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The Effect of Phonomotor Treatment in a Telepractice Model: An Experimental Study

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THE EFFECT OF PHONOMOTOR TREATMENT IN A TELEPRACTICE MODEL: AN EXPERIMENTAL STUDY

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The Effect of Phonomotor Treatment for Apraxia of Speech in a Telepractice Model:

An Experimental Study

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ABSTRACT

THE EFFECT OF PHONOMOTOR TREATMENT IN A TELEPRACTICE MODEL: AN EXPERIMENTAL STUDY

This study provides an investigation into the effectiveness of a modified version of Phonomotor Treatment (PMT) for treating apraxia of speech (AOS) in a telepractice model. A single-subject design was utilized to provide treatment to a participant with post-stroke apraxia of speech and aphasia. Treatment occurred two hours a day, five days a week, for four weeks. Targets were selected specifically for the participant after initial probing and testing. Data was taken to measure the chosen targets for acquisition, maintenance, and generalization. The data collected includes pre-treatment (before starting treatment), post-treatment (directly after treatment), and follow-up (10 weeks after the treatment was concluded). Probe data was also collected during treatment. Results from this study indicate that a modified version of PMT can be effective for the treatment of AOS in a telepractice model. Additionally, results show that generalization and maintenance occurred for the participant involved in this study. Based on the findings of this study, further research into modified PMT in a telepractice model is warranted.

I dedicate this thesis to my parents, Marc and Lori, and my husband, Cole.

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Introduction

Apraxia of speech (AOS) is a motor speech disorder that affects the brain's ability to translate abstract linguistic representations into speech motor commands (Duffy, 2013; Maas et al., 2008). Because most of speech used in everyday life is voluntary, AOS can severely impact a person's functional communication and life participation (Cowell et al., 2010; Tanner & Gerstenberger, 1988). Researchers have found that AOS is typically caused by damage to the left frontal lobe of the brain (Wertz, LaPointe, & Rosenbek, 1992; Duffy, 2005). More specifically, it can often be correlated with damage to Broca's area, resulting in concomitant AOS and nonfluent aphasia (Bislick, 2020). This damage is commonly caused by stroke, degenerative disease, trauma, or tumor. Individuals with this disorder are primarily working to restore articulation and prosody functioning. Distortion errors caused by incorrect articulatory placement are one of the most common errors seen in AOS and it may often take clients multiple attempts for correct phonemic placement (Bislick, 2020). A slowed rate of connected speech, incorrect stressing of syllables, and pauses between words or syllables are all linked back to the prosodic qualities of AOS (Bislick, 2020).

Current Treatment for AOS

There are four general behavioral treatment approaches being considered for treatment for AOS. These include articulatory kinematic treatment, intersystemic facilitation/reorganization, rate and rhythm treatment, and alternative and augmentative communication (Wambaugh et al., 2006b). A recent systematic review of AOS treatment studies revealed that articulatory kinematic treatment is currently the most frequently researched and analyzed treatment approach. Out of the 27 studies reviewed, 22 of the studies used articulatory kinematic treatment as their primary approach, two studies used rate and rhythm, while one study, classified as ‘other,’ used Action for Speech and Communication treatment (Munasinghe et al., 2023). The review completed by Munasinghe and colleagues concluded that the recent studies on AOS treatment have increased methodological quality and contain a greater level of evidence that supports positive treatment results. Additionally, they discovered that recent research supports technological advances in AOS treatment. Evidence continues to grow when examining computer or tablet-based treatment, warranting further research in this area (Munasinghe et al., 2023).

Articulatory kinematic treatments used for acquired AOS include two main goals: the improvement of articulation and re-establishing motor commands (Knock et al., 2000). In a recent study, an outline of exactly how articulatory kinematic treatment aims to reach these goals is provided. Bislick (2020) states that in order to improve the movement and positioning of articulators, articulatory kinematic treatment uses verbal practice, verbal feedback, modeling, and integral stimulation. Another important aspect of these treatments includes the frequent practice and repetition of the targets that have been chosen for the client. External sensory input should be provided in the form of auditory, visual, or tactile cues. Stimuli should also be provided and be specific to what is being targeted. These targets may include single sounds, clusters, nonword or real words, phrases, and/or sentences (Bislick, 2020).

Phonomotor Treatment

Phonomotor treatment (PMT) is an articulatory kinematic approach that has been shown to be effective when treating individuals with aphasia, alexia, and AOS (Bislick et al., 2014; Brookshire et al., 2014; Bislick, 2020). Initially, PMT was adapted from the Lindamond Phoneme Sequencing Program (LiPS) to treat a participant diagnosed with acquired phonologic alexia, as well as severe nonfluent aphasia with agraphia and AOS (Kendall et al., 2003). After success was seen in this treatment plan, Kendall and colleagues continued to experiment with using this treatment to improve articulation in participants with AOS (Kendall et al., 2006).

