The Effect of Blocked Versus Serial Practice in the Treatment of Developmental Motor-Based Articulation Disorder

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Abstract

The application of specific motor learning principles (MLPs) in treatment for developmental motor-based articulation disorder in children has not been reported to date. The aims were to determine treatment effects of a novel hybrid intervention approach for a single participant with motor-based articulation disorder, and to examine the role of specific MLP, namely blocked versus serial practice schedules, in performance, generalization, and maintenance of speech skills. Results suggested that the novel hybrid treatment approach produced measurable gains in most instances. However, there were no systematic differences between the different practice schedules. Possible reasons for these specific treatment and generalization effects were explored.

Keywords speech sound disorder, developmental motor-based articulation disorder, motor-based treatment, motor learning, serial practice, blocked practice

Introduction

Subtype Treatment of Speech Sound Disorder (SSD)

Classification for subtypes of SSD is a challenge even under the umbrella term (Lewis, Avrich, & Stein, 2011). The Linguistic Profiling and Speech Subtypes Model (Dodd, 2005) comprises five subtypes of SSD: phonological delay, consistent deviant phonological disorder, inconsistent speech disorder, childhood apraxia of speech (CAS), and articulation disorder. *Articulation disorder*, with the exception of difficulties due to structurally based anomalies, is said to be the result of an incorrectly learned motor plan/program according to Fey (1992) and Crosbie, Holm, and Dodd (2005). The nature of the disorder is therefore motor-based, but not neuromotoric as for CAS, which accounts for the term used in this article "developmental motor-based articulation disorder."

In the past, both phonological SSD and motor-based articulation disorder have been effectively treated through *motor-based* approaches (Bauman-Waengler, 2016). The traditional phonetic-placement approach (PPA) of Van Riper (1978) primarily focuses on teaching motor behaviors associated with the production of a particular sound through the placement and movement of the articulators in an easy-to-hard treatment target hierarchy. A number of examples of recent research support the notion that the PPA's historical effectiveness still stands firm for developmental motor-based articulation disorder (Skelton & Funk, 2004) and the treatment approach is said to be popular in phonological disorder

among practitioners in the United States (Brumbaugh & Smit, 2013). Traditional approaches to treatment may be effective to a certain extent in the treatment of phonological disorder (Bowen, 2014; Hesketh, Adams, Nightingale, & Hall, 2000), and also have merit at the phonetic level (Lousada et al., 2012). However, these approaches were neglected in recent research, and this dearth warrants further investigation into specific details such as the treatment principles, hierarchy, and conditions underlying the nature of the approaches and the steps embedded in them. For example, as these motor-based articulation errors are presumed to be the result of an incorrectly learned motor plan/program for the production of certain speech sounds (Crosbie et al., 2005; Fey, 1992), investigation should focus on the principles of *motor learning* that underlie the nature of the motor-based approaches, such as the long-standing effective PPA. In the context of speech motor learning (SML), discerning relations between speech sound positions within a specified speech "unit," initial conditions, desired outcomes, and parameters specified should be investigated (Maas et al., 2008).

SML in SSD Treatment

Motor learning is the study of the acquisition of motor skills, the improvement of learned motor skills, or the reacquisition of skills that are difficult to perform due to injury or disease (Magill, 2007). Several principles underlie the teaching of motor skills in speech. Based on a review by Hegde (1998b), it appears that traditionally (in the 1980s and earlier) the amount of practice was the focus of speech learning in SSD. When the treatment of SSD is discussed, reference is made to programmed instruction, behavior modification, and general principles of learning (Bernthal, Bankson, & Flipsen, 2013). However, research in neuromotor speech disorders paved the way for investigation into more specific *motor learning principles* (MLPs).

Knock, Ballard, Robin, and Schmidt (2000) provided early evidence that the application of certain MLP may be similar in effect on learning of speech motor acts for acquired apraxia of speech (AOS) as the recorded effects for limb movements. In a later example of such a general SML approach to treating AOS, Van der Merwe (2011) provides guidelines for the treatment of acquired motor speech disorders. The SML approach (Van der Merwe, 2011) is primarily based on a four-level model of speech sensorimotor control as described by Van der Merwe, Schmulian, and Groenewald (1997) and Van der Merwe (2011). In the SML approach (Van der Merwe, 2011), each target sound is rehearsed in systematically changing phonetic contexts in a series of nonwords. The aim is to foster adaptation of the movement parameters of a speech motor target to changes in the phonetic environment. The adaptation of *spatial specifications* of each speech sound to the phonetic context and rate of production, as well as the adaptation of *temporal specifications* to segmental duration, coarticulation potential, rate, and interarticulatory synchronization, happens at the second level of *motor planning* (Theron, Van der Merwe, Robin, & Groenewald, 2009). The systematically changing phonetic contexts can also be adapted to training in different orders (Van der Merwe, 2011). If multiple speech motor targets are targeted simultaneously, the implementation of series of utterances (nonwords) in the SML creates the opportunity to also apply different MLP.

The application of certain MLP is thought to positively influence SML into the specific guidelines, strategies, and techniques provided by the SML approach (Van der Merwe, 2011) and the PPA (Van Riper, 1996). Both the PPA and the SML approach "programs" generalization of acquired skills. Applying the MLP may thus address an ever-present problem of *generalization* of the correct production of treated sounds (speech motor target) to different phonetic contexts and connected speech in natural communication (Wambaugh & Nessler, 2004). Furthermore, the application of MLP may additionally affect *performance and maintenance of skills* where specific options may affect learning according to their impact on motor learning (Maas et al., 2008; Magill, 2007; Schmidt & Lee, 2011). These factors are termed *practice conditions*, and they influence the amount of information available for motor learning (Schmidt & Lee, 2011).

Practice Conditions and Motor-Based Articulation Disorder

A number of conditions of practice should be taken into consideration during treatment where MLP are applied (Magill, 2007; Schmidt & Lee, 2011). Examples of such conditions are the *practice schedules* which include *random, blocked*, and *serial practice. Random practice* is a specific schedule in which different speech targets are practiced in a random order. *Blocked practice* (BP) is the repeated production of a target skill without involving other targets before switching to another target. *Serial practice* (SP) involves the production of several discrete actions simultaneously during a set sequence or order (Schmidt & Wrisberg, 2008). These schedules are proposed to establish a more reliable schema for a generalized motor program (GMP; Schmidt & Lee, 2011). Therefore, although these schedules may all be equal regarding the amount of parameter variability within the conditions, blocked-, serial-, and random-practice schedules (in this order) show increasingly poorer performance practice during trials, but enhanced true learning during maintenance and generalization measures (Shea & Wulf, 2005).

