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PRECISION TEACHING: DISCOVERIES AND APPLICATIONS

The Use of Prompts and Precision Teaching to Address Speech Sound Disorders in a 17-Year-Old Girl With Autism

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Abstract

Precision teaching is a measurement system that uses frequency as its basic data and plots those data on a standard celeration chart for practitioners to make decisions (Maloney, 1998). Kay, a 17-year-old girl with autism spectrum disorder and profound speech sound disorder, participated in this multiple-baseline across-behaviors study. The syllables "thu," "fu," and "cu" were targeted for higher frequencies of correct echoic responding in isolation. Lip-tongue-teeth position prompts, frequency building (Fabrizio & Moors, 2003, *European Journal of Behavior Analysis*, *4*(1–2), 23–36), and feedback were used in brief timed practice trials for the first 2 skills. Priming (Cihon et al., 2017) was also added to the third syllable. The frequency of correct responses accelerated from low levels in baseline to a frequency aim of 60 per minute or higher, with intervention for all 3 targets. The accuracy of her articulation with 30 functional words with the component consonant sounds was measured and showed significant improvements from baseline to postintervention. The outcomes representing fluent performance were also achieved. The implications of training for fluency of syllables on word speech are discussed.

Keywords Articulation · Autism · Lip-tongue-teeth prompts · Precision teaching · Speech sound disorders

Speech can occur as phonemes, syllables, word approximations, or words. A phoneme is the smallest unit of sound in a word that can change the word's meaning (Owens, 2015) and includes vowels and consonants. For instance, substituting "p" with "m" changes *pan* to *man*. Syllables are a part of a word that contains a vowel sound. A syllable has at least one vowel in a cluster of sounds (e.g., *cat* and *car* have two syllables, both with one vowel, and *poem* has two syllables, both with one vowel each). Word approximations contain at least one accurate consonant and vowel combination occurring in the correct position and have either the correct number of syllables or a developmentally appropriate reduction in syllables (Yoder & Stone, 2006). For instance, a child could say "wateh" for *water* or "pe fe" for *perfume*. A word is the smallest series of speech sounds or syllables that communicates a meaning.

Typically developing toddlers have an expressive vocabulary of 10 words by 15 months, 50 words by 18 months, and a spoken vocabulary of 200 words by age 2. Around this time, they can speak using simple two-word phrases (Paul, 1991). Further, children by age 2 produce 70% of the consonants correctly, use 9 to 10 different consonant phonemes, and a variety of syllables (Stoel-Gammon, 1987, as cited in Paul, 1991). By the time they are in their fifth year, typically developing children can speak in sentences with eight or more words and use compound and complex sentences to tell stories or engage in conversation (Age-Appropriate Speech and Language Milestones, n.d.).

In contrast, a significant proportion of children with autism spectrum disorder (ASD) fail to develop word or phrase speech, even by the time they are 8 years old (Anderson et al., 2007). Among children from this population who do have word or phrase speech, if such speech has several articulation errors, it can have an adverse effect on their communication and social outcomes. Such children may also have unusual intonational contours in speech and a higher rate of speech errors (Cleland, Gibbon, Peppé, O'Hare, & Rutherford, 2010; Shriberg, Paul, Black, & Van Santen, 2010). Shriberg et al. (2010) reported a prevalence of speech errors of 31.8% in 6- and 7-year-old participants with ASD. This lends strength to the argument that speech intelligibility issues in the ASD population are an area of remarkably high clinical significance.

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Speech sound disorders (SSDs) are characterized by difficulties with the production of speech sounds that interfere with speech intelligibility. Such unintelligible speech, according to the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2013), could manifest as speech errors in the form of phoneme addition, omission, distortion, or substitution. Addition involves the inclusion of unnecessary sounds while saying a word (e.g., saying "palay" instead of "play"), omission involves deletion of a sound (e.g., pronouncing "fun" as "un"), distortion involves altering the correct sound (e.g., "tate" for "teeth"), and substitution involves using an incorrect sound (e.g., "thun" for "sun.")

Tager-Flusberg and Kasari (2013) describe minimally verbal children with ASD as having an expressive language of just a few words or fixed phrases with vocalizations that include only atypical nonspeech sounds and some vowel approximations. Tager-Flusberg and Kasari (2013) further state that, despite the development of effective interventions for young children with ASD, virtually nothing is known about older children on the spectrum who are minimally verbal. If such children were given the benefit of interventions addressing articulation, the improvement in articulation of speech sounds, words, phrases, and, later, sentences could potentially improve their communication and social outcomes.

To an extent, the fields of speech-language pathology and behavior analysis have explored improving articulation. Two widely used methods by speech-language therapists are nonspeech oral motor exercises (NSOMEs) and prompts for restructuring oral and muscular phonetic targets (PROMPTs; Dale & Hayden, 2013). However, there is little empirical evidence about the efficacy of either (Lof & Watson, 2008; McCauley, Strand, Lof, Schooling, & Frymark, 2009). The extremely small number of published studies and the issues concerning the basic premises for using NSOMEs make their clinical use controversial. Practitioners' choice is primarily driven by articles appearing in non-peer-reviewed publications, information on websites, and anecdotal reports from other practitioners (Lof & Watson, 2008). Lass and Pannbacker (2008) reviewed 45 articles and reports over a 15-year period and concluded that sufficient evidence does not exist to derive conclusions about the efficacy of NSOMEs in improving speech. They further went on to state that the few studies that did have a strong experimental design produced evidence against the use of NSOMEs for modifying speech.

Behavioral techniques such as prompting, differential reinforcement, chaining, and shaping have been used to address articulation problems in the population with ASD (Aravamudhan & Awasthi, 2019; Eikeseth & Nesset, 2003; Koegel, Camarata, Koegel, Ben-Tall, & Smith, 1998; Lovaas, Berberich, Perloff, & Schaeffer, 1966). Behavior analysts use prompt and prompt-fading strategies to occasion correct responding as part of skill acquisition. A search on YouTube with a phrase such as "eliciting the r sound" or "eliciting the f sound" can produce many videos, several of which offer suggestions for appropriate placement of the lip, tongue, and teeth for occasioning correct sound production. Although some may appear promising, they are anecdotal in nature, based on the presenting clinicians' experience, and their effectiveness is not scientifically tested or documented. A few studies in the behavioral literature, to a limited extent, mention the use of lip-tongue-teeth position prompts. Eikeseth and Nesset (2003) used the modeling of correct mouth, lip, and teeth position as a part of their intervention. Koegel et al. (1998) used such prompts contingent on an incorrect echoic response from a participant. Dyer (2009) mentions prompts such as holding a child's jaw open, using a tongue depressor to position the tongue, and touching the cheeks.

Fabrizio, Pahl, and Moors (2002) used practicing a sound in isolation, vocal imitation training with words, and precision teaching (PT) to remedy a speech error involving substitution in a 7 years, 7 months old boy with moderate ASD. PT derives its scientific attributes from Skinner's experimental analysis of behavior (Kubina, Morrison, & Lee, 2002). PT interventions are guided by five key principles: (a) teaching students guided by their current level, (b) emphasizing observable and measurable behavior, (c) using frequency or count over a recorded time, (d) graphing the behavior on a standard celeration chart (SCC), and (e) evaluating the data to make decisions (White & Neely, 2012). Within the context of PT, interest in the value of performing skills at high frequencies led to the paradigm of behavioral fluency and strategies and tactics for frequency building.

