

A picture description task provides a mechanism to measure changes in spontaneous speech and language production. Changes in speech production as illustrated by picture description samples obtained at the end of each treatment cycle demonstrate an increase in length, semantic content, and syntactic complexity of BP's speech production. To quantify the verbal output improvement, a content unit analysis was completed to compute an index of lexical efficiency (ILE) and index of grammatical support (IGS) through a method used for *The Cookie Theft* picture from the Boston Diagnostic Aphasia Exam (Goodglass, Kaplan, & Barresi, 2000; Helm-Estabrooks, Martin, & Nicholas, 2014; Yorkston & Beukelman, 1980). The ILE improved at each sample with the 3 months post-treatment performance (ILE = 3.6, IGS = 3.4) consistent with the average of typical adults (ILE = 3.7, IGS = 3.5) (Table 2). Below is an excerpt from the language sample from the WAB-R picture description task comparing the pre-intervention to three months post Phase 2:.

Pre: Man Woman Uh uh a a near the … lake. She was … a … drink. He was … wad … . ah … .. reading. And … boy was … a … running with a … sh … shake, no.

Post: *Um, there's a family with a..a … a pic a picnic. A … with near a house and a lake. It looks like a family a … a father is wa … a reading a book. a … has his shoes off. The mother is drinking. a … they were a … it looks like … listening to the ra ra radio. Um, the boy is running with a kite … kite. And a..a … a … and running with a dog behind him.*

To address treatment effects beyond the selected treatment targets, social validity measures were obtained through a mCETI (Ball et al., 2004) (Table 5). BP gave self-ratings of mostly all 1's at pre-treatment; post-treatment self-ratings improved to average rating of 5 across most communication situations. Spouse ratings coincided with improvement in communication effectiveness with slightly higher ratings of 6 across most communication situations.

Table 5. Modified Communication Effectiveness survey (mCETI).

Participant			Spouse		
Pre	Post	16 months Post	Post	16 months Post	
2	4	5.5	5	6	Having a conversation with familiar persons in a quiet environment.
1	2	5	5	6	Having a conversation with strangers in a quiet environment.
1	3	5.5	4	5	Having a conversation with a familiar person over the phone.
1	2	4	6	6	Having a conversation with young children.
1	2	4	3	3	Having a conversation with a stranger over the phone.
1	3	4	4	6	Having a conversation while traveling in a car.
1	2	4	3	6	Having a conversation with someone at a distance.
1	2	4	3	3	Having a conversation with someone in a noisy environment.
1	2	5	3	3	Speaking or having a conversation before a group.
1	1	5	3	4	Having a long conversation with someone (over an hour).

Discussion

The purpose of this study was to further investigate the effectiveness of MLG treatment for acquired AOS. We had two objectives in this case study involving a person with aphasia and acquired AOS. First, we wanted to investigate the influence of self-controlled practice on SML using MLG across 3 practice conditions: high (clinician + self-controlled practice), low (clinician only), and untreated. Our second objective was to identify the influence of stimuli selection on SML within and across these treatment conditions.

Overall, BP demonstrated improvement in SML in all conditions of practice only after the initiation of training on stimuli occurred. This coincides with findings of Lasker et al. (2010) in which SML occurred only on treated phrases. In both treatment cycles of this study, the high dose phrases reached criterion for mastery in fewer sessions than the low dose set of phrases independent of the stimuli content relationship within or across treatment conditions. The content of the stimuli did not appear to have a direct influence on SML for our participant.

There was an unexpected and noteworthy finding on the degree of change in the aphasia quotient pre- and post-treatment. During the pre-assessment testing, BP provided an accurate written response to all stimuli presented during the naming task indicating his word recall skills were intact. However, his ability to verbalize the response was impaired. This change in ability to verbally respond to the stimuli is a direct reflection of speech production improvements following our intervention. While we did not see a direct transfer of SML in our untreated condition of practice, the changes in speech production did impact performance on all measures of the WAB due to the heavy verbal output required for most tasks on the WAB.

We would like to offer two possible explanations for the linguistic and speech changes seen in this individual. The theoretical framework of MLG is founded on the PML addressing motor control through the sensorimotor feedback system. This framework addresses the primary motor control process that affects the phonetic coding according to the theoretical framework that AOS is a phonetic-motoric disorder (Kent & McNeill, 1987). As previously identified, the phonetic level errors have implications at the phonological level (Code, 2009). The structure of our stimuli included complex articulatory tasks in varying contexts (Wulf & Shea, 2002). One possible explanation for the linguistic and speech changes seen in this case is that as BP improved the motor control, he was better able to allocate resources resulting in better phonological processing (Rogers and Storkel, 1999). We were able to capture this transition in the picture description task thus prompting us to quantify the transition of improvement in spontaneous speech by completing a content analysis. The theory that improvements in the motor control resulted in better phonological processing is further supported by the change in aphasia quotient pre- and post-treatment.