Few reports are available for limb and speech motor learning during a *SP* schedule. The Schmidt and Lee (2011) hypothesis regarding more reliable schemas for GMP was tested for *non-SML* in a study by Giuffrida, Shea, and Fairbrother (2002). These authors found a SP schedule to be superior to BP for task learning, when the task was governed by a *different GMP*. It seems from this study that the *more predictable* SP schedule (Shea & Wulf, 2005) does induce a more stable learning environment for non-SML (as proposed in the limb-motor learning literature, and also postulated by the stability hypothesis [Shea, Lai, Wright, Immink, & Black, 2001]). A much older study by Lee, Magill, and Weeks (1985) also suggested that trial-to-trial motor target changes provide superior performance for serial over blocked practice, but these effects have yet to be confirmed in SML.

The Present Study

Few studies to date have demonstrated the possible motor learning benefit of different practice conditions in novel speech tasks for unimpaired speakers, or in the disordered developmental motor-based speech domain (Maas et al., 2008). Maas et al. (2008) suggested that MLP may apply to any situation and have also recognized the dearth in further research in the speech domain. More recently the Bislick, Weir, Spencer, Kendall, and Yorkston (2012) systematic review has indicated that the current level of evidence for

the application of MLP to healthy adults and individuals with acquired and developmental motor speech disorder warrants continued investigation. Unfortunately, research of motor-based articulation disorder treatment where certain principles of motor learning are *defined for specific language or age groups* is scant (Bislick et al., 2012; Maas et al., 2008). Furthermore, no treatments for developmental motor-based articulation disorder make specific reference to *specific practice conditions* (Magill, 2007; Schmidt & Lee, 2011). Given the various hypotheses and evidence in motor-limb literature in this regard, it is reasonable to believe that similar practice performance and learning outcomes will arise from empirical investigations for motor-based articulation disorder.

The aim of this research was to compare the outcomes of particular MLP (blocked vs. serial practice schedules) in the treatment of developmental motor-based articulation disorder in children. Subsidiary aims were to evaluate the value of the application of these MLP to the treatment of developmental motor-based articulation disorder in children, through the combined utilization of the treatment stimuli and strategies of the SML (Van der Merwe, 2011) and the PPA (Van Riper, 1996). The following research question was proposed to answer to the objectives of the study: Will blocked- versus serial-practice schedules differentially impact SML in treatment for children with developmental motor-based articulation disorder?

We hypothesized that MLP would impact SML in children with motor-based articulation disorder in the same way as proposed in the limb-motor learning, because MLP may apply to any situation in which motor learning must take place. Furthermore, the application of a SP schedule would induce greater positive change (a) in the articulation of target sounds in *treated* nonwords and real words (acquisition) and (b) in the amount of generalization to *untreated* nonwords and real words, because this schedule was proposed to show enhanced true learning due to a more reliably established schema for a GMP. Finally, improved production would be maintained to a greater extent in the SP schedule for a period of 2 weeks after treatment had been terminated.

Method

Participant Description

A male nonnative English (first language: Sepedi) speaking participant aged 7 years 10 months presenting primarily with developmental motor-based articulation disorder, participated in the study. The participant was an early bilingual. The term *early bilingual* refers to a child who learns a second language before puberty and the second language is usually the language of learning and teaching (Baker, Trofimovich, Flege, Mack, & Halter, 2008). The participant had been exposed to English as his language of learning and teaching since the age of 3 years. Many early bilinguals can establish phonetic categories for the second-language phonemes because the first-language phoneme inventory does not have a marked impact on that of the second language when the phonemes are acoustically similar (Baker et al., 2008). As such, it had earlier been hypothesized by Holm and Dodd (1999) that if a bilingual child presents with a SSD, the disorder will fall in the same category in both languages. This hypothesis suggests that a single underlying deficit may affect both phonetic systems (Holm & Dodd, 1999).

The phoneme inventory of Sepedi contains consonants that overlap with and are, in most cases, similar to those of English. Examples of these consonants are the aspirated plosives /ph/, /kh/; nasals /m/, /n/; the liquid /l/; fricatives /f/, /s/ /ʃ/; and glides /w/ and /j/ (Kotzé, 1989). Furthermore, available data in isiXhosa (which belongs to the same Bantu language family as Sepedi) suggests that most consonants in isiXhosa are acquired by the age of 3 years, with exception of the aspirated plosives, affricates, fricatives, and clicks which develop a bit later (Maphalala, Pascoe, & Smouse, 2014). These available norms seem to correlate with reports of consonants generally being acquired earlier in Bantu languages than in English (Pascoe et al., 2016). Although there are no specific normative data available in Sepedi, data on the aforementioned Bantu language family, the phonological and phonetic systems of an early bilingual, as well as the similarity of the phoneme inventories in Sepedi and English to the speech sounds in error in the present study, lead to the diagnosis of SSD rather than a speech difference.

The participant was academically proficient in English and recruited via convenience sampling from available clients at the SSD clinic of the University of Pretoria, South Africa. A faculty ethics committee granted approval for the research. The diagnosis of motor-based articulation disorder was made by a qualified and certified speech-language pathologist. CAS was ruled out following available diagnostic criteria from the American Speech-Language-Hearing Association (ASHA; 2007). Inconsistent consonant and vowel errors with repeated productions and inappropriate prosody during spontaneous speech were absent for the speech motor targets of the present study. Primary phonological disorder or delay, as well as inconsistent speech disorder (Dodd, 2005), were ruled out based on consistent incorrect production of the error sounds across phonetic contexts and elicitation methods (Bauman-Waengler, 2016; Crosbie et al., 2005).

Assessment Material and Results

The Goldman–Fristoe Test of Articulation (GFTA-2; Goldman & Fristoe, 2000) was performed to determine the nature of the articulation errors and Speech-in-Sentences scores (SiS) of the participant. The mean length of utterance (MLU) of the participant was calculated according to the number of morphemes in a 100-utterance sample size (Miller, 1981). Later, Finestack, Payesteh, Rentmeester Disher, and Julien (2014) advised that this sample may not be adequate. MLU results in the present research which were derived from Miller (1981) had therefore only been a guideline. *The Peabody Picture Vocabulary Test–III* (PPVT-III) was administered to determine the levels of receptive vocabulary of the participant. The *Test for Auditory Comprehension of Language–Third Edition* (TACL-3; Carrow-Woolfolk, 1999) was used to determine levels of receptive language. Finally, a complete oral-facial examination (Shipley & McAfee, 2009) was performed to determine the structure and functioning of the oral structures. Results are depicted in Table 1.

Table 1. Participant Characteristics.

Gender	Age (years; months)	Error sounds	Pretreatment results
Male	7; 10	/s/ (consistent omission), /ʃ/ (consistent substitution), /l/, /r/, /tʃ/	MLU: 5.9 (>5; 0) PPVT: SS: 114 (6;10) GFTA: %tile: 1ˢᵗ TACL: CQ: 80

Note. MLU = mean length of utterance (morpheme-based; Miller, 1981); PPVT: SS = Peabody Picture Vocabulary Test Standard Scores; GFTA = Goldman–Fristoe Test of Articulation (Goldman & Fristoe, 2000); TACL = Test for Auditory Comprehension of Language; CQ = composite quotient (Carrow-Woolfolk, 1999).