Haughton (1980) suggested certain benefits of the performance of a skill at high rates. In plain language, fluency refers to performance with speed and accuracy and is often described by words such as *smooth*, *rhythmic*, *effortless*, *fluid*, and *masterful* (Binder, 1996). When a skill is performed to a certain performance standard, also referred to as a frequency aim, it increases the likelihood of certain critical outcomes occurring. These critical outcomes include retention, endurance, stability, and application and are denoted by the acronym RESA (Binder, 1996). Retention refers to being able to perform a skill after a period without practice or opportunity for reinforcement, endurance refers to performance over extended durations, stability refers to performance in the presence of distracting stimuli, and application refers to the integration of component response classes into composite response classes. Binder (1996) further defines application as an integration of component response classes into composite ones. Training one or more component skills to fluency could lead to improvements in performance of such complex skills. Some examples from the PT literature include (a) fluent performance of most of the 12 component fine motor skills (reach, touch, point, grasp, place, release, push, pull, shake,

squeeze, tap, twist), resulting in an increased number of steps performed correctly in composite skill performances such as pulling up socks and shirt (Twarek, Cihon, & Eshleman, 2010); (b) building frequencies of the component skills of handwriting, directly improving the performance of the composite skill of essay writing (Kubina & Wolfe, 2005); (c) fluent performance in two component skills of hearing letter sounds, writing the corresponding letter, and segmenting words into component sounds, directly improving performance on the composite skill of spelling regular words (Kubina & Wolfe, 2005); and (d) fluency in the component skill of construction of simple sentences, increasing the performance on the composite skill of paragraph writing (Datchuk & Kubina, 2017).

Drawing upon these examples, it is possible to conceptualize the articulation of phonemes and syllables as components of the articulation of words. Training on these components could help with the development of word and phrase speech. The number of speech sounds, syllables, and their combinations to be trained may be large depending on the severity of SSDs in a person with ASD. It is important that the specific speech sounds whose correct articulation was taught are retained well without additional practice while newer targets are worked on. Thus, fluency outcomes are especially relevant while training articulation.

Hughes, Beverley, and Whitehead (2007) demonstrated an example of how frequency building can produce superior outcomes compared to conventional teaching. Hughes et al. (2007) conducted a 10-week program targeting the improvement of the frequency of reading words accurately with seven pupils whose reading performance was significantly below their same-age peers. The words were drawn from a list of high-frequency words that constitute over 80% of children's literature. Five pupils were assigned to the PT group, and two peers were assigned to the treatment-as-usual (TAU) group. The PT pupils underwent timed practice sessions aimed at frequency building, whereas the TAU pupils received only corrective feedback when they made mistakes while performing reading exercises. Four out of the five pupils in the PT program read words at twice the frequency at the end of the intervention compared to their performance on the first day. In comparison, there was little improvement in the frequency of words read correctly by TAU pupils. On achievement of frequency aims, the researchers tested for fluency outcomes. With only one exception, the PT pupils who achieved higher frequencies of reading also performed better in tests after a period of no practice, suggesting superior retention. In endurance, retention, and application tests, too, PT pupils read four to five times more words correctly compared to the TAU pupils. These outcomes suggest that if the articulation of phonemes, consonants, or syllables was targeted for performance to an appropriate frequency aim, fluent performance could improve the correct articulation of words.

Fabrizio et al. (2002) used PT and frequency building to address limited speech intelligibility in a 7.7-year-old boy with moderate ASD. The participant could mand using three- to four-word phrases, tact using one to two words, and engage in reciprocal conversations involving two to three turns. He would substitute "b" for "v" in the final position of words (e.g., saying "gabe" instead of "gave"). In Phase 1, he was trained to say the sound "v" in isolation during 10-s timed practice sessions. His performance improved from 43 correct responses per minute to a fluent frequency of 100 correct responses per minute with one session per day for a total of 8 days. In Phase 2, he was trained to read and say consonant-vowel-consonant sounds, with "v" and "b" endings interspersed in random order. With 1-min timed practice sessions, conducted one to three times a day, in 15 days, his performance improved from 22 correct responses and 3 incorrect responses per minute to 61 correct responses per minute. In Phase 3, "v" and "b" were present in all three positions of words (initial, middle, and final). Performance improved from 40 correct responses and 2 incorrect responses per minute to 100 correct responses and 2 incorrect responses per minute in 23 days, meeting the frequency aim. The median practice sessions were two per day. A quick calculation shows that remediation of the one targeted speech error took around 80 min of teaching over 46 days, demanding just 1 to 2 min per day.

The current study extended the methods in Fabrizio et al. (2002) and examined if, in conjunction with prompting strategies, PT can be used to improve the articulation of syllables in an older child with ASD. It also evaluated whether building the frequency of the correct articulation of syllables to a frequency aim could lead to improvements in the articulation of words using those syllables and whether other critical outcomes of fluency could be achieved.

Method

Participant

Kay was a 17-year-old girl with SSD and ASD diagnosis from a pediatric neurologist in Mumbai, India. She had been undergoing intensive behavioral interventions since age 12. With intensive mand training, she had acquired a repertoire of 30 word approximations to mand for preferred items or activities. The Early Echoics Skills Assessment (EESA; Esch, 2008) subtest measures a child's early vocal imitation repertoire through phonemes, words, phrases, and intonations typically acquired by children by 30 months of age. Kay scored 16½ out of a possible 25 in Group 1, comprised of simple and reduplicated syllables; 11 out of 30 in Group 2, comprised

of two-syllable combinations; 6 out of 30 in Group 3, which tests three-syllable combinations; ½ out of 10 in Group 4, which tests prosody and spoken phrases; and 0 in Group 5, which tests prosody in other contexts. One of the prerequisites for echoic responding is intact hearing, or the ability to engage in discriminated responding to auditory stimuli. Kay could engage in discriminatory responding to listener responding tasks involving auditory stimuli. For example, she could select a spoon, cup, or pen from a messy array of objects based on the spoken instruction of her therapist or caregivers. She could mand for preferred items and activities using word approximations and signs. She could label 30 objects using signs, point at the correct item from a messy array of six items given the name of the item to select, and match identical and non-identical items. She could fill in with word approximations for a few select words in rhymes and answer the question "What's your name?" Assessments conducted using the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, 2008) indicated a mand score of 7.5 out of a maximum possible 15, a tact score of 5.5 out of 15, an intraverbal score of 2 out of 10, a visual performance score of 10 out of 15, and a listener responding score of 7 out of 15. Her total score on the VB-MAPP milestones was 63. Kay could not count, identify, or label numbers.

In addition to the EESA, to identify the specific consonants she had difficulties with, an echoic assessment designed by the authors was conducted for all the consonant sounds. She could echo back only the "m" sound and "s" sound correctly when consonants were presented by the assessor. Next, an assessment using consonant-vowel (CV) sounds was carried out. A trained assessor presented opportunities to the participant to echo CV sounds such as "ka," "ke," "ki," "lo," and "fu." The participant's responses were transcribed by the assessor and a trained independent observer. It was found that there were no errors in echoing back CV sounds with "b," "m," "n," "p," "s," "v," "w," and "y." The participant could not articulate back CV sounds containing "d," "f," "h," "j," "l," "r," "x," and "z" correctly. With the consonants "c," "k," "g," "q," and "t," the articulation of the consonant had errors of substitution and omission and some correct responses mixed. The assessment results are presented in Table 1.