As an articulatory kinematic treatment, PMT incorporates motor description, speech production, and speech perception tasks through repetition, modeling, verbal requests, and visual stimuli (Kendall et al., 2008, 2015). It also emphasizes frequent and repetitive production of sounds and words (Kendall et al., 2008, 2015). An important component of PMT is the use of nonwords during treatment tasks, as this helps to facilitate phonological awareness and sequencing knowledge needed to improve verbal expression (Kendall et al., 2006; Silkes et al., 2017; Storkel, 2018). To promote accurate placement of the articulators, PMT uses a variety of supports including articulation placement cues, images of the articulators, verbal instructions, visual modeling, and tactile cues (Bislick, 2014). The multimodal component of PMT is essential as it encourages the client to use motor, auditory, and tactile strategies (Bislick, 2020). In PMT, the clinician uses Socratic questioning to get the client to recognize their own errors and potentially self-correct (Bislick, 2020). This type of feedback gets the client more involved in their treatment and learning, especially when compared to corrections from the clinician (Bislick, 2020). The implementation of motor learning principles (PML) in PMT has also been shown to increase generalization and long-term maintenance of skills learned in treatment, which is why PML is considered an essential element of PMT (Bislick, 2020). PML details various practice and feedback conditions that enhance the acquisition and maintenance of motor skills (Masa et al., 2008). Practice conditions include the amount, distribution, variability, and schedule of practice, as well as attentional focus, and target complexity. Feedback conditions include the type of feedback given, the feedback frequency, and feedback timing. Details of these can be found in Tables 1 and 2 of Mass's (et al., 2008) tutorial on PML. Together, the multimodal approach, Socratic questioning, and the application of PML make PMT an effective treatment strategy (Bislick, 2020).

PMT shares characteristics with other articulatory kinematic treatments that have been documented as successful. One of these being sound production treatment (SPT; Wambaugh et al., 1998). A few commonalities include embedding problematic targets into treatment stimuli, an emphasis on repetition tasks, inclusion of contrast drills, and repetition of correct productions. The major differences between the two are the stimuli selection and hierarchy of cueing. SPT uses real words in the stimulus sets, whereas PMT focuses on nonwords in treatment. SPT also includes a five-step hierarchy in cueing that begins with minimal cues and progresses as needed (Wambaugh et al., 1998), whereas PMT focuses on Socratic questioning as the main form of cueing.

PMT treatment has been documented as a successful approach for AOS in several recent research studies. Four specific studies have taken a closer look at PMT and examined the effect it has on AOS. In all three studies, the participant's AOS was a result of damage to the left hemisphere of the brain caused by stroke. These studies used a single subject design and had many of the same inclusion criteria. Although they vary in intensity protocols, each study showed speech improvements to some degree (Bislick, 2020; Bislick et al., 2014; Kendall et al., 2006; Raymer et al., 2002).

In a study completed by Bislick in 2020, she investigated a modified version of PMT on motor planning in two individuals with apraxia of speech. Bislick's modified PMT uses sounds and targets that are specific to the participant, versus traditional PMT which teaches all sounds. The participants in this study received treatment 3 days a week and length of treatment was dependent on meeting the criteria for acquisition of targets. Findings from this experimental study show improved accuracy of trained targets, generalization to untrained targets, and maintenance effects as measured at 10 weeks posttreatment. This demonstrates strong evidence for the use of modified PMT in clients who have AOS. The goal of this current study was to replicate Bislick's study with the main difference being the service delivery model. Dr. Bislick provided services in-person, whereas the current study provided services in a telepractice format (Bislick, 2020).

In an early-stage investigation of PMT as a restorative approach to AOS, another treatment protocol consisted of six weeks of treatment, two hours a day, for four days a week (Bislick et al., 2014). This totaled 48 hours of direct PMT between the client and clinician. The overall outcome of this study showed an increase in trained sounds, generalization to untrained sounds, and generalization of trained sounds in real words and nonwords as well as trained sounds in isolation. The baseline collected before treatment showed a 2% accuracy. During treatment, this percentage increased to 18%, and post-treatment this number was even higher, finishing at 27%. Two months after PMT ended, maintenance testing was conducted and all treatment and generalization effects had been maintained and even increased, apart from CVC nonwords being maintained but not increased (Bislick et al., 2014).

In an investigation of the efficacy of PMT on AOS and changes in quality of life, the participant received 14 weeks of treatment, for 4-5 days a week, with 2 hours of treatment each session totaling 104 hours of PMT. Results indicated an improvement in individual sound production, decreased labor in discourse production, and an improved quality of life. Additionally, scores taken from the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006) were able to document overall language function improvements (Kendall et al., 2006).

Raymer et al. (2002) explored an intensive training of isolated consonants (/p/, /b/, /k/) incorporating tactile, auditory, and motor cueing. It consisted of 20 treatment sessions with each session lasting one hour. This protocol called for four days of treatment weekly and included at-home practice to be completed with a partner. The client demonstrated progress with phonemes in the initial position of words and generalization to the voiced cognates of /p/ and /b/. The client also experienced overgeneralizations of /p/ and /b/ to /k/ and untrained /f/ and /g/. However, the improvements documented were not as large as the improvements in the studies described above. This could be attributed to the shorter sessions, or the fact that treatment time totaled to 20 hours, which is significantly less than similar studies (Raymer et al., 2002).

Telepractice

The history of telepractice, also referred to as telemedicine, can be dated back to the early 20th century, with one of the first historical examples being the use of radios to give medical advice to clinics on ships in the 1920s (Lustig & Nesbitt, 2012). Later in the 1950s and 1960s, closed-circuit television links could be established between hospitals for consultations (Lustig & Nesbitt, 2012). Throughout the history of medicine and technology, there are countless examples of effective telepractice being used when distance, cost, or efficiency were contributing factors.

In the present day, telepractice is a widely accepted form for delivery of services in speech and language pathology. The American Speech-Language-Hearing Association (ASHA) has deemed telepractice an appropriate model for service delivery and states that it may be used as the primary service delivery model if the quality of services remains equal to in-person services (ASHA, n.d.). There are currently three types of telepractice service used in speech and language pathology; these include a synchronous model, asynchronous model, and hybrid model (ASHA, n.d.). Synchronous services occur in real-time and help to create an experience that would be similar to an in-person visit. Examples of synchronous services include telehealth visits or virtual consultations. Asynchronous services occur when information, images, videos, or other data are stored and sent to the client or participant to view at a later time. This could include the transmission of test results, pre-recorded voice clips, or patient education materials. Lastly, the hybrid model works to combine synchronous and asynchronous telehealth. This model may look like the provider and client using an online, real-time platform to discuss asynchronous information such as test results (ASHA, n.d.).