Pretreatment speech and language profiles

The oral-facial examination established that the oral-facial structures were intact and functioned normally. No immature swallowing pattern was present. The participant had three motor-based speech sound errors at the start of the treatment. Speech was characterized by consistent speech sound errors of the fricative /s/ sound and the /ʃ/ sound in all word positions. The fricative /s/ was omitted in all word positions. The /ʃ/ was substituted with a /s/ sound in all word positions. The /r/ sound was distorted with a /w/ sound, or omitted in all positions of words. The /l/ sound was omitted in medial cluster positions of words. Cluster reduction of the /tʃ/ combination to a /t/ sound also occurred. In regard to the motor-based speech sound errors, the /ʃ/ and /r/ sound errors were not age appropriate as the /r/ sound should have been acquired by the age of 6 years and the /ʃ/ sound by the age of 7. The English /s/ should be acquired by the age of 4. The norms for these English speech sounds were suggested by Templin (1957); Prather, Hedrick, and Kern (1975); and Wellman et al. (2011). The participant displayed a near age-appropriate MLU, receptive vocabulary, and auditory comprehension of the English language. These scores may be attributed to the fact that the participant was a nonnative English speaker and was not assessed in his first language, Sepedi. No speech assessment material or informal translations of assessment material are currently available in Sepedi. Scholastic authorities reported that the participant did not struggle academically and did not display any cognitive, behavioral, or emotional problems.

Design

A two-phase alternating multiple baseline, multiple probes across behaviors design was used (Barlow, Nock, & Hersen, 2009; McReynolds & Thompson, 1986). A novel hybrid treatment approach was employed, which combined elements of the SML program (systematic phonetically varied and correct production of nonsense CVC (consonant, vowel, consonant) syllables, integral stimulation; Van der Merwe, 2011) and the PPA establishment stage/production phase (repetitive single-syllable treatment stimuli rehearsal; Van Riper, 1996). These elements of the PPA and the SML program provided a framework for a treatment hierarchy within which the repetitive production of the CVC stimuli and the two practice schedules could be explored and controlled. The study was furthermore designed specifically to counterbalance speech motor targets across conditions and phases so that effect sizes (ES) as outcomes of the specific schedules, rather than the novel hybrid approach itself, may be more reliable.

Target selection and assignment to treatment conditions

Different sets of treatment stimuli were selected according to the error profile of the participant (see the appendix). The speech motor targets were present in the treated stimuli (nine in each practice schedule condition in each phase) to determine practice and maintenance performance, and in the untreated stimuli designed to assess maintenance and generalization performance of these stimuli (nine in each practice schedule condition in each phase). Stimuli were assigned to treated and untreated sets in a pseudorandom manner to control for the number of nonwords and real words. All stimuli were sets of phonotactically legal CVC combinations containing an as closely balanced as possible number of nonwords and real words across conditions. The addition of nonwords enabled us to present the speech motor target in different combinations in the BP versus the SP conditions.

The pairing of the error sounds with the practice schedule conditions was counterbalanced across phases to control for a possible order effect and that systematic differences may be ruled out as possible causes of the demonstrated effects. Speech motor targets were treated in the *word initial* positions during Phase 1 and *word final* positions during Phase 2. Table 2 provides an overview of the treatment timeline including phases, speech motor targets, and stimuli. Table 2 also displays the order in which the treatment stimuli were practiced in the different schedules.

Table 2. Phases, Practice Schedules, SMTs, and Probes.

Baseline	Treatment Phase 1	M1	Treatment Phase 2	M2
	BP = initial /s/ SP = initial /ʃ/ (control = initial/final /r/) (control = medial /l/)		BP = final /ʃ/ SP = final /s/ (control = initial/final /r/) (control = medial /l/)	
P P P	T T T T T T T T P	P P	T T T T T T T T	P P
	P P P		P P	
1 week	4 weeks	2 weeks	4 weeks	2 weeks

Note. SMTs = speech motor targets; M = maintenance phase; BP = blocked practice; SP = serial practice; T = treatment; P = probe.

Probe stimuli

Probe stimuli comprised of treated stimuli (containing the target sounds), untreated stimuli (containing control, generalization, and maintenance probes), and baseline probes. The treated stimuli can be described as measures of acquisition (which indicates performance during practice), and the generalization and maintenance probes are indicative of carryover and conservation of learned skills. As such, the latter can be viewed as *true learning* taking place (Schmidt & Lee, 2011).

Procedures

Pretreatment

All pretreatment and treatment procedures were captured as audio recordings. Appropriate auditory perception and stimulability to produce the target and control sounds in isolation (Maas et al., 2008; Van Riper, 1978, 1996) were established prior to the treatment

procedures (i.e., before the first baseline phase). The auditory training phase took two 1-hr treatment sessions before the participant correctly discriminated the error sounds in different phonetic contexts 100% of the time (real-time accuracy was 1 hr 45 min). Auditory training entailed identification, isolation, stimulation, discrimination, and self-hearing of the treatment targets and control sounds and was assessed informally throughout the pretreatment phase. The auditory training phase also included the production of the error sounds in isolation. This production required successful elicitation and production of the treatment targets and control sounds through the visual stimulation and imitation techniques suggested by Van Riper (1996). A criterion of 50% correct elicitation in isolation was set to ensure probable production progress during CVC treatment trials. Stimulability to produce the treatment targets (/s/ and /ʃ/) and control sounds (/l/, /r/) in isolation was therefore established prior to the commencement of the study.

Treatment

Treatment phases lasted 4 weeks. Treatment was conducted *twice* a week for 40 min, 20 min per treatment condition. The blocked- and serial-practice conditions were alternated according to a priori determined schedule in the sessions to counteract a possible order effect. In the first session of the week, the BP was presented in the initial 20 min and the serial condition in the second 20 min. In the second session of the week, the SP was presented in the initial 20 min and the BP in the second 20 min. A 10-min break with a physical play activity of ball-play was introduced between the two treatment conditions of each treatment session to minimize possible fatigue and lack of interest. The sessions therefore lasted 50 min each. The dose of speech sound productions was not controlled across both schedules due to the predetermined time schedule.

BP schedule

For the BP schedule, the speech motor target was practiced in blocks of 10 productions of the same stimuli containing the same speech motor target in initial position in Phase 1, and the same speech motor target in final position in Phase 2. Only after completion of a block of productions of the same stimuli containing the speech motor target was the following block of repeated productions introduced. The nature and sequence of the BP practice trial was determined by the consecutive repetitions of the same stimuli with the same speech motor target practiced in a blocked condition, before moving on to the next stimuli containing the speech motor target. All items were elicited with a typical rate and voice pitch (i.e., no systematic manipulation of variability). The set of nine CVC stimuli contained the first-speech motor target /s/, three vowels (one neutral, two rounded), and three final consonants (/m/ /p/ /t/) in Phase 1. The stimuli contained the second speech motor target /ʃ/, three vowels (one neutral, two rounded), and three initial consonants (/m/ /p/ /t/) in Phase 2.