Kay would use signs in conjunction with word approximations such as "swi" for *swing* and "opah" for *open*. These were intelligible to familiar caregivers. A year before this study, she had undergone articulation training for two blends, "st" and "sp." The intervention with vocal imitation training, within stimulus prompts, extra stimulus prompts, and a sufficient response exemplar training instructional arrangement, involved a total of 6,850 trials over 125 training days (Aravamudhan & Awasthi, 2019). She successfully acquired articulation of 10 target words with "st" and 6 target words with "sp" in the initial position.

Setting, Materials, and Sessions

The interventions were carried out in a center providing intensive behavioral interventions based in applied behavior analysis (Baer, Wolf, & Risley, 1968) with a focus on verbal behavior (Skinner, 1957). The articulation training was delivered in one-to-one teaching sessions by a therapist with a master of science degree. She had 2 years' experience in delivering behavioral interventions to children with ASD under the supervision of both authors. Baseline assessments and articulation training were conducted in timed practice sessions, to be referred to as "sessions" hereafter. Each session was set to 15 or 30 s depending on the target, as described later in this article, in the Response Definition and Measurement section. During baseline, only one assessment session was conducted per day. There were 3 baseline measurements for the "thu" syllable, 8 measurements for the "fu" syllable, and 10 for the "cu" syllable. During intervention, the therapist completed two blocks of three sessions each, Monday to Friday, barring weekends, holidays, and the days when the participant or the therapist was absent. Thus, there were six sessions per day during intervention. In each block, between two sessions, there would be a brief break of approximately 20 s for the participant to consume an edible reinforcer or play with her iPad. The first and second authors trained the therapist on running the sessions and conducted treatment integrity checks.

Stimulus Preference Assessments

A multiple-stimulus without-replacement (Halvey & Rehfeldt, 2005) preference assessment was used to identify Kay's six most preferred stimuli. Five of these were edibles, and the sixth was her iPad. Only items that could be delivered at the table were considered in the preference assessments. Thereafter, each day, before the first session, the therapist presented access to these for 1 min (Carroll & Klatt, 2008). The edibles that Kay accepted and consumed or the iPad were then randomly used for the six sessions on that day.

Response Definition and Measurement

Based on the assessments described earlier, Kay's echoic repertoire was better with CV sounds than with stand-alone consonant sounds. Thus, CV sounds were targeted considering the common functional words in English and her native language, Tamil. Her mother and one of the study authors involved in developing her individual curriculum judged that she would benefit most, to start with, if the syllables "thu," "fu," and "cu" were targeted for correct responding. The targets used in the study were "thu" (as in *thump* or *Thursday*), "fu" (as in *fun* or *fur*), and "cu" (as in *cup* or *cuddle*). The errors sought to be addressed in this study were errors of

Table 1 Consonants Assessment Results While Echoing CV Sounds

Targets	Performance	Type of Errors in Baseline
"b," "m," "p," "n," "s," "v," "w," "y"	All corrects, no errors	
"d," "f," "h," "j," "l," "r," "z"	All errors, no corrects	Substitution: "d" with "th" or "k"
		Substitution: "j" with "k" or "th"
		Substitution: "l" with "n," "r" with "n"
		Omission: "h," "f," "x," "z"
"c," "g," "q," "t"	Mixed corrects and errors	Substitution: "t" with "th"
		Substitution: "c" with "th"
		Substitution: "g" with "c"
		Substitution: "q" with "c"

substitution ("thu" for "cu" and vice versa) and omission (omission of the "f" sound). Although just these three syllables would not be adequate for word training, it was hypothesized that training with one syllable could also improve the articulation of words that had the same consonant. Table 2 presents a set of such words used in the postintervention assessment of application. The response was defined as correct when the participant echoed the therapist's model with point-to-point correspondence within 5 s. This included responses in trials in which lip-tongue-teeth prompts were provided. When the sound echoed by the participant did not match the instructor's model—for example, saying "thu" or "su" when the therapist presented "cu"—it was recorded as incorrect. The "thu" sessions were set to 30 s each, except for the last 3 days of the intervention, which were set at 15 s due to a shorter duration of her attendance at the center. With the "fu" syllable, sessions were 30 s each throughout the intervention. Because incorrects were high in baseline conditions, it was decided to train the "cu" sound with 15-s timings for better cooperation from the participant and to reduce the number of errors; all the "cu" sessions were 15 s.

Researchers used a count per minute to measure the response. The number of correct and incorrect responses in each session was divided by the session duration in seconds and multiplied by 60 to arrive at the frequency of correct responses per minute and the frequency of incorrect responses per minute, respectively. For example, in a timed session of 30 s, six correct responses and two incorrect responses would translate to 12 corrects per minute and 4 incorrects per minute. The frequencies from the fourth session of each day were plotted on an SCC, as it was felt that they would likely be the most representative performance of the day compared to those of the first or the last session.

Interobserver Agreement

A trained second observer checked the number of correct and incorrect responses for each session, using video records of 48% of the baseline sessions and 20% of all intervention sessions. These were compared with the corrects recorded by the therapist. For each session, interobserver agreement (IOA) was calculated as the lower of the two counts divided by the higher of the two counts, multiplied by 100.

The mean IOA for the study was 87% (range 83%–100%). Three sessions in the entire study had very low IOAs (40%, 45%, and 55%), and data for these sessions were discarded. In these three instances, the therapist did not discriminate between the correct and incorrect responses emitted by the child. Additional training was provided until the therapist was able to demonstrate accurate discrimination before continuing with the intervention.

Frequency Aim and Mastery Criteria

The authors of the current study conducted six 1-min trials to determine the criteria for fluent echoic responding with competent performers (i.e., persons with no articulation

Table 2 List of Words Assessed With Component Consonants

Component	Word Assessed
"th + vowel"	thumb, thupu (wrong), thatha (grandpa), thunni (water), thumbi (little brother), thumana (neighbor's name), thuva (pan), thunay (neighbor's name), thunvi (neighbor's name), thulai (head)
"f + vowel"	fun, fuss, fan, fast, fit, fine, few, fuse, foam, fone (phone)
"c + vowel"	come, cup, coffee, caay (vegetable), cavi (uncle's name), cuthu (shout), cunnu (eye), cuthi (knife), caacaa (crow), cumbu (stick)

Note: The meaning or functionality of the words in the participant's native Tamil language is presented in parentheses.

difficulties). It was found that a frequency of 90 per minute was achievable. However, in additional tests, where the competent performers were instructed to randomly make 5 to 10 mistakes in echoing the target sound back, it was found that the therapist's ability to spot incorrects that occurred randomly was compromised when the pace of responding was at 90 per minute. At a pace of 60–70 echoic responses per minute, the therapist was able to accurately identify the incorrect responses. Further, when there were less than 4 incorrects per minute, it was possible to record higher frequencies of up to 100 per minute. Considering the need to spot errors as they occurred and provide feedback, for this study and for each of the target behaviors, the frequency aim for corrects was set at 60 per minute and the frequency aim for incorrects at 4 per minute. Further, the authors decided to test whether these frequency aims were appropriate by testing for fluency outcomes if these aims were to be reached.

Experimental Design

A delayed multiple-baseline design across behaviors was used. In a delayed multiple baseline design, an initial baseline and intervention are started, and thereafter, subsequent baselines and interventions are added in a staggered or delayed fashion (Cooper, Heron, & Heward, 2019). This design is used when continuous baseline measurements are not essential or when they are unethical. A functional relation can be demonstrated in delayed multiple-baseline studies if, during intervention in one tier, sufficient baseline measurements are also taken in the other tier(s). In this study, the authors ensured that adequate baseline measurements were taken in subsequent tiers when a previous tier was in the intervention phase with significant improvements in that tier.