In an unpublished study exploring the feasibility of using PMT as an intensive restorative treatment for nonfluent aphasia through telepractice, a participant received 60 hours of treatment across six weeks. Results indicated that synchronous telepractice service delivery was feasible and potentially feasible for future participants as supported by the participant's improvement for trained real words as well as generalization to some secondary outcome measures as determined by scores on the Comprehensive Aphasia Test (CAT; Howard et al., 2010), the Standardized Assessment of Phonology in Aphasia (SAPA; Kendall et al., 2010), and the Boston Naming Test (BNT; Kaplan et al., 2001). Also, there was no significant change in a measure of control and the authors were able to mirror previous administration protocol of treatment (i.e., Kendall et al., 2015) with minor modifications. Results of this study found an insignificant effect size for untrained nonword repetition indicating little generalization of learned phonological skills over time. Additionally, a small effect size for trained nonwords at a three-month follow-up may be indicative that more than 60 hours was needed for the participant to acquire phonological skills necessary for generalization to the maintenance phase (Davis et al., 2019).

Recent research provides us with evidence that PMT shows improvements in individuals diagnosed with AOS (Bislick, 2020) and that it may be potentially feasible to use a telepractice delivery model for treatment. One difference between the published studies listed above and the study being presented is the mode of delivery. In-person treatment has been documented and measured, but evidence is lacking when it comes to delivering PMT via telepractice. Because research shows that PMT is effective, specifics on service delivery, generalization, and maintenance should now be examined more closely in a telepractice delivery model.

Research Questions

For the current study, the following research questions were investigated: (1) Is a telepractice model feasible when treating AOS with modified PMT? (2) Will the skills taught generalize to trained targets in untrained words? (3) Will the provided treatment result in long-term maintenance after treatment has concluded as measured at 10 weeks post-treatment?

Methods

Proper institutional review board (IRB) approval was obtained through Western Kentucky University. The participant provided written consent to all procedures.

Participant Inclusion Criteria

A single participant was recruited for this study by word of mouth through the American Speech Language Hearing Association Special Interest Group (SIG) for Neurogenic Communication Disorders. The participant met inclusion criteria chosen from previous literature on PMT, whereas all participants had experienced a stroke at least six months prior to the initial baselines being given (Bislick et al., 2014; Kendall et al., 2006; Raymer et al., 2002). In 2020, Bislick completed a successful single case experimental design study on PMT with the following inclusion criteria: (a) right-handedness; (b) English spoken as a primary language; (c) minimum of 12th grade education; (d) passed an audiometric pure-tone, air-conduction screening at 35 dB HL at 500, 1000, and 2000 Hz in at least one ear; (e) normal or corrected-to normal visual acuity

(20/20 to 20/40) as determined by passing of vision screen using the Tumbling E eye chart; (f) score above a 23/36 on the Raven's Coloured Progressive Matrices (Raven CPM; Raven et al., 1998); and (g) demonstrate sufficient auditory comprehension by following a minimum of one-step commands (Bislick, 2020). Aside from the audiometric pure-tone air-conduction hearing screening, inclusion criteria described above was also implemented for the current study.

The participant's diagnosis of aphasia was confirmed through the administration of the Comprehensive Aphasia Test (Howard et al., 2004). Additionally, the Apraxia Battery for Adults-Second Edition subtests I, II, IV, and V were given to assist with eliciting verbal productions during testing (Dabul, 2000). The following clinical characteristics of AOS were used when confirming the participants diagnosis of AOS: (a) slow speech rate characterized by lengthened segment and intersegment durations, (b) sound distortions, (c) distorted sound substitutions, and (d) prosodic abnormalities (Bislick et al., 2017; McNeil et al., 2009; Wambaugh et al., 2006b). After thorough testing and observation, two licensed speech-language pathologists (SLPs) agreed on the diagnoses of aphasia and AOS (second and third authors). All testing and tasks were administered and scored by the first author, a graduate student in speech-language pathology who was trained and supervised by a certified SLP (second author).

Participant Description

CW was a 30-year-old male, who was 66 months post-onset left-hemisphere stroke at the time of the study. He completed 12 years of education along with a certification program in welding. CW resides at home with his father and grandmother. Post CVA, CW received speech services as an inpatient. After being released from the hospital, he received no speech services for six months. During this time, he experienced a significant deterioration leading to resuming speech therapy at a local university clinic. His primary diagnosis at the time was AOS. At the time of recruitment, CW's AOS diagnosis was categorized by sound distortions, syllable segmentation across words and phrases, slow speech rate, and articulatory groping. His rating on the Apraxia of Speech Rating Scale was 40, with 0 showing no impairments and a maximum score of 52 showing severe impairments.

Table 1. Participant assessment results.

Timeline	CAT subtests				ASRS (52)	RCPM (37)	CPIB (30)
	Spoken Language Comprehension (66)	Written Language Comprehension (62)	Repetition (74)	Naming [(58) + fluency]			
Pre	43	44	27	35 + 3	39	31	20
Post	40	42	33	36 + 2	-	-	14
Follow-up	44	36	35	38 + 4	-	-	15

Note. CAT = Comprehensive Aphasia Test (Howard et al., 2004); ASRS = Apraxia of Speech Rating Scale (Strand et al., 2014); RCPM = Raven's Coloured Progressive Matrices (Raven et al., 1998); CPIB = Communicative Participant Item Bank (Baylor et al., 2013); - = ratings for the ASRS and the RCPM were only collected during pretesting.