SP schedule

For the SP schedule, the speech motor target was practiced in series of stimuli containing the speech motor targets in word-initial position in Phase 1 and word-final position in Phase 2. Once the series of words containing the speech motor targets was completed, the whole

series was repeated from the start. These series were completed 9 consecutive times to ensure the same number of productions as for the BP schedule. The nature and sequence of the SP practice trial was determined by the groups of serial repetitions of the different stimuli with the same speech motor target practiced in a serial condition. Once the series containing all stimuli was completed, the series was repeated to ensure the same number of trials as for the BP condition. This sequence of SP was randomly changed from session to session. All items were elicited with a typical rate and voice pitch (i.e., no systematic manipulation of variability). The set of nine CVC stimuli contained the second speech motor target /ʃ/, three vowels (one neutral, two rounded), and three final consonants (/m/ /p/ /t/) in Phase 1. The stimuli contained the first-speech motor target /s/, three vowels (one neutral, two rounded), and three initial consonants (/m/ /p/ /t/) in Phase 2.

The treated stimuli of the practice schedules were rehearsed as indicated in the participant-treatment hierarchy protocol. These trial stimuli were presented on red and blue cards for the BP and SP conditions respectively as a stimulus to ensure that the participant knew which treatment was conducted during the sessions (Byiers, Reichle, & Symons, 2012). The speech motor target trials were always presented in *a priori determined* order during the treatment sessions within each practice schedule to control for any possible influence a randomized presentation of the blocks may induce.

Augmented feedback was provided in a set fading schedule to not interfere on another level of motor learning (Schmidt & Lee, 2011). This external feedback is verbal feedback provided by the clinician to the client. Two types are distinguished: Knowledge of Performance (KP) is feedback provided about the movement characteristics of the motor act. Knowledge of Results (KR) is feedback on the outcomes of the motor act (Schmidt & Lee, 2011). For the present study initial KR was provided for both schedules of treatment.

Additional ways to support these augmented verbal feedback schedules are the addition of auditory and visual ways of instruction. These ways are labeled integral stimulation and were first introduced by Milisen (1954). Integral stimulation also uses a myriad of strategies such as gestural, tactile, and prosodic cues to facilitate learning and generalization of speech motor skills (Caruso & Strand, 1999). An example is the instructions given in the present research by visually demonstrating the placement of the sound, and requesting auditory attention to the outcomes of the production attempt (KR). Other examples such as vocal emphasis, the use of metaphors, or facilitation correction were not included in the instructions. This very specific way of integral stimulation and phonetic placement was designed as part of the controlled novel hybrid SML-PPA protocol which excludes other possible variables that could influence motor learning and generalization and increased fidelity (see below).

The participant-treatment hierarchy protocol for both treatment schedules was as follows:

BP (Treated for 20 Min as Indicated Per Biweekly Session)

The repeated production of the *first* target stimulus was practiced in an arranged series in blocked fashion—nine productions with a *fading feedback* (FB) *schedule for the initial three repetitions. KR was given as FB*. Integral stimulation was provided during the first 3

repetitions within the block. The instructions were as follows (only one treatment stimulus included in the example):

First target: "som"

- ➢ Instructions: "Let's say "som." We are going to say it nine times. I will count with my fingers. Look at my mouth and listen to how I say it. Okay, let's say "som."
- ➢ *Participant responds "som." (Clinician provides FB).*
- • *Repeat 8 times (FB on first 3 trials).*

Next target: "sim"

- ➢ Instructions: "Let's say "sim." We are going to say it 9 times. I will count with my fingers. Look at my mouth and listen how I say it. Okay, let's say "sim."
- ➢ *Participant responds "sim." (Clinician provides FB [e.g., I did not hear the sharp "s"]).*
- • *Repeat 8 times (FB on first 3 trials).*

Next target: "sum"

- ➢ Instructions: "Let's say "sum." We are going to repeat it 9 times. I will count with my fingers. Look at my mouth and listen how I say it. Okay, let's say "sum."
- ▪ *Participant responds "sum." (Clinician provides FB [e.g., that was a clear, sharp "s"—well done!]).*
- ➢ *Repeat 8 times (FB on first 3 trials).*
- ▪ *Continue treatment protocol for all remaining BP target stimuli as above.*

10 minute break

SP (Treated for 20 Min as Indicated Per Biweekly Session)

The repeated production of the *second*-target stimulus was practiced in an arranged series in a serial fashion—nine productions with a *FB schedule for the initial three repetitions. KR was given as FB.* Integral stimulation was provided during the first 3 repetitions. The instructions were as follows (only one treatment stimulus included in example):

First target: "shom"

- ➢ Instructions: "Let's say "shom." We are going to say it once. Look at my mouth and listen to how I say it. Okay, let's say "shom."
- ➢ *Participant responds "shom." (Clinician provides FB).*

Next target: "shim"

- ➢ Instructions: "Let's say "shim." We are going to say it once. Look at my mouth and listen to how I say it. Okay, let's say "shim."

- ➢ *Participant responds "shim." (Clinician provides FB [e.g., I want to hear a stronger "sh"]).*

Next target: "shum"

- ➢ Instructions: "Let's say "shum." We are going to say it once. Look at my mouth and listen to how I say it. Okay, let's say "shum"
- ➢ *Participant responds "shum" (Clinician provides FB)*

Continue treatment protocol for remaining SP target stimuli. Repeat precise protocol 8 times.

Probe procedures

Data were collected in the same way and in similar sound-proof therapy rooms for each probing session. Probing took place at the end of the session after a 10-min break to capture short-term retention. All the probe stimuli (included in the appendix) were used during these sessions. Responses were recorded on a digital voice recorder (Apple Nano Touch iPod). Probes involved an imitation task: The examiner produced each CVC probe stimulus (see the appendix) one at a time, without any repetition, and asked the participant to repeat the word. No time restriction was imposed and no feedback was given. Treated, untreated, and control stimuli were all presented together from the same list. The groups of stimuli were presented in a random order with each presentation of the probe list. Each probe session included the treated stimuli, the untreated stimuli as well as the control probe stimuli for both the serial and blocked practice. The different stimuli within each group were presented in a random order different from the treatment hierarchy order. All items were completely randomized regardless of which set they belonged to, and different random orders were assigned to each individual probe.