Treatment Integrity

Treatment integrity was measured by the first author to assess whether the therapist implemented the intervention as planned. Researchers used a checklist of all the key intervention steps for scoring and determined whether the therapist implemented the replicable steps as designed (Carroll & Klatt, 2008; Krohn, Skinner, Fuller, & Greer, 2012; MacDonald & Ahearn, 2015). The first author conducted in situ observations for 40% of the sessions in the first week of intervention and 20% of the sessions in subsequent weeks for each target sound. Using a higher percentage of sessions in the first week was to ensure that any errors in running the sessions were identified early and corrective feedback given to the therapist. Three therapist behaviors were observed for each trial in each session: (a) whether the discriminative stimulus was clear, (2) whether predetermined prompts were used correctly for the subsequent sessions in the event of an incorrect response, and (3) whether the therapist consequated correctly. Consequating correctly meant that, if the response was correct, the therapist would move on to the next presentation of the discriminative stimulus, or briefly nod her head. If the response was incorrect, she would shake her head left to right and back to indicate "no." One point was awarded for each correct behavior demonstrated by the therapist in each trial. A score of three was possible for each trial. In some trials, where a prompt was not required, a point was awarded anyway for the parameter to keep the calculations simple. Treatment integrity was then calculated as the actual score achieved in the session divided by the maximum possible score for the session and multiplied by 100. The mean treatment integrity score for the study was 93% (range 82%–100%).

Social Acceptability of the Dependent Variable

The participant's mother actively participated in target selection. A structured questionnaire determined that, with respect to Kay, articulation and speech intelligibility were among her mother's top three concerns. At the end of the intervention, Kay's mother rated her satisfaction with the outcome in terms of the clarity of the three syllables and the clarity of the specific words emitted during assessment postintervention. A 5-point Likert scale was used, with 1 labeled as *very dissatisfied* and 5 as *very satisfied*. She gave a rating of 5 for all the syllables and words tested. She was also asked if, based on the study outcome and the procedures used, she would recommend that this intervention be continued with other syllables and words. She responded to this question with a "definitely yes."

Social Validity of the Independent Variable

The child's mother and the therapist were given a description of the procedures in simple everyday language. The parent confirmed in writing that she was comfortable with the procedures as explained to her and seen on demo videos. It is important to test the acceptability of the procedures with the personnel involved in the implementation as well. The therapist received extensive training from the first author prior to commencement of the study. After running timed practice sessions for 2 days with guided supervision, a questionnaire with three questions was administered. The therapist could respond using a scale of 1 to 5, with 1 at *completely disagree* and 5 at *completely agree*. She confirmed that, in her opinion, (a) the treatment would be beneficial to the student, (b) she would be comfortable running the intervention, and (c) the methods did not involve any undue risks to the child or herself.

Procedures

Baseline In baseline conditions, the therapist set a timer to a predetermined timing length, presented the target sound, and waited for a maximum of 5 s for the participant's response. The therapist started the timer after the participant emitted the first response. As soon as an audible response was heard, the therapist marked a check for a correct response or a dash for an incorrect response on a data sheet and simultaneously presented the target sound for the next trial. She proceeded in this fashion until the timer went off, signaling the end of the session. At the end of the session, the therapist provided a small quantity of an edible, such as popcorn, or access to an iPad for approximately 20 s. This was done to reinforce the participant's cooperation with the procedure and was not contingent on the corrects or lower incorrects. In baseline conditions, the therapist did not provide any feedback or prompts. The charting of each session's data was done at the end of each session. The number of trials per session ranged from 6 to 12 in baseline conditions depending on the pace at which the participant emitted the responses. No effort was made to speed up the responses or provide feedback on any incorrect responses. Three baseline assessments were taken for the "thu" syllable. For the "fu" and "cu" syllables, after two to three assessments on successive days in the beginning, additional assessments were carried out only once a week, up to the commencement of the intervention on that target. This was to ensure that adequate baseline measures were available while minimizing the possibility of practice effects. Further, it would have been unethical to carry out daily baseline measurements on a skill with many incorrect responses. Though the baseline measurements were not concurrent, following a delayed multiple-baseline design, care was taken to ensure that adequate baseline assessments were available for "fu" and "cu" when the independent variable was in effect in the preceding tier(s).

Frequency building with lip-tongue-teeth position prompts, feedback, and priming Researchers conducted brief timed practice sessions with prompts and feedback given within sessions. In addition, at the end of a session, the therapist delivered a reinforcer identified from the brief preference assessment of the day along with social praise statements such as "you did so well" and "that was fabulous." Within the sessions, the therapist provided lip-tongue-teeth position prompts. These prompts were developed by observing the lip-tongue-teeth positions adopted by competent speakers to emit the sound. While teaching the "thu" syllable, the therapist modeled the tongue sticking out about a millimeter with the upper and lower rows of teeth pressing slightly on either side, as in Fig. 1. For the "fu" syllable, the therapist used a model prompt with the lower lip slightly pulled back, by a millimeter, with the upper row of teeth pressed slightly over the lower lip, and then released the lower lip with an expulsion of air and the production of the "fu" sound (Fig. 2). For the "cu" syllable, Kay was trained to respond first to a physical lip-tongue-teeth position prompt and later to a model prompt over the course of 20 untimed trials the day prior to the commencement of intervention. As Kay substituted the "thu" sound frequently, the therapist held Kay's wrist gently, with the index finger alone stretched out, and guided Kay to touch the tip of her tongue with the index finger to push it back slightly by about a millimeter (Fig. 3). She then presented the "cu" sound for Kay to emit an echoic response. After three trials, the therapist switched to a model prompt. She used her own index finger to touch the tip of her tongue and push it back slightly, and Kay would imitate the tongue-retraction procedure. Once Kay responded to the model lip-tongue-teeth position prompts in five consecutive trials, the therapist started using the model prompt in the intervention phase for "cu." Once the

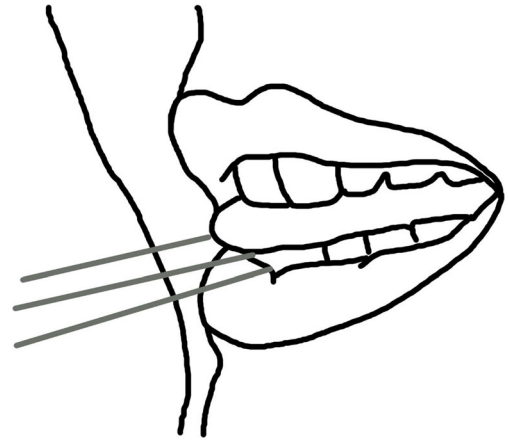

Fig. 1 Model prompt, lip-tongue-teeth position, for the "thu" syllable. Adapted from "The 'Rude' Sound–Tongue Out," by PLD Organisation Pty. Ltd., 2019, https://pld-literacy.org/literacy-strategies-for-th-and-f-sounds/. Reprinted with permission

Fig. 2 Model prompt, lip-tongue-teeth position, for the "fu" syllable. Adapted from "Speech Sounds f. How to Elicit the /f/ Sound in Young Children," by D. Newman, 2019a, http://www.speechlanguage-resources.com/speech-sounds-f.html. Reprinted with permission

Fig. 3 Self-prompt with index finger to retract the tongue for the "cu" syllable. Sanjeevi, B.G., personal communication, January 2, 2020). Reprinted with permission.

participant's tongue was slightly retracted (illustrated in Fig. 4), the therapist presented the "cu" syllable and waited for the participant's echoic response.