Experimental Design

The goal of this experiment was to closely duplicate Bislick's study in 2020. A single-case experimental design was used in order to examine modified PMT in a telepractice model. In Bislick's 2020 paper, two distinct Stimulus Sets were selected based on the participant's needs. Time constraints prevented the author of the current study from administering treatment for a second Stimulus Set. Therefore, the targets chosen for 'Stimulus Set 2' were modified to reflect a 'Response Generalization Set'. Aside from dosage, all other procedures for treatment and data collection aimed to follow Bislick's design.

Stimuli Selection

Prior to the initiation of baseline data collection and treatment, stimulability testing was completed to determine targets for treatment. Stimulability testing consisted of 685 monosyllabic and multisyllabic words that the participant was asked to repeat during a preliminary Zoom session. These words varied in complexity, examining single sounds and clusters in various positions of the word (i.e., initial, medial, and final positions; Bislick, 2020). The results of the stimulability testing were examined closely and word types with less than 60% accuracy were considered as potential targets. Ultimately, targets were chosen by the first and second author based on the participant's errors and need for remediation (Bislick, 2020). Two target sounds were selected for the Stimulus Set (i.e., /sk, tr/; Wambaugh et al., 2001; Wambaugh, West, et al., 1998), and two targets were selected for the Response Generalization Set (i.e., /st, tw/).

After targets for the Stimulus Set were determined by the author, five baseline data points were collected across five independent data collection sessions for all Stimulus Set word sets. This was completed after stimulability testing and before the initiation of treatment. These baseline data points were collected to ensure the stability of the participant's performance before beginning treatment (Byiers et al., 2012; Kratochwill et al., 2010). After the collection of these baseline data points, treatment began for the Stimulus Set. Dosage for treatment included two hours of therapy daily, five days per week for four weeks. Once treatment began, all words from the Stimulus Set and Response Generalization Set were probed throughout the duration of the study. Probes were delivered once every four hours of therapy (every two days), immediately following the completion of therapy, and ten weeks post-treatment. Probes included trained and untrained words. Trained nonwords were the focus of treatment sessions and used to measure acquisition of target sounds. Untrained nonwords and real word probes were also used to measure the generalization effects of modified PMT. These words were avoided during treatment sessions to maximize generalization measurement.

Probes in Stimuli Sets

Traditional PMT uses nonwords and real words to target sounds (Silkes et al., 2017). Trained stimuli include the targets in isolation and progresses to the targets in nonwords, whereas untrained stimuli include the targets in nonwords and real words. These untrained stimuli provide the ability to measure generalization effects. For this study, the same pattern of treatment was followed. Other stimuli also occurred during treatment sessions as sounds were being targeted. These other stimuli included nonwords that were not in the trained or untrained list of the stimulus set. Treatment began with the sounds in isolation and then slowly became more complex as skills were mastered. Once a certain skill consistently reached 80% accuracy, a new level of difficulty would be introduced. For example, after mastering sounds in isolation, the clinician would introduce the cluster with a vowel at the end. After these CV combinations were mastered, the clinician moved onto more complex combinations including CVC nonwords. In this study, treatment primarily focused on monosyllabic words including the target sound, but with further mastery, multisyllabic words could have been targeted as well.

The Stimulus Set chosen for CW included /sk/ and /tr/ blends, and the Response Generalization Set included /st/ and /tw/ blends; both sets measured these blends in the initial position of words. For each set, sixteen nonwords were chosen to be trained during treatment. The set of sixteen words was further divided so there were eight words for each blend (see Table 2 for trained and untrained probes). Each set also included untrained words to account for generalization. For each blend, there were eight nonwords (four monosyllabic and four bisyllabic) and eight real words (four monosyllabic and four bisyllabic; Bislick, 2020).

Probes were used to collect data approximately after every two sessions. All word probes were pre-recorded and presented to CW in a video format through a shared screen on Zoom. The

PI recorded all probes with their mouth being the primary focus of the screen. Words would be played one at a time to the participant and he would be asked to repeat the word before moving onto the next word. Word lists were randomized using a number generator to ensure the participant was not relying on sound patterns. Feedback was not provided during probe sessions. Both the PI and participant used high-quality headphones with microphones to ensure clear and consistent sound.

Table 2. Trained and untrained probes for CW.

Stimulus Set	**Response Generalization Set**
Trained	**Untrained**
Targets in isolation:	Targets in isolation:
/sk/, /tr/	/st/, /tw/
Targets in nonwords:	Targets in nonwords:
/skɪv/, /skuːb/, /skap/, /skob/	/stɪv/, /stab/, /stæp/, /stef/
/skæd/, /skɚn/, /skʌd/, /skɪf/	/stɪn/, /starn/, /stat/, /sti/
/trɛb/, /tram/, /trɛʃ/, /trɪn/	/twɚ/, /twam/, /twɛs/, /twæd/
/træd/, /truːl/, /trʌg/, /trɪθ/	/twɪʃ/, /twʌg/, /twɛk/, /twe/
Untrained	**Untrained**
Targets in nonwords:	Targets in nonwords:
/skɪθ/, /skʌp/, /skɪg/, /skæf/	/stik/, /stɪp/, /stɔrt/, /stæs/
/skudəl/, /skæpɚ/, /skidɚ/, /sketəm/	/stupəl/, /starnɚ/, /stɪmi/, /staʊɚ/
/truf/, /trɛl/, /træv/, /trʌp/	/twɪf/, /twas/, /two/, /twæg/
/træbəl/, /træbəl/, /trobɪn/, /træmi/	/twɝbi/, /twɪpɚ/, /twɚpəl/, /twæbɚ/
Targets in real words:	Targets in real words:
ski, scoot, scar, skip, scamper, skinny	stay, stop, steam, steel, stable, stagger
scooping, skater, tree, trap, trim	staircase, stunning, twin, tweak, twig
true, traffic, trombone, travel, tricky	twice, twilight, twister, twiddle, twinkle