Alternatively, the speech and linguistic changes may be attributed to the overlap in the theoretical framework of principles of neuroplasticity and PML. They both support saliency, treatment specificity, multiple practice productions, and complexity of exemplars (Schmidt & Lee, 2011; Warraich & Kleim, 2010) all of which are included in the MLG treatment protocol. In addition, when selecting our stimuli we took a communication approach accounting for the whole person and the co-existing aphasia. This differs from most AOS treatment protocols, which focus on specific articulation errors. Therefore, the combination of the commonalities of the theoretical framework for aphasia and AOS and the positive influence of the acuity post-onset offer another possible explanation for the the linguistic and motor speech outcomes seen in this case study.

In terms of the influence of self-control practice on SML, the number of sessions to criterion between the high and low practice conditions differed only by 2 and 3 sessions in Treatment Cycle 1 and 2, respectively; while the untrained condition met criterion in the same number of sessions in both treatment cycles. Of interest in this finding is the number of minutes reported in self-controlled practice on the high dose set of phrases. While we are unable to comment directly on the quality of the self-controlled practice, given the difference in time reported in each treatment cycle one could infer that the quality of practice may have differed. If indeed the quality of practice during Treatment Cycle 2 was better, this could account for the faster rate of SML. One other hypothesis is that the number of productions per phrase may contribute to the differing rate of change. The number of sessions to meet criterion was equivalent for low dose phrases in Treatment Cycle 2 and untrained set of phrases. Another contributing factor could be the distribution of practice. Based on the reported amount of time spent on self-controlled practice, the distribution for practice in Treatment Cycle 1 was distributed compared to massed in Treatment Cycle 2. This does align with the faster acquisition however, unlike reported outcomes in limb motor learning, long-term maintenance of SML was equally maintained for both practice conditions (Schmidt & Bjork, 1992; Shea, Lai, Black, & Park, 2000). Future research investigations on dose, particularly influence of amount and conditions of practice, are germane in a time when reimbursement for treatment is limited.

We must acknowledge the acuity post-onset and that while BP was beyond acute epoch, he was still within the realm of spontaneous recovery. We would argue though, that the degree of change would not have occurred in the absence of our intervention. He had exhausted his insurance benefits, but still not speaking well enough to meet his personal goals. There is limited documentation of recovery from acquired AOS during the acute phase. From two separate case narratives, the most prominent changes occur within the first 3 months (Haley, Shafer, Harmon, & Jacks, 2016; Mauszycki, Wamabugh, & Wright, 2014). In aphasia research, intervention in the acute phase had little to no effect on outcomes (Godecke et al., 2014; Nouwens et al., 2017) while improvement in semantics and syntax occurred prior to phonology (El Hachioui et al., 2013). While the acuity post-stroke may have had a positive influence on the outcome, we can state with confidence that through this 5-month intervention BP's speech improved to an acceptable level of function in most situations.

Conclusion

This case study contributes to the evidence on the effectiveness of MLG in the treatment of acquired AOS. For the participant in this case study, when MLG training was implemented (either by clinician or self-controlled practice), speech production outcomes improved – regardless of the personal relevance or thematic nature of the stimuli. Future studies should focus on using an experimental design to advance and strengthen the evidence on the effectiveness of MLG for the treatment of acquired AOS – particularly focusing on aspects of the protocol related to dosage in a variety of clients with greater impairment severity and longstanding AOS.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Motor Learning Guided (MLG) Protocol.
Stage 1: Divide the 30 stimuli into *random* groups of 5.
1. Clinician present the written stimuli accompanied by a verbal model.
2. The participant immediately attempts to say the target.

3. A 3 s pause is allowed between each attempt for the participant to self-analyze their production and to formulate corrections as appropriate.
4. The participant repeats Step 2 and 3 two more times (total of 3 attempts).
5. Clinician provides a verbal model of the stimulus followed by summary KR feedback as appropriate (i.e., 'you had it on the second one', 'that was perfect' or 'how do you think you did?').
6. 30 s pause between each group of 5.
7. Repeat Steps 1-7 until all of the stimuli have been attempted.

Stage 2: Divide the 30 stimuli into *random* groups of 5.
1. The clinician provides written presentation of the stimulus without a verbal model.
2. Repeat Steps 2-7 from Stage 1.

Stage 3: Combine all 30 stimuli. Repeat Stage 2 presenting stimuli in successive *random order*.