Within a session, on the first 3 days of the intervention on a syllable, prompts were provided for the first three trials. If an incorrect response occurred twice in a session, after the second incorrect response, the therapist shook her head left to right and back, indicating a "no." Prompts were reinstated after the second incorrect response for three successive trials or up to the end of the session, whichever occurred earlier. From the fourth day of intervention on any syllable, only if an incorrect response occurred twice in a session did the therapist shake her head left to right to indicate "no" and reinstate prompts for three subsequent trials or up to the end of the session (indicated by the timer going off), whichever occurred earlier. The prompts were withdrawn again and not reinstated in the session unless two more incorrect responses were emitted. When the intervention began on a target syllable, feedback for correct responses was given in the first 3 days on a variable ratio schedule of two. The therapist would nod her head to indicate "yes" when the participant emitted a correct echoic response, on an average, for every second correct response within a session, and then present the next discriminative stimulus. After the third day, a correct response from the participant resulted in the therapist presenting the next discriminative stimulus without any feedback. A reinforcer was delivered at the end of each session to reinforce the participant's cooperation and participation throughout the session.

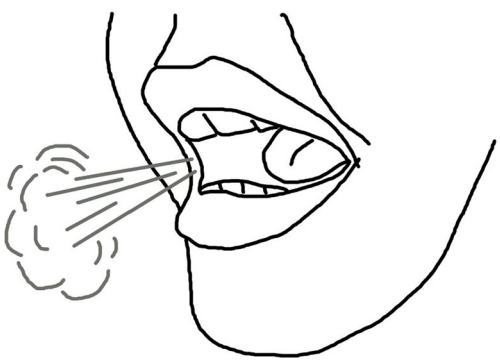

Fig. 4 Model prompt, lip-tongue-teeth position, for the "cu" syllable. Adapted from "Speech Sounds k. How to Elicit the /k/ Sound in Young Children," by D. Newman, 2019b, http://www.speechlanguage-resources.com/speech-sounds-k.html. Reprinted with permission

Accuracy building Even if the corrects improved, if the visual analysis of the SCC indicated that the incorrects did not show a declining trend, an accuracy-building phase was initiated. In this phase, the therapist initiated prompts after every incorrect response instead of after the second occurrence of an incorrect response within a session. The prompts were withdrawn after three correct prompted responses in each instance unless the session ended (when the timer went off). The priority in such a case was to minimize the incorrects as rapidly as possible, even if it meant a reduction in corrects and the total number of practice opportunities in the short term. This part of the procedure was needed only with two of the three targets, "fu" and "cu."

Priming For the third target, "cu," on account of a high frequency of substitution of "thu" for the "cu" sound, a priming procedure (Cihon et al., 2017) was used before each session in the first 10 days. A timer was not used in a priming session. The therapist would present the target sound with the predefined prompt and provide feedback by saying "correct" for a correct response and "try again" for an incorrect response. Once the participant emitted a minimum of three consecutive correct responses, the actual timed session was conducted. The objective of priming was to make the expected response clearly discriminable and get correct responding in momentum before the actual timed practice session began.

RESA assessments In the current study, researchers assessed for fluency by testing for RESA. Retention was tested for all the syllables 3 weeks after intervention on the last syllable, "cu," ended. There was no practice in the intervening period.

Two endurance assessments were done by measuring the dependent variable for three times the timing length used during practice sessions for each target after the intervention phase. Stability was tested by conducting two assessments for each syllable in noisy environments and with the participant's favorite music playing in the background. The stability assessment durations were 30 s, 15 s, and 15 s for the "thu," "fu," and "cu" syllables, respectively.

Application was tested by measuring accuracy in echoic assessments (untimed) of two- to three-syllable words that used the targeted consonant sounds in a word (Table 2). The

words were a mix of English words and those of the participant's native language, Tamil. The word assessments were conducted once during baseline, on the fifth intervention day, and 1 week after the conclusion of intervention on each targeted syllable. The assessments were untimed, as the participant displayed signs of distress when timed word assessments were attempted. Instead, a discrete-trial training (Leaf & McEachin, 1999) format was used for application assessments. The assessor recorded the percentage of words in which the targeted CV sound was articulated correctly, as well as the percentage of whole words that were articulated correctly.

Chart display and analytics Researchers used the conventions for displaying data on an SCC based on White and Neely (2012). In addition to dots for corrects and x's for incorrects, horizontal dashes called "record floors" represented the lowest nonzero frequency that could occur during that period. For example, for a 15-s session, the record floor would be plotted at a frequency of four per minute because if the behavior happened one time in 15 s, when converted to a minute, the lowest nonzero frequency would be four per minute; a 30-s session's record floor would be placed at two per minute. It is possible that, in a session, a correct or incorrect response may not have occurred even once. The corrects or the incorrects in such instances were plotted slightly below the record floor, at the 80% mark of the record floor value. For example, if, in a 15-s session, there were no correct responses, the record floor would be plotted at 4 and the dot would be plotted at 3.2. If the sessions were conducted on consecutive days, the dots and x's were connected by lines representing a data path. Such connecting lines were not drawn when there were intervening days with no timed practice sessions. A horizontal dashed line in the upper part of each chart segment represented the frequency aim for correct responding. Vertical lines represented a phase change.

Although improvements in skill performances are normally described by percentage increases, precision teachers use celeration values, frequency multipliers, and celeration multipliers (Datchuk & Kubina, 2011). Celeration is the rate of change of response frequency over a unit of time called the celeration period. Accelerations are prefixed by x and decelerations by ÷. When daily per-minute charts are used, the celeration period is 1 week. An increase in corrects from 20 to 40 per minute in 1 week would be represented by a celeration of x2.0 per week, and a decrease in incorrects from 10 to 5 per minute would be denoted by a celeration of ÷2 per week. The correct and incorrect data for the fourth session of each day were also entered into a web application SCC, CentralReach's PrecisionX (CentralReach, 2019). The celeration per week for corrects and incorrects in each condition was calculated by the software.

To capture the immediate effect of the intervention and to check whether such an effect continued well into the intervention, Datchuk and Kubina (2011) suggest the use of frequency multipliers and celeration multipliers. A frequency multiplier was used to quantify the change between the end of one condition and introduction of the next. For example, if the last correct in baseline was four per minute and the first correct in intervention was six per minute, the frequency multiplier would be x1.5, denoting the immediate effect of introduction of the intervention.

Celeration multipliers, however, indicate whether improvements or reductions indicated by frequency multipliers were continued into the next condition. When the celerations in the two conditions were in opposite directions, the values were multiplied and prefixed with the sign, x or ÷, that was the same as the one that applied to the second condition. A celeration C1 of ÷2 in baseline and a celeration C2 in intervention of x3 would imply an upturn and a celeration multiplier value of x6. If C1 were x1.3 and C2 were ÷3.0, as may happen with incorrects or behaviors targeted for decrease, it would be a downturn with a celeration multiplier value of ÷3.9. If the celerations were in the same direction, C2 would be divided by C1 and the resulting value prefixed with the same sign as C1 or C2. If C1 were x1.5 and if C2 were x2.5, it would denote an upturn with a celeration multiplier value of x1.7. In the current study, in all these calculations, if one of the frequencies were below the record floor, implying zero occurrences in an observation period, instead of using a 0 in the numerator or denominator, 80% of the floor value was used for the frequency of the behavior. For example, in a 30-s session, the record floor is two per minute. An instance of zero occurrences, in such a session, was plotted at a frequency of 1.6 per minute, and the frequency and celeration multipliers were calculated based on 1.6 per minute.