Measure of Ecologic Validity

To assess the participant's perceived change in communicative participation as a result of treatment, the Communicative Participation Item Bank (CPIB; Baylor, et al., 2013) 10-item short form was administered pre-treatment, immediately post-treatment, and at the 10-week follow-up. The participant was given these questions in a modified format using one question at a time with visual supports for response mode. These questions were shared on the screen on Zoom, and they were read aloud one by one. CW was given control of the mouse to point to or circle the desired response. This was administered before treatment, directly after treatment, and during the follow-up session. A validation study of the administration of the CPIB in people with aphasia indicated success in the use of this form for people with aphasia (Baylor et al., 2017). However, it was noteworthy that supports (e.g. questions being read aloud) may still be needed if the client has higher limitations (Baylor et al., 2017).

Dependent Variable

In 2020, Bislick used the accuracy of articulation of the target sounds in trained and untrained stimuli as the dependent variable of her study. Words were scored as either "correct" or "incorrect" during probe sessions. As detailed in Bislick's research (2020), words were counted incorrect if there were, "sound distortions, distorted substitutions, perceived substitutions, additions, omissions, and errors in voicing" (pg. 2115). Sound production was separately scored by the inter and intra raters. Audio and visual perceptions were used to score the target words. All sessions were recorded to allow for review of articulatory accuracy.

Treatment

As previously mentioned, the goal of this study was to create a close duplication of Bislick's 2020 research regarding a modified version of PMT, while also addressing whether it is feasible in a synchronous telepractice model. Therefore, for this study, a modified version of PMT was used (Bislick, 2020). Traditional PMT procedures can be found in the manual written by Silkes et al. (2017). Traditional PMT differs from the modified version of PMT in that traditional teaches all sounds of the English language. All phonemes are taught whether they are problematic for the client or not. Modified PMT works differently as it focuses on sounds that have been identified as problematic. In modified PMT, nonproblematic sounds can and should be used. They can be quickly introduced and then used with the problematic target sounds to create syllables in treatment. Another difference between traditional PMT and modified PMT is that the modified version of treatment focuses on production while traditional PMT focuses on perception. In modified PMT treatment, the goal is to produce the target sound frequently in various formats. These formats can include direct repetition, reading syllables created with grapheme tiles, producing a syllable from looking at mouth pictures, etc. (Bislick, 2020).

The initial stage of treatment, which teaches the sounds in isolation, moves quite quickly in this modified version. Once the sound has been mastered in isolation, the second training stage (sound in syllables), is able to begin. The goal of this modified treatment approach is to maximize the number of productions being made by the participant (Bislick, 2020). Details of the treatment tasks can be found in the appendix of Bislick's 2020 paper. Treatment was administered five days a week for two hours a day for four weeks, totaling 40 hours.

The length of each stage of treatment was based on the mastery of skills being taught. The criterion for mastery was set at 80% accuracy across three consecutive sessions per the recommendation of Bislick et al. (2020). The Stimulus Set chosen did not show 80% accuracy across three consecutive sessions; therefore, this set remained the focus of the treatment plan for our participant.

In order to provide effective treatment through telepractice, adaptations were made to tasks to include the visual, auditory, and tactile cues that are the core of PMT. All materials used by the clinician were mailed to the participant prior to the initial evaluation. This provided the opportunity for a hands-on experience despite the telepractice model. The modified treatment plan consists of two distinct stages. Stage one focuses on the target sounds in isolation. The participant must verbalize these sounds and discriminate them auditorily. Once the target sounds are mastered (80% across 3 consecutive sessions), phase 2 begins. Phase 2 builds on phase 1 by including the target sounds in more complex combinations. These combinations build on each other gradually, beginning with simple CV nonwords and progressing to CVC nonwords. If monosyllabic nonwords are mastered, multisyllabic words may be targeted as well. Treatment tasks included motor description, speech production, speech perception, and grapheme-to-phoneme correspondence. Each of these treatment tasks are utilized throughout each phase. Socratic questioning must also be provided throughout treatment. Questioning should be used whether the participant's responses are correct or incorrect and may be scaled back after success has been shown (Bislick, 2020).

This treatment was conducted by the first author of this study, a speech-language pathology graduate student from Western Kentucky University. The student was thoroughly trained to complete this treatment through a combination of direct instruction from instructors, as well as online modules provided through the University of Washington. All sessions received direct, synchronous supervision by the second author. Additionally, weekly data was kept ensuring that all aspects of treatment were conducted reliably.

Reliability

Both inter and intra raters were utilized in this study to maintain reliability. The interrater for this study was the PI, a trained speech-language pathology graduate student. The interrater scored all probes in real-time as the participant verbalized them. Probe sessions were recorded through the online platform, Zoom, so that they could be reviewed by the intrarater, who was also a trained speech-language pathology graduate student. The intrarater scored all trained probes from each probe session using the recorded videos. Cohen's kappa was used to determine reliability between the inter and intra raters. Additionally, a coefficient of stability through test-retest reliability was determined for the probes both before and after treatment to ensure the untrained words and nonword probes are consistent measures. (Landis & Koch, 1977). Twenty percent of CW's responses on the probes were randomly selected to be reanalyzed via narrow phonetic transcription by trained transcribers. Interrater reliability for agreement for narrow phonetic transcription was κ=.95, and intrarater reliability was κ=.94, indicating a near perfect agreement.