Three baseline probes were administered on the Monday, Wednesday, and Friday of a single week directly prior to treatment. During both treatment phases weekly probes were administered. An additional two probes were administered on two consecutive days at the end of a 2-week withdrawal period between Phases 1 and 2. Two final probes were administered on two consecutive days 2 weeks after Phase 2 during the maintenance period. The probes at the end of the withdrawal and maintenance periods after Phases 1 and 2 were administered to track retention of treated items and maintenance of any generalization to untreated probed stimuli. The researchers perceptually judged these target sounds during probing to make decisions regarding the termination of treatment. These judgments were not used for data analysis. The a priori performance-based termination criterion of 100% correct on all target sounds on two consecutive probes during the treatment phase was not met; thus, both treatment phases for the participant lasted 4 weeks (the a priori determined time-based criterion).

Data analysis

Perceptual scoring of the data was done by a panel of three listeners who were all trained speech-language pathologists with normal hearing. The participant was unknown to the

panel. The treating speech-language pathologist presented the responses of the participant to the panel on a single occasion (two sessions with an hour lunch break) in the same sound-proof lecture room with free field amplification. The responses were presented to the panel in a random order with regard to treatment conditions, target sounds and phases, to establish blinding. A total of 644 productions were presented to the panel. These probes represented a proportion (*n* = 92) of the total of 1,296 treated stimuli productions, and also included the untreated control (*n* = 20) and generalization (*n* = 36) stimuli (see Table 2 and the appendix). Thus, 92 probe stimuli were presented 7 times: for three baseline measures and two mid-treatment and two posttreatment recorded sessions. The panel was requested to make independent binary judgments regarding the accuracy of the *target sounds* in the stimuli presented, without any discussion. A panel member could not view the responses of another panel member. The listeners were instructed to regard any substitution, omission, or distortion of a target sound as an error. Substitution was defined as the clear and accurate production of another speech sound instead of the target sound, and distortion as an inaccurate version of the target sound, either due to temporal distortion or to spatial misplacement of articulators (Van der Merwe, 2011). The panel noted their binary judgments of the responses on a recording sheet.

Statistical analyses

A percent correct was calculated for each treated stimulus across the raters. Scores were then averaged across targets within a given condition, and these average percent correct scores served as the dependent measure. ESs were calculated with a pooled standard deviation to account for the possibility of zero variance during baseline conditions (Beeson & Robey, 2006; Busk & Serlin, 1992): ES = (mean post-tx – mean pre-tx) / pooled *SD* pre- and post-tx.

ESs were calculated based on the three data points immediately preceding treatment and the two data points immediately following treatment, due to changes in baseline for Phase 2 items in Phase 1. Following the example of Maas, Butalla, and Farinella (2012), we operationally defined an effect to be present when ES > 1, indicating that the magnitude of change exceeds the standard deviation. A visual analysis of the levels, trends, variability, latency, and consistency for both the baseline and treatment phases was also carried out to support the statistical analyses.

Reliability and fidelity

Intra-rater reliability was determined by a point-to-point agreement for each item for each individual listener through the blind repetition of a randomly selected single probing session. The repeated session scores were compared for each listener. Kappa statistics were calculated in this study for every probe of the participant. Intra-rater agreement ranged from a slight systematic disagreement on probe 8 (*k* = −0.02) to moderate agreement on probe 14 (*k* = 0.49).

Inter-rater agreement was calculated according to the binary scores from the three raters. A score of 0/3 or 1/3 was taken as incorrect, and 2 or 3/3 as correct. No additional raters were brought in to resolve a score of 1/3 as the dependent measure was an average across

targets. Overall inter-rater agreement between the three raters for the participant was fair (k = 0.32) but did not reach the preferred 0.6 agreement levels suggested by Kratochwill et al. (2010).

Fidelity time checks were conducted by a student speech-language pathology student who assisted with these checks to prevent bias. Treatment times were compared to ensure that both the treatment schedules had equal treatment opportunities. The time for BP treatment was recorded to be 19 min on average (M = 19.7 min, SD = 0.41). The time for SP treatment was 19 min on average (M = 19.5 min, SD = 0.67). These treatment times did not differ (t = 0.56, p = .32). The feedback schedule was specifically developed prior to each session, and integral stimulation provided for the initial three repetitions as part of fidelity measures. FB (KR) was provided for the initial three repetitions. Integral stimulation was also provided for the initial three repetitions.

Results

BP stimuli are depicted in Figure 1 and SP in Figure 2. Solid lines represent the treated stimuli and broken lines the untreated stimuli for both conditions. The control stimuli are indicated in black with distinctive icons. The vertical lines across the graphs indicate treatment of the specific phases.
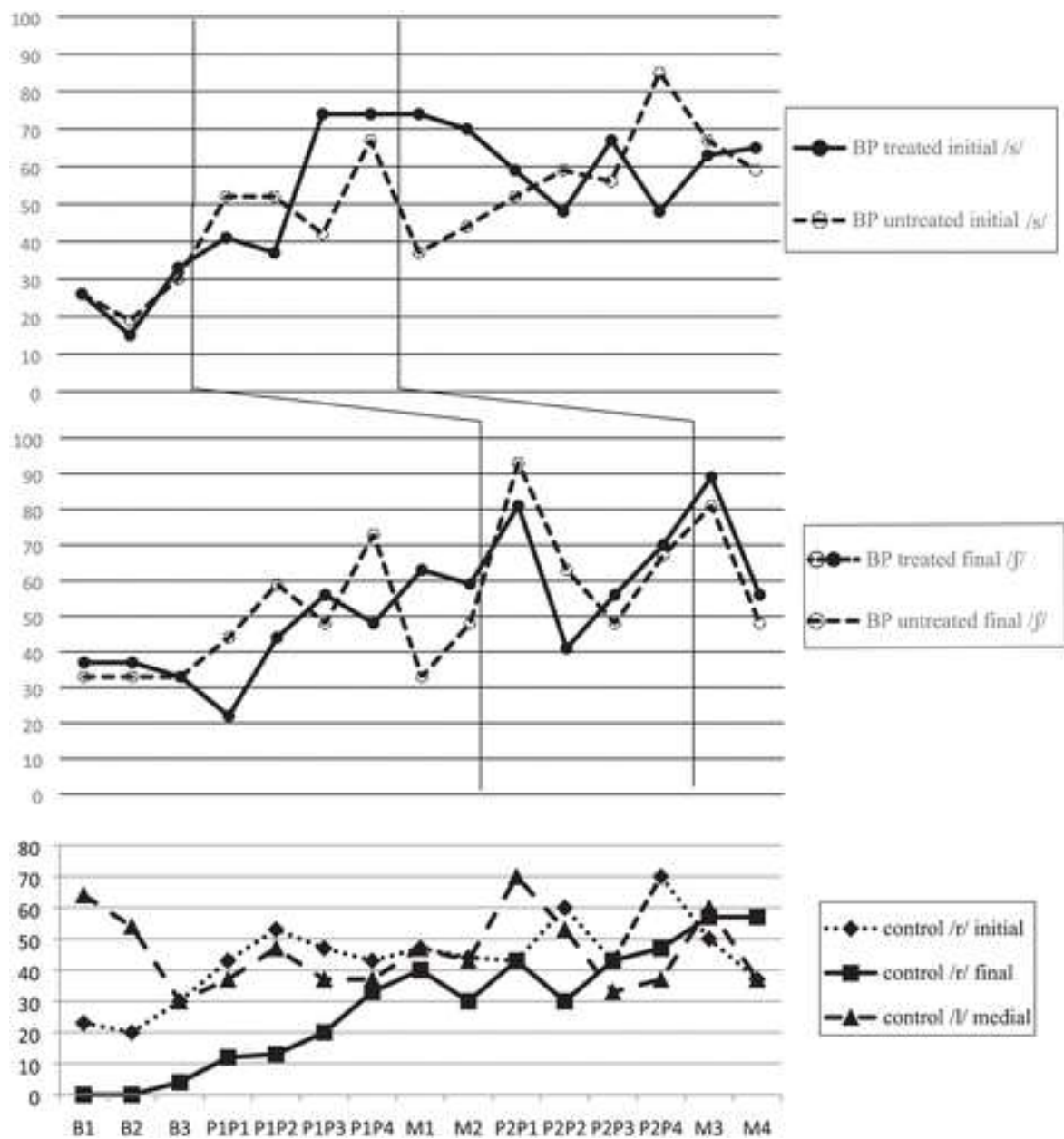
Figure 1. Phase 1 BP items (top panel), Phase 2 BP items (middle panel), and control items (bottom panel).