Results

Corrects, Incorrects and Celerations

The results of the study are presented in Fig. 5. Table 3 presents the celeration values for each behavior in each condition, the frequency multipliers, and the celeration multipliers. The frequency aim for all three behaviors was set at 60 corrects per minute and 0-4 incorrects per minute. For the first target behavior, echoic responding to the syllable "thu," in the baseline condition, the corrects averaged 7.6 per minute with a celeration value of ÷2.8 per week, and incorrects averaged 10.8 per minute with a celeration value of x1.43 per week. The errors with echoing back "thu" were entirely substitution errors—that is, substitution of the "th" sound with the "c" sound. The corrects for "fu" were below the record floor, and incorrects averaged 17.3 per minute with a celeration of x1.31 per week. The errors with "fu"

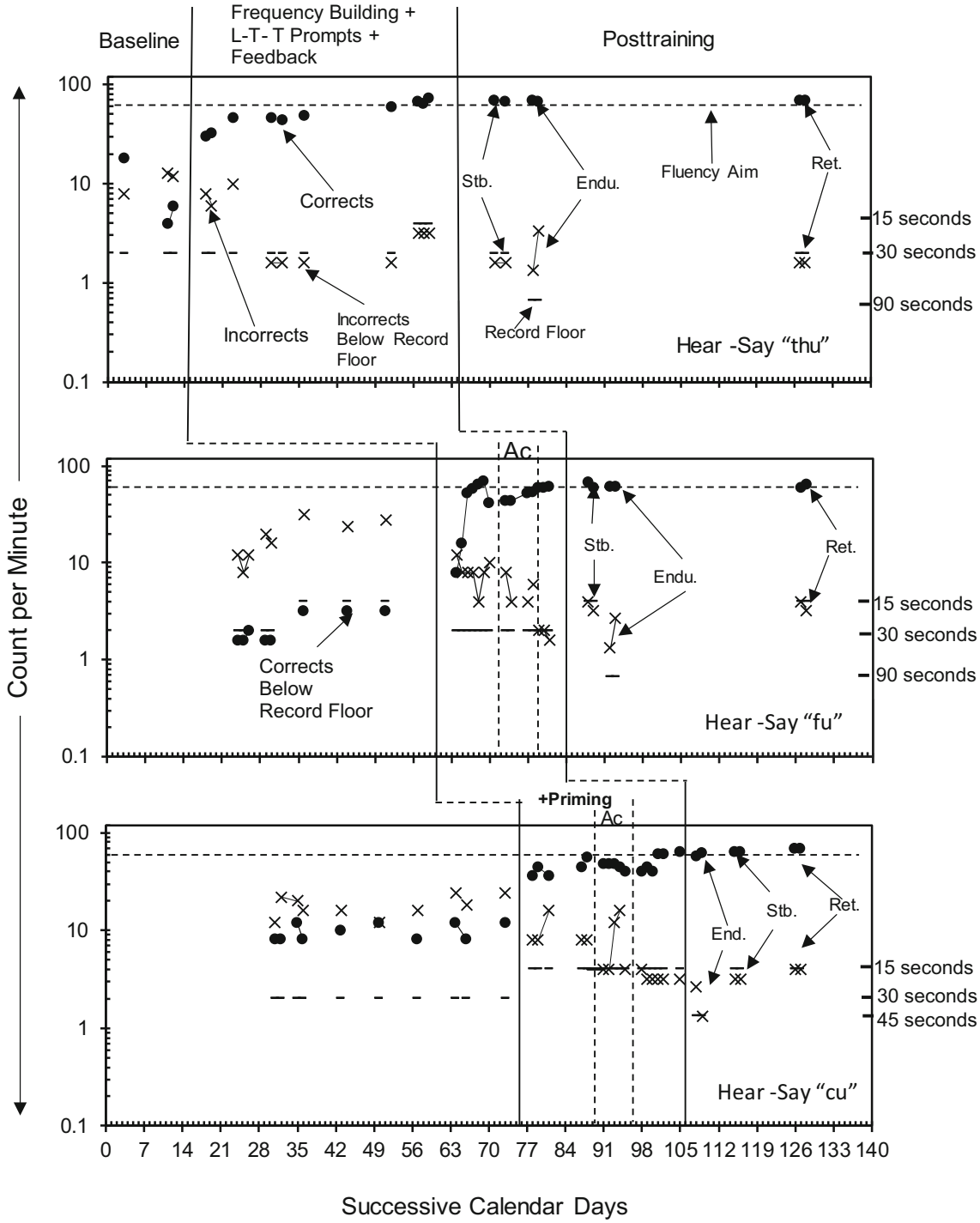

Fig. 5 A delayed multiple-baseline study demonstrating the effectiveness of prompting, frequency building, feedback, and priming with precision teaching to teach speech articulation of syllables; Stb. = stability; Endu. = endurance; Ret. = retention; Ac. = accuracy; L-T-T = lips-tongue-teeth. These are celeration chart segments. Standard celeration charts are available at http://www.behaviorresearchcompany.com

involved the omission of the sound "f." With "cu," the corrects averaged 19.2 per minute with a celeration of x1.03 per week, and the incorrects averaged 35 per minute with a celeration value of x1.05 per week. The errors with the "cu" sound, too, were errors of substitution involving substitution of the "th" sound for "c" sound.

Once the intervention started for "thu," corrects increased to 60 per minute on the seventh training day and to an average of 68 per minute in the following 3 days, meeting the frequency aim for corrects. The frequency multipliers that capture the immediate effect of the introduction of intervention were x5.0 for corrects and ÷1.5 for incorrects. The intervention

Table 3 Celeration Values, Frequency Multipliers, and Celeration Multipliers

	Celeration per Week				Multipliers			
	Baseline		Intervention		Frequency Multiplier		Celeration Multiplier	
	Corrects	Incorrects	Corrects	Incorrects	Corrects	Incorrects	Corrects	Incorrects
"thu"	÷2.81	x1.43	x1.13	÷1.22	x5.0	÷1.5	x3.18	÷1.74
"fu"	x1.19	x1.31	x1.47	÷1.99	x2.5	÷2.5	x1.75	÷2.60
"cu"	x1.03	x1.05	x1.09	÷1.41	x3.0	÷3.0	x1.12	÷1.48

celeration value for corrects was x1.13 per week, whereas incorrects decelerated by ÷1.22 per week. The celeration multipliers that indicate whether the immediate gains reflected by the frequency multiplier were sustained through the intervention were x3.16 and ÷1.75 for corrects and incorrects, respectively.

With the "fu" syllable, when the intervention started, the corrects improved to 8 per minute and 16 per minute during the first 2 days. Thereafter, although the corrects improved to an average of 57 per minute, the incorrects were above the acceptable frequency of 4 per minute, at 8 per minute on the third day and 10 per minute on the fourth day. In the next 4 days, in the accuracy-building phase, the incorrects dropped to below 4 per minute and corrects were at an average of 48 per minute. Following the accuracy-building phase, with an additional 3 days, the corrects improved to the frequency aim of 60 per minute, with incorrects within the 4 per minute limit. The frequency multiplier value between intervention and baseline was x2.5 for corrects and ÷2.5 for incorrects. During intervention, the celeration value for corrects was x1.47 per week and for incorrects was ÷1.99 per week. The celeration multiplier from baseline to intervention was x1.23 for corrects and ÷2.61 for incorrects.