Data Analysis

Percent accuracy was gathered during each probe session before, during, and after treatment. This allowed for the measurement of percent change as detailed by Wambaugh et al. (2017) to show a clinical significance in improvements. Additionally, benchmark effect sizes as established for speech production therapy (SPT; Wambaugh et al., 2017) were used. Data analysis procedures are detailed in the results section.

Results

Data collected representing targets for probes are shown in Figure 1 & 2 and are delineated by data collected during baseline, during treatment, immediately following treatment, and at 10 weeks post-treatment. The graphs represent each target list (i.e., trained sounds in nonwords, untrained sounds in nonwords, and untrained sounds in real words).

Effect Size, Benchmarks, and Percent Change

Effect Size Analysis

Effect sizes (ES) were calculated for the Stimulus Set to assess the effects of PMT immediately following treatment and at a 10-week follow-up. One list was comprised of trained stimuli embedded into non-words targeted during the intervention. The second list consisted of untrained stimuli that were not targeted during the intervention, which included trained targets embedded into nonwords and real words. As such, six separate effect sizes were calculated and included effect sizes for (1) treatment phase for trained targets in nonwords, (2) treatment phase for trained targets in untrained nonwords, (3) treatment phase for trained targets in untrained real words, (4) follow-up phase for trained sounds in trained nonwords, (5) follow-up phase for trained sounds in untrained nonwords, and (6) follow-up phase for trained sounds in untrained real words. Treatment phase and follow-up phase effect sizes were calculated using the delta index formula (Bloom et al., 2003; Busk & Serlin, 1992). The delta values were calculated using the following equations: $ES=(M_{A2} – M_{A1})/SD_{A1}$, where A1 is the baseline mean value and A2 is the comparison mean value (i.e., end of treatment, 10-week follow-up).

Benchmark Effect Sizes

When looking at the effect of PMT on sound production, benchmarks specific to AOS were used to measure the effect of treatment on sound production accuracy for (a) trained items (small = 5.32, medium = 6.98, large = 10.6), (b) follow-up for trained items (small = 5.9, medium = 7.12, large = 10.19), (c) untrained items (small = 2.25, medium = 3.75, large = 6.66), (d) follow-up of untrained items (small = 2.59, medium = 4.23, large = 6.47) (Bailey et al., 2015). Benchmark effect sizes and benchmarks referenced for this study may be found in Table 3 and 4.

Percent Change Analysis

Percent change was calculated for all probe sets to examine any changes in sound production. This was done by finding the difference between the highest baseline probe and the highest treatment probe. The process of calculating percent change was repeated for the Stimulus

Set and Response Generalization Set both post-treatment and follow-up. Percent change can be found in Table 4.

Results

Generalization Effects

Immediately post-treatment, effect sizes demonstrate positive acquisition in some areas and generalization in others. Results are as follows: in trained nonwords (Stimulus Set: ES = 2.89), generalization of sounds into untrained nonwords (Stimulus Set: ES = 3.4), and generalization of sounds into untrained real words (Stimulus Set: ES = 3.2). Percent change demonstrates an increase in skills in trained nonwords (Stimulus Set: PC = 88%, Response Generalization: PC = 56%), generalization of sounds into untrained nonwords (Stimulus Set: PC = 56%, Response Generalization: PC = 50%), and generalization of sounds into untrained real words (Stimulus Set: PC = 69%, Response Generalization Set: PC = 69%).

Maintenance Effects

Follow-up data demonstrates various findings as far as maintenance of word sets. Results show the following: trained nonwords (Stimulus Set: ES = 1.9), generalization into untrained nonwords (Stimulus Set: ES = 2.2), and generalization into untrained real words (Stimulus Set: ES = 2.1). Percent change calculated for follow-up data finds similar results with trained nonwords (Stimulus Set: PC = 56%, Response Generalization Set: PC = 44%), untrained nonwords (Stimulus Set: PC = 55%, Response Generalization Set: PC = 38%), and untrained real words (Stimulus Set: PC = 62%, Response Generalization Set: PC = 44%).

Table 3. Effect size (Δ Values) and benchmarks for target sounds in trained and untrained stimuli.

	Stimulus Set /sk, tr/			
	Δ Values		Benchmarks	
Effect	**Imm. Post**	**Follow-up**	**Imm. Post**	**10-week follow-up**
Treatment effects				
Trained nonwords	10.57	5.8	Large	N/A
Generalization effects				
Untrained nonwords	3.4	3.8	Small	Small
Untrained real words	3.2	2.1	Small	N/A