Note. BP = blocked practice; B = baseline; P = probe (phase; number); M = maintenance (number of retention probe).
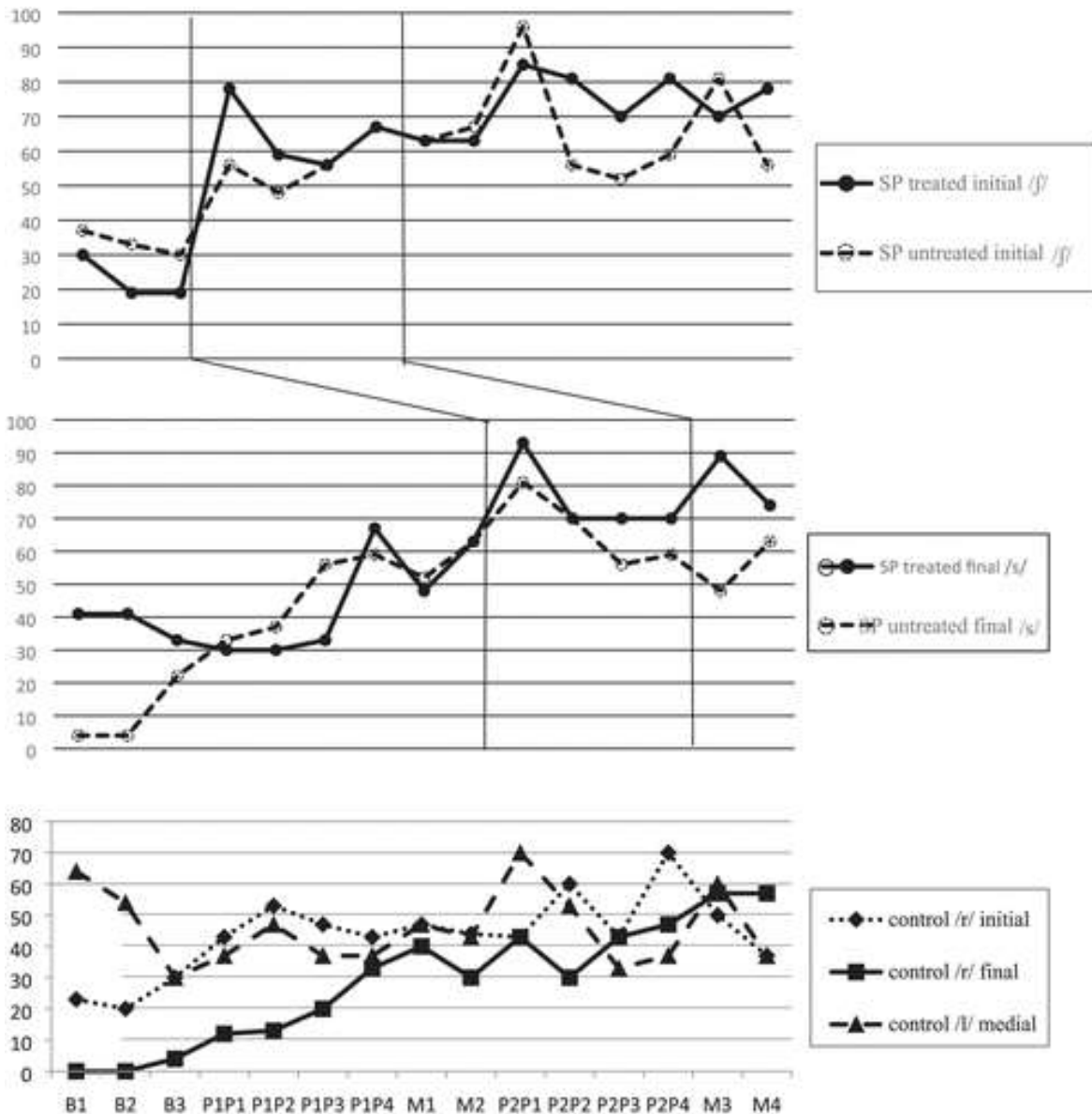
Figure 2. Phase 1 SP items (top panel), Phase 2 SP items (middle panel), and control items (bottom panel).

Note. SP = serial practice; B = baseline; P = probe (phase; number); M = maintenance (number of retention probe).

Phase 1

As can be seen in Figures 1 and 2, prior to any treatment the participant demonstrated stable baseline *levels* for most of Phase 1's treated and untreated items for both conditions. Treated items were scored 26%, 15%, and 33% (*SD* = 9.07) for BP, and 30%, 19%, and 19% (*SD* = 6.4) for SP respectively. Untreated items reflected percentages of 26, 19, and 30 (*SD* = 5.6) for BP, and 37, 33, and 30 (*SD* = 3.5) for SP. The SP untreated Phase 2 items, however, improved at the final baseline probe. Control stimuli displayed erratic performance levels throughout the entire study. Upon initiation of Treatment Phase 1 the participant displayed a positive response *trend* from baseline to treatment for Phase 1 stimuli in both conditions, although the *latency* of the positive response was more rapid in the SP condition than in the BP condition. Erratic performance levels for both treatment conditions followed this initial

response. The final treatment probe displayed a sloped improvement in performance for SP /ʃ/ items from the erratic performance of these items following their initial rapid positive response. Performance on untreated generalization items generally followed performance of the treated items in both conditions, with the exception of BP-untreated items which declined after the second probe.