With the "cu" syllable, corrects improved to a frequency of 48 per minute in 6 days, but with incorrects ranging from 4 per minute to 8 per minute. The corrects did not improve to the frequency aim of 60 per minute with continued practice, even over the next 5 days. The incorrects went up to 12 and 16 per minute on the eighth and ninth days of the intervention, respectively. With the introduction of the accuracy-building phase for the next 4 days, the incorrects dropped to 4 per minute or below the record floor. Thereafter, over the next 3 days, the frequency aim for corrects of 60 per minute was achieved, with incorrects below the record floor on Days 14 and 15. The frequency multipliers were x3.0 and ÷3.0 for corrects and incorrects, respectively. During intervention, the celeration for corrects was x1.09 per week and incorrects ÷1.41 per week. The celeration multiplier from baseline to intervention for corrects was x1.12 (upturn), and it was ÷1.48 (downturn) for incorrects.

When the intervention was underway on "thu," there were seven baseline measurements on "fu" and six baseline measurements in the "cu" tier. Similarly, during the intervention phase on "fu," there were three measurements under baseline conditions in the "cu" tier. While the intervention was underway in Tier 1 or Tier 2, in the subsequent tiers, there was no improvement in responding under baseline conditions, thus ruling out the effect of any extraneous variable on the dependent variable. Thus, a functional relation between the dependent and independent variables can be inferred.

The "thu" syllable was taught over 60 sessions of 30 s each across 10 days of training. The total time invested was thus 30 min. The "fu" syllable was taught over 84 sessions of 30 s each with a total investment of 42 min across 18 days of training. The improvement in the "cu" syllable was achieved with 96 sessions of 15 s each with a total training time of 24 min across 16 days of training. The total intervention time across the three syllables in this study was thus 96 min over 44 days of training.

Retention, Endurance, Stability, and Application

Retention Assessments were conducted at 8 weeks, 7 weeks, and 3 weeks postintervention, respectively, for "thu," "fu," and "cu," with no practice opportunities between the last day of the intervention and the retention assessments. These demonstrated retention of performance at frequency-aim levels for all three target behaviors. Kay echoed the "thu" syllable at 70 corrects per minute with no incorrects in both the assessments. She echoed the "fu" syllable at 60 corrects per minute and 64 corrects per minute with incorrects at 4 per minute in the first assessment and below the record floor in the second. The corrects for the "cu" syllable had improved further to 68 per minute in both the timed assessments, with incorrects below the record floor.

Endurance Endurance assessments were conducted with 90-s timings for the "thu" and "fu" syllables and with 45-s timings for the "cu" syllable. With the "thu" syllable, in the first 90-s assessment, Kay produced 104 correct responses and 2 incorrects, which translated to 69 correct per minute and 1 incorrect per minute. In the second 90-s endurance assessment, the frequency of corrects was 67 per minute and incorrects 3 per minute. With the "fu" syllable, the corrects were at 61 per

minute and 62 per minute with the frequency of incorrect responses at 1 and 3 per minute, respectively. For the "cu" syllable, the corrects were at 57 and 61 per minute with incorrects of 3 and 1 per minute, respectively.

Stability Two assessments for each target behavior were conducted in a noisy setting, where, in a 4.6 m × 3.0 m room, four other sessions with therapists emitting vocal instructions for various tasks were going on and music was playing in the background. The corrects for "thu" were at 70 per minute and 68 per minute, with incorrects below the record floor. The corresponding corrects for "fu" were at 68 per minute and 60 per minute, with incorrects at 4 per minute in one assessment and below the record floor in the other. With the "cu" syllable, the corrects were 64 and 60 per minute, with incorrects below the record floor in both assessments.

Application The results of application checks are presented in Fig. 6. During application checks, with "th + vowel," "f + vowel," and "c + vowel" as components, word articulation as a composite skill was assessed. The percentage of words in which the "th + vowel" component was correctly articulated improved from 30% in baseline, to 90% on the fifth day of the intervention, to 100% correct postintervention without direct training. In the same trials in which the percentage of correct responses with "th + vowel" component was measured, the correct responses with the whole words were also recorded. The percentage corrects for the composite whole words were 20%, 90% and 80% respectively in baseline, fifth day of intervention and postintervention. This implies that, post intervention, only 2 of the 10 words were not articulated correctly while the targeted component sound of "th + vowel" was articulated correctly in all the 10 words tested. For the "f + vowel" word targets, component syllables were correctly articulated in 0%, 60%, and 100% in baseline, on the fifth day of the intervention, and postintervention, respectively. The corresponding accuracy levels for word articulations with the "f + vowel" component syllable were 0%, 60%, and 90%. With "c + vowel," the component syllable was echoed accurately in 10%, 40%, and 60% of the words during baseline, the fifth day of the intervention, and postintervention, respectively. At a composite-word level, the corrects were 0%, 20%, and 60%,

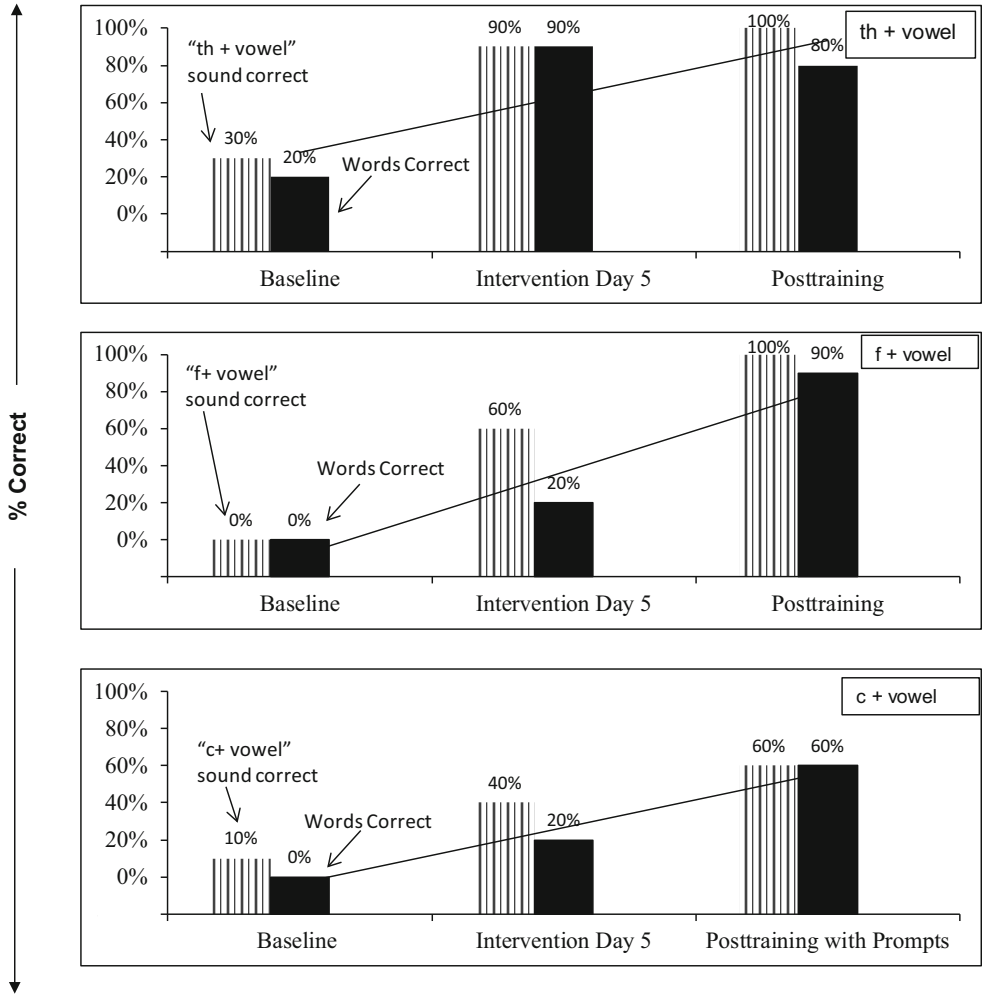

Fig. 6 Assessment of word articulation and CV component articulation during baseline, intervention, and posttraining for Kay

respectively. The substitution of "c" with "th" occurred when tested at a word level.