Figure 1. Stimulus Set /sk, tr/: trained nonwords

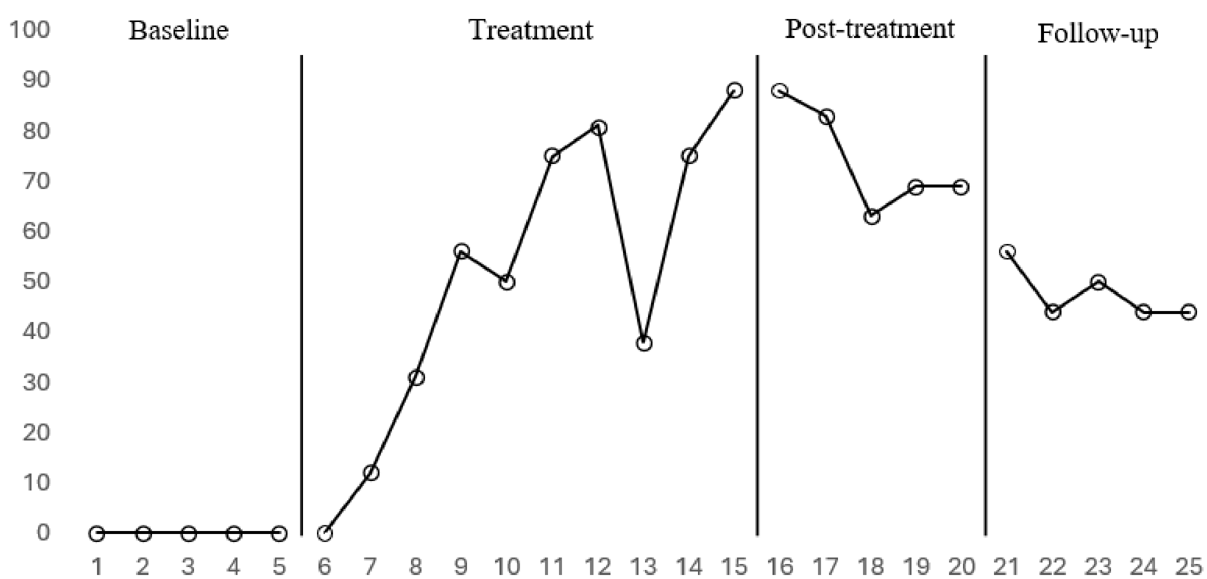

Figure 2. Stimulus Set /sk, tr/: untrained nonwords & untrained real words

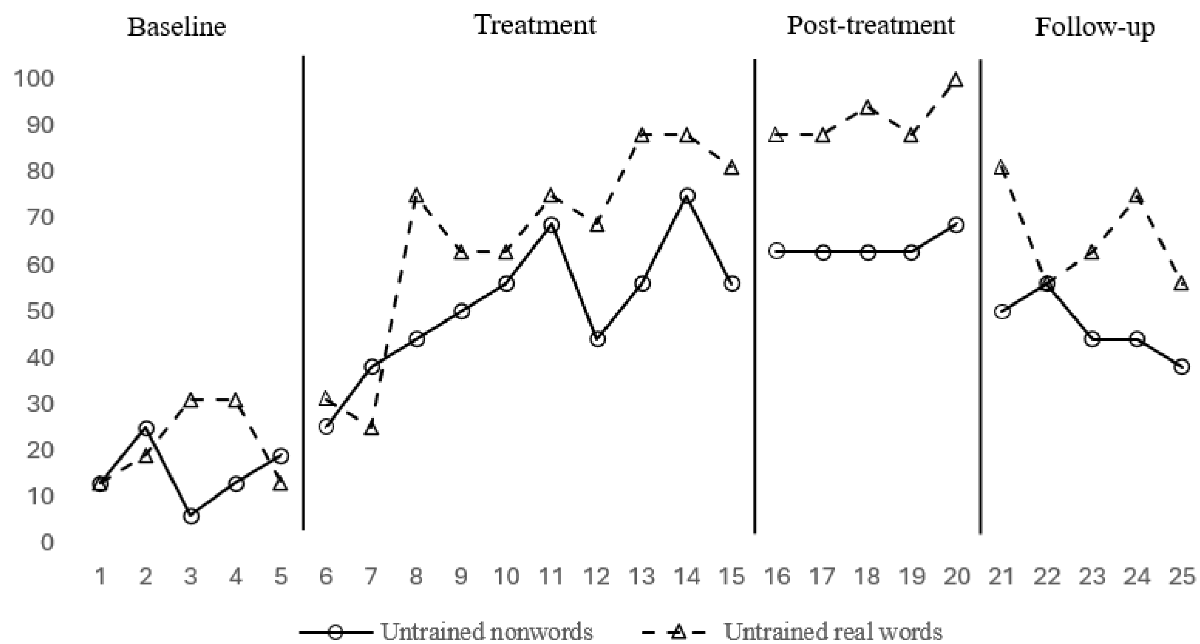

Table 4. Percent change above average baseline performance

Effect	Stimulus Set /sk, tr/		Response Generalization Set /st, tw/	
	Imm post	10-week follow-up	Imm. post	10-week follow-up
Treatment effects				
Trained nonwords	88%	56%	56%	44%
Generalization effects				
Untrained nonwords	56%	55%	50%	38%
Untrained real words	69%	62%	69%	44%

Note: Imm. = Immediately

Ecologic Validity

The CPIB was used as a measure of ecologic validity. This form was given to the participant on three occasions, pre-treatment, post-treatment, and at the follow-up. A higher score on the CPIB indicates less interference in self-perceived communicative participation, while a lesser score indicates a greater perceived interference in communicative participation. CW's scores and corresponding T scores were as follows: pre-treatment (score = 20, *T* score = 52.70), post-treatment (score = 14, *T* score = 45.50), and follow-up (score = 15, *T* score = 46.70). CW received a lesser score post-treatment and at the 10-week follow-up, indicating an increase in perceived restriction of communicative participation at both post-treatment and follow-up.

Discussion

Previous studies have shown that PMT can be effective when treating AOS. Modified PMT has also been shown to have a positive impact on language and articulation in those with AOS (Bislick, 2020). The purpose of this study was to investigate the feasibility of PMT via telepractice service-delivery model and if modified PMT will show generalization and maintenance in a telepractice model. Overall, findings show that positive results with modified PMT through telepractice are possible and warrant further exploration. Additionally, generalization and long-term maintenance were observed through data collection.