Phase 2 items also showed a notable improvement in performance *level* during Phase 1 treatment, albeit with erratic performance. Given the potential external influence between Phase 1 and Phase 2 items, ESs were calculated on the three probes immediately preceding and the two probes immediately following each treatment phase to provide a relatively uncontaminated assessment of treatment effects.

ESs confirmed the visual analysis (see Table 3) in that positive ESs >1 were evident in both conditions in Phase 1, with comparable ESs for the BP condition (ES = 6.53; absolute change = 47%) and the SP condition (ES = 8.2; absolute change = 40%). Similarly, performance on generalization items demonstrated positive ESs, with larger effects for the SP condition (ES = 9.73; absolute change = 32%) than for the BP condition (ES = 2.91; absolute change = 16%). Gains for Phase 1 treatment items remained above initial (pretreatment) baseline levels at the final maintenance probes, albeit with a decline from immediate post-Phase 1 performance for treated and untreated SP final /s/ items.

Table 3. ESs and Absolute Change.

Condition	Treatment/ generalization	Phase 1		Phase 2	
		ES	% change	ES	% change
BP	Tx	6.53	47	0.99	16
	Gen	2.91	16	1.58	25
SP	Tx	8.2	40	2.16	22
	Gen	9.73	32	−0.31	−3

Note. ES = effect sizes; BP = blocked practice; SP = serial practice.

Phase 2

For Phase 2, items in the BP condition (final /ʃ/) already displayed improved performance *levels* when considering the immediately preceding three probe points (44%, 56%, and 48% for treated and 59%, 48%, and 37% for untreated items). Therefore, treatment for Phase 2 was initiated with re-baselined calculations. Despite an initial positive response *trend* to SP treatment (final /s/) and BP treatment (see P2P1 for treated SP and BP items in Figures 1 and 2), performance subsequently plateaued for both treated and untreated items. BP-treated items (final /ʃ/) actually declined in performance from the initial gains made in baseline levels during Phase 1 (see P2P2 in Figure 1). BP-untreated items (final /ʃ/) performed erratically with a quick, negative response visible at P2P3.

While performance on treated BP items (final /ʃ/) improved slightly from the re-baselined levels (treated items: ES = 0.99; absolute change = 16%) and demonstrated slightly more improvement for untreated items (ES = 2.54; absolute change = 32%), a different pattern emerged for the treated SP items (final /s/) (see Table 3). The visually apparent plateaued treatment *trends* for SP P2P2–P2P4 were evidenced by smaller ESs for treated items (ES = 2.16; absolute change = 22%). The untreated items displayed negative trends (ES = −0.31; absolute change = −3%). Performance levels on the final maintenance probes were therefore above initial (pretreatment) baseline levels for both conditions, although the performance declined for SP generalization items.

Discussion

The SML approach (Van der Merwe, 2011) and the PPA (Van Riper, 1996) are both suggested to "program" generalization of acquired skills. The SML also creates the opportunity to apply different MLPs which could furthermore affect performance and maintenance of these skills. In the present study, BP was compared with SP within a novel hybrid SML-PPA as platform to apply both these MLPs.

SML-PPA Novel Hybrid Approach

With respect to the overall effect of the novel hybrid combination-treatment approach, the findings indicate inconsistent treatment effects. The participant demonstrated evidence for positive treatment effects in Phase 1, with improved accuracy coinciding with initiation of treatment following relatively stable baselines (SD < 10). However, experimental control, viewed in agreement with Kratochwill et al. (2010), was not lost as the small SD occurred in the reported presence of *both* visual trends, and statistical ES measures. These are set criteria for evidence standards (Kratochwill et al., 2010). The disordered initial and final /r/, as well as the medial /l/, displayed erratic performance congruent with phonological processes. Still, apart from the initial improvement in baseline behavior for the SP untreated stimuli (B3), all other baselines were stable and the present findings suggest that the treatment was likely responsible for the observed improvements. The novel hybrid treatment approach (Van der Merwe, 2011; Van Riper, 1996) is therefore beneficial as gains were made.

Generalization in the Novel Hybrid SML-PPA Approach

Generalization refers to the possible effect of a certain practiced skill on other similar, untrained skills—also known as the specificity-of-learning principle (Maas, Gildersleeve-Neumann, Jakielski, & Stoeckel, 2014). In the present study, Phase 2 items (which were still untreated during Phase 1) showed improvement coinciding with onset of treatment in Phase 1. Data from treatment Phase 2 were therefore more difficult to interpret given this improvement of Phase 2, resulting in some rising baselines and limited room for improvement. Still, given that the changes followed stable baselines in most cases, it is probable that these changes reflected generalization from the Phase 1 items. Recall that the target sounds were the same across phases but in different word positions, with counterbalancing of target sounds across conditions. Forrest, Elbert, and Dinnsen (2000) reported that generalization of target sounds across word positions occurred for children

with consistent substitution patterns but not for children with inconsistent substitution patterns. Thus, given that the participant demonstrated consistent error patterns for the target sounds, it is suggested that generalization across word positions occurred. To mitigate the possible effect of the increased performance levels for Phase 2 items before Phase 2 treatment due to external factors, the design again utilized only the three probes immediately preceding Phase 2 treatment as baseline. In most cases, these three probe points indicated a relatively stable performance level, as described earlier. (Recall that the data presented here were based on blinded ratings by three independent listeners, and were not used to determine initiation or termination of treatment.)

Maintenance in the Novel Hybrid SML-PPA Approach

Improved performance is best evident when the skill is maintained after a period of time post-practice. Care should be taken not to interpret changes in performance on practice trials as "learning," as performance during practice is a poor predictor of both maintenance and generalization (Maas et al., 2008). As such, performance should be probed after practice periods via maintenance probes as well, before any conclusions regarding true learning can be made (Maas, 2014). Overall, the participant demonstrated improvements that could be attributed to the intervention, and which for the most part were maintained at above pretreatment baseline levels. However, the decline in accuracy in Phase 2 for some item sets means that further study is needed to determine the factors that influence the response to treatment for children with developmental motor-based articulation disorder before it can be recommended for clinical use.

Generalization in Blocked Versus Serial Practice

BP schedules are reported to have enhanced acquisition or practice performance outcomes according to limb-motor learning research (Schmidt & Lee, 2011). However, these schedules are not suggested to enhance the recall schema, as per the Schmidt (1975) hypothesis. Therefore, true learning is said to be less likely in BP. SP, on the contrary, should be superior for task learning, inducing a more reliable schema (Maas, 2014). With respect to the second main aim and proposed hypothesis regarding SML for the present study, the potentially differential effects of serial- versus blocked-practice, the findings again indicated few and inconsistent differences between conditions. In Phase 1 the participant showed a slightly higher ES for the SP-treated items than the BP-treated items. However, the absolute change indicated that practice performance was indeed a bit higher for BP items, as suggested by Schmidt and Lee (2011). Generalization to untrained items showed a similar trend in both ES and absolute change (SP > BP). Thus, no clear pattern emerged in Phase 1.