Discussion

From zero to low corrects and high incorrects in baseline conditions, with intervention, echoic responding to all three targeted syllables reached the frequency aims. Further, with two targets, namely "thu" and "cu," substitution errors were remedied, and with the "fu" sound, the omission error was remedied. The findings suggest that the intervention package can be effective, even for older children with ASD, in remedying speech sound errors that involve omission or substitution.

In the Fabrizio et al. (2002) study, the participant could use three- to four-word phrases and had only one specific speech error. In contrast, the participant in the current study had only a repertoire of 30 word approximations that were intelligible only to her parents, therapists, and caregivers. She emitted numerous errors in articulating syllables with consonant sounds and had profound difficulties with articulating words that involved chains of syllables. The intervention was effective in remedying speech errors with all three targeted syllables, suggesting that even older children with ASD and profound SSDs could benefit from targeted behavioral interventions to improve their speech intelligibility. The results further suggest that correct articulation of syllables can be trained to fluent levels with possibilities for additional training on word articulation and functional speech. The Fabrizio et al. (2002) study involved frequency building with only vocal imitation training, whereas the current study required the use of lip-tongue-teeth prompts, priming, and feedback as additional components.

It would be beyond the scope of competence of the authors to delve into the components of speech production addressed and the participant characteristics that facilitated training of the production of targeted syllables to success. However, it can be surmised that certain lip-tongue-teeth positions previously not in the participant's repertoire were acquired and played an important role in occasioning correct echoic responses. In addition, PT as a measurement system offered significant advantages. The emphasis on frequency as a dependent measure afforded a larger number of practice opportunities within short durations, as short as 15–30 s. Real-time visual analysis of the SCC helped ascertain progress toward the frequency aim and make decisions to modify the intervention when required. When the corrects showed an immediate increase with the introduction of intervention and the trend continued into the intervention phase, it helped the researchers decide to continue with the intervention without any modifications. When the incorrects increased or did not show a decreasing trend toward acceptable levels, it helped the researchers decide to introduce an accuracy-building phase. With the third target, "cu," the decision to introduce priming as an additional component of the treatment could be taken when the frequency of corrects was not improving in conjunction with the incorrects not declining.

Frequency building to predetermined aims resulted in the achievement of fluency, as reflected in the critical outcomes; RESA was achieved with all three targets. This finding lends support to findings from prior studies, such as Twarek et al. (2010), Cihon et al. (2017), Fabrizio et al. (2002), Hughes et al. (2007), and Kubina and Wolfe (2005). All these studies have also been successful in demonstrating improvement in composite skill performance of which the trained skills were components. Correct articulation in this study transferred to 20 of the two- to three-syllable words tested with "th + vowel" and "f + vowel" sounds, suggesting that the training in component sound production can facilitate word production without direct training on the latter. With the "cu" syllable, performance at the composite level of words reached only 60% correct. It was observed that substitution of "thu" for "cu" continued to occur, though at lower levels compared to baseline, at the word level. This was still a significant improvement from the baseline level of 0% accuracy and 20% accuracy on the fifth day of intervention when application checks were performed. These findings suggest that phoneme production and syllable production as components can be targeted using prompts and PT for word speech. These can be an important part of individualized education plans, prioritized along with other targets in other domains such as joint attention, mands, tacts, intraverbals, math, and reading.

An earlier study by Aravamudhan and Awasthi (2019) with the same participant, Kay, involved the use of vocal imitation training with prompts and sufficient response exemplar training to teach the correct articulation of blends. The articulation of words with "st" in the initial position was trained over 299 sessions and "sp" in the initial position over 71 sessions. Mastery in word articulation with these blends in the initial position, defined as at least 8 out of 10 words articulated correctly in probes, was achieved with an approximate training time of 1,480 min (approximately 4 min per session) or nearly 25 hr. In the current study, direct training on the component syllables with a total training time of just 96 min, or 1.6 hr, resulted in similar gains in articulation of words with these syllables. The efficiency gain with PT procedures alone offers a substantial incentive for further research.

Although the prevalence of speech errors in this population is high, several questions remain unanswered. For example, what are the academic and social outcomes for children from this population who have profound speech errors? Cleland et al. (2010) state that articulation distortions occur at a significantly higher rate in the speech of children and adults with ASD and that this adds to their social and communication barriers. However, there are hardly any studies that capture the magnitude of such barriers. Can articulation training that

remedies such speech errors result in significant improvement in the social and communication outcomes for such children? Many well-controlled studies that address teaching verbal behaviors, such as mands, tacts, intraverbals, initiating interactions, responding to other's initiations, taking turns in conversation, and other skills that improve conversation, have been published over the last three decades. However, there is very little research on articulation disorders that affect speech intelligibility and outcomes in social and communication domains in the ASD population (Aravamudhan & Awasthi, 2019). The lack of such studies should not limit research in the direction of improving articulation and remedying SSDs in this population. If anything, many more carefully controlled studies are required.

Despite the positive gains made by the participant, the current study has several limitations. First, with only one participant, the generality of the findings is limited. Additional studies are required with more participants with ASD across younger and older children. When remedying substitution errors (e.g., emitting "thu" when "cu" is required), additional discrimination assessments and training may be necessary. Fabrizio et al. (2002) observed the participant substituting "b" for "v" while pronouncing words. In the third phase, the participant was trained to articulate words with "v" randomly interspersed among words with "b" within each timed practice session. In the current study, although training was given to the participant to fluently echo "thu" and "cu" in separate sessions, it did not target fluent responding of "thu" and "cu" with the two discriminative stimuli interspersed randomly within timed sessions. Future studies could examine the amelioration of substitution errors by randomly interspersing them within each timed practice session. If discriminated responding reaches fluent levels, it is possible that responding can reach fluent levels for each sound independently with better performance when assessed with words. Further use of the words by the participant in natural speech contexts has not been studied, and this reduces the social significance of the study somewhat.

When performances at the composite-word level were assessed, only short words with two to three syllables were taken up. Future studies could examine the accuracy of echoic responding with longer words. Further, training on only three syllables limited the number of functional words for which correct articulation could be acquired. Additionally, in this study, only the accuracy of responding with words at a composite level was assessed. At a word level, Kay could only echo the selected words in a discrete-trial training format of instruction. Binder (1996) discusses the option of starting with short intervals such as 10 s, called sprints, to achieve frequency aims and then increasing the intervals to 30 s or longer as appropriate. Kay could have benefitted from such a shaping exercise, building from shorter to longer sprints, for words with the component syllables she was trained on. This, however, was not undertaken as part of this study due to time constraints and remains a limitation.

In summary, PT is a promising line of treatment with lip-tongue-teeth position prompts and priming components to remedy SSDs in children with ASD and merits many further, carefully controlled experiments. The specific prompts that are effective in promoting sound production of other phonemes, syllables