Participant Findings

This investigation supports further research in PMT using a telepractice model. Despite PMT being a highly tactile treatment plan, CW was able to participate and manipulate materials as needed, even through the online platform. Positive results were seen with trained nonwords in the Stimulus Set during treatment. Carry-over was noted during the follow-up sessions in trained nonwords, as well as generalization into untrained nonwords and untrained real words.

There are several factors that must be taken into consideration while examining CW's scores. While benchmarks demonstrate an increase in acquisition, generalization, and maintenance, the effect sizes may have been impacted by CW's health during post-treatment and follow-up data collection. During post-treatment data collection, CW's father reported that he had been experiencing multiple seizures throughout the day. CW began to trial different seizure medications in the following months, which could have had an impact on his scores in follow-up sessions. While the exact number and frequency of seizures is not recorded, this could be a contributing factor to CW's performance.

Additionally, the reliability of the CPIB must be taken into consideration. When given subtests from the CAT, CW's scores showed severe impairments in both spoken language and written language. While supports were put into place to assist with receiving accurate answers, the scores from this test may not be entirely representative of CW's feelings towards his communicative functioning. The answers given by CW varied significantly between all three data collection sessions. This could be attributed to difficulties with comprehending the questions, as they were lengthy compared to treatment tasks.

One of the final and most important takeaways from this study was the participant and his family's feedback. Throughout treatment and even into the follow-up sessions 10 weeks post-treatment, positive feedback was given to the PI regarding CW's communicative efforts. CW and his father reported increased communication at home and in the community. Both reported that this could be due to increased confidence in CW's speech and language skills. After the study, CW began part-time work and resumed activities that he had previously enjoyed before his CVA. While the data taken for this study is worth investigating, it is crucial to mention that CW's subjective quality of life has been positively affected by his increased ability to communicate.

Interpretation and Comparison of Findings

Interpretation

The question of PMT generalizing into untrained targets can be addressed by the benchmarks and effect sizes calculated for the Stimulus Set. Both untrained nonwords and untrained real words in the Stimulus Set were calculated to have a small effect size, demonstrating stimulus generalization into untrained word sets. This can also be supported by the large percent change calculated in the Stimulus Set's untrained nonwords and real words. Generalization can also be seen through the response generalization noted by the untreated sounds into nonwords and real words. The data collected through the percent change analysis demonstrate that the participant was able to generalize the trained sounds to untrained blends with similar articulatory placement, /st/ and /tw/. He was also able to use untrained sounds in untrained nonwords and real words. A percent change of 56% was noted for untrained nonwords and a percent change of 69% was noted for untrained real words during post-treatment data collection.

Maintenance of learned sounds is demonstrated by the effect sizes and percent change calculated at the 10-week follow-up data collection sessions. The untrained nonwords in the Stimulus Set continued to demonstrate a small effect size, showing carry-over of learned sounds. Additionally, while percent change decreased at the follow-up sessions, there is still a notable change calculated in the Stimulus Set. Because generalization and maintenance are the main goals of PMT, these results indicate that PMT can still be effective and meaningful in a telepractice service delivery model.

Comparison

As the goal of this paper was to duplicate Bislick's study from 2020, there were multiple differences in findings that must be noted. First and foremost, Bislick's intervention was conducted in-person, whereas the intervention for the current study was conducted in a synchronous telepractice model. The second most notable difference between the studies is the dosage of treatment delivery. While this study delivered treatment 5 days a week, for 2 hours a day totaling 40 hours, the comparative study provided intervention 3 days a week, for 1 hour a day ranging from 25-29 hours. Despite the change, generalization and maintenance were seen in both studies. The comparative study was able to treat two Stimulus Sets with varying targets, creating an experimental control variable that the current study lacked.

Limitations

There were several limitations to this study. First, this study utilizes a multiple baseline, single-case experimental design. Because there was one participant, further research would be needed to confirm telepractice is a viable option for individuals with AOS. While positive results were demonstrated, there is no current, direct comparison to how the participant would have performed with PMT in-person. Another limitation of PMT in practice is the intensity and hours required. Because sessions take place daily and can be up to two hours in length, it may be difficult to get PMT approved by insurance. This leads to the question of how PMT can be implemented in a way that does not become a financial burden for patients and their families. Additionally, benchmarks used are not specific to tactile kinesthetic treatment. While the benchmarks have been used in studies relating to AOS and even in other studies investigating PMT, it is worth noting that they were originally designed for Speech Production Treatment (Bailey et al., 2015). Moving forward, it may be beneficial for new benchmarks to be created for tactile kinesthetic treatments. Lastly, the authors recognize that the lack of a control variable is a limitation to this study. If this study were to be replicated, two stimuli sets with target sounds differing in articulatory placement (i.e. place and manner) would contribute to adding a control variable, demonstrating further evidence of PMT's effectiveness in a telepractice model. While this study did not contain a control variable, Bislick's research in 2020 provides a strong control variable that may be referenced to further demonstrate effectiveness of modified PMT.

Conclusion

In conclusion, a telepractice platform may be beneficial when using a modified version of PMT in patients who have an AOS diagnosis. Telepractice allows for connection where it might not otherwise be found. In this case, adaptations were able to be made to provide the participant with the tactile and kinesthetic learning experiences that would traditionally be offered by PMT. While further research is needed to provide more evidence to the feasibility of PMT in telepractice, results from this study give positive indications that this could be an effective treatment and treatment model for those with AOS. Moving forward, it may be beneficial to collect data in a side-by-side comparison of modified PMT with both an in-person participant and virtual participant.

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