In Phase 2, the participant showed a decline in the BP schedule, specifically. However, the participant showed a greater decline for especially SP generalization items during Phase 2, a finding that contradicts true learning effects predicted in the hypothesis. Interpretation relative to practice conditions in Phase 2 should be taken with caution, if one recalls that the BP speech motor targets of Phase 2 were the same sounds as the SP targets in Phase 1 (in different word positions). This striking decline in performance for all SP generalization item sets is a caveat to consider. A possible explanation is that the increased performance prior to Phase 2 treatment meant that there was less room for improvement for the Phase 2 item

sets. Thus, the positive effects from Phase 1 may have been substantially negated by the negative Phase 2 performance. Nonetheless, treatment performance and generalization gains in Phase 1 concur with the present hypothesis. That is, although not clearly visible in the ES, the BP condition reflected a greater treatment performance absolute change (consistent with suggestions in limb-motor learning [e.g., Schmidt, 1975] and SML [Maas et al., 2008]). Also, the participant demonstrated greater generalization to untreated SP items, which concur with suggestions regarding true learning in the limb-motor learning literature, and is therefore seemingly in support of the Schmidt and Lee (2011) hypothesis in regard to more reliable schemas for GMPs. The superior generalization may therefore also be in support of the stability hypothesis posted by Shea et al. (2001). In addition, the greater regression of Phase 2 BP-treated stimuli may suggest that overlearning is more probable to occur for this practice schedule specifically. Overlearning may happen when a desired outcome has been reached, but the client still has to attend to repeated trial sessions in conformation to the treatment design (Schmidt & Lee, 2011).

Another important consideration is the small differences in treatment and generalization gains between the different conditions (see Table 3). These smaller gains may, in part, have been caused by the auditory similarities between the /s/ and the /ʃ/ target sounds as mentioned earlier. Although the panel of listeners reported normal hearing abilities, only *fair* levels of kappa inter-rater agreement (k = 0.32) were calculated. The fact that these similar sounding targets may have influenced the ES for the different treatment schedules should be considered. This perceptual similarity of the speech motor targets may also have induced a degree of observer drift (Kratochwill et al., 2010).

Maintenance Effects

Differential treatment maintenance effects across conditions were evident. Phase 1 items showed a noticeable decline directly post-treatment (M1) for the SP-untreated initial /ʃ/ specifically, but these stimuli improved in maintenance performance thereafter. The rest of the speech motor targets erratically maintained performance from their final treatment probe. However, the SP-treated stimuli thereafter (M2–M4) maintained and improved from their positive performance of Phase 1, whereas the BP-treated stimuli displayed a more erratic pattern of retention. An interesting occurrence was the spike in performance during post-Phase 1 maintenance of the SP-treated initial /ʃ/ (P2P1). A similar pattern was evident in Phase 2 of treatment at P2P1 for SP treated and untreated final /s/ items, suggesting a possible trade-off between these speech motor targets.

Phase 2 items maintained performance above baseline levels (see M3 and M4) for all stimuli, except SP generalization items. An initial sharply sloped posttreatment improvement was noted for the treated SP final /s/ items (M3), but this display then returned to premaintenance phase levels (M4). Overall, it seemed that retention (M2–M4 for Phase 1 items and M3–M4 for Phase 2 items) displayed superior maintenance trends for SP-treated items when compared with BP-treated items.

Conclusion

The overall effect of the novel hybrid combination-treatment approach indicated inconsistent but mostly positive treatment effects. That is, this novel approach which incorporated MLPs may be utilized in the treatment of children with motor-based articulation disorder, as positive treatment outcomes were evident. A few important caveats were proposed which, unfortunately, limited the strength of the findings. The following design and evidence considerations should be contemplated:

1. Speech motor targets should be counterbalanced across conditions, phases, and participants so that such target effects could be ruled out and condition effects could be established with greater confidence;
2. The choice of speech motor targets should be carefully considered to rule out auditory perceptual challenges by the panel of listeners due to phoneme similarity;
3. The listening panel may be supplemented or replaced by acoustic analyses;
4. The order of presentation of the conditions should be randomized to rule out a possible treatment-order effect or even fatigue toward the end of a treatment session, which could impact on the performance effects of the condition always treated at the end;
5. Probing schedules should be randomized regarding the content and conducted at the beginning of sessions rather than at the end to better capture short-term retention (across a few days rather than 10 min following the treatment session);
6. Treatment sessions should be visually recorded to ensure systematic evaluation of treatment fidelity.

With regard to *evidence considerations*:

1. To prohibit possible rising baselines in future research, studies could sample more target behaviors in more contexts, or include longer baseline periods;
2. Possible trade-offs between speech motor targets can induce counter-effects in treatment performance, generalization, and maintenance. Choice of target stimuli is once again highlighted here as an important consideration before the study commences, if alternative choices are indeed possible and reasons for the possible trade-offs are known;
3. As with any single participant empirical investigation, exact repetition of these studies is advised to increase evidence levels and validity.

In spite of what is often reported in limb-motor learning, and more recently in certain speech- and voice motor-learning domains, this attempt to indicate similar findings for treating motor-based articulation disorder in children has offered some suggestions regarding the overall efficacy of the treatment approach. The beneficial effects with regard to specific treatment and performance outcomes for individual MLP have been shown to be neither conclusive nor specifically sustainable post-treatment. However, more investigations yielding the proposed adaptations mentioned here may offer other researchers the chance to take these investigations a step closer to much needed evidence-based practice in this population.

Appendix

Treatment and Probe Stimuli

Schedule/target type	Phase 1	Phase 2
BP-treated stimuli (practice + maintenance)	som, sop, sot, sim, sip, sit, sum, sup, sut	mosh, posh, tosh, mish, pish, tish, mush, push, tush
BP-untreated stimuli (generalization + maintenance)	sog, son, sol, sin, sif, sig, suf, sun, sul	losh, fosh, gosh, fish, nish, lish, lush, fush, nush
SP-treated stimuli (practice + maintenance)	shom, shop, shot, shim, ship, shit, shum, shup, shut	mos, pos, tos, mis, pis, tis, mus, pus, tus
SP-untreated stimuli (generalization + maintenance)	shol, shof, shog, shif, shin, shil, shul, shuf, shun	gos, nos, los, nis, fis, gis, fus, nus, lus
Control stimuli	/r/ initial $n = 10$ (CVC), /r/ final $n = 10$ (CVC): mor, far, tir, lier, poer, neer, fier, lar, peer, tor; rim, roen, reet, raf, riep, rol, rip, roem, reen, rit	
	/l/ medial position deletion: $n = 10$ (CVCV): molid, falik, tilut, mielot, nelug, fielom, palap, tolum, poelip, teelup	

Note. BP = blocked practice; SP = serial practice; CVC = consonant, vowel, consonant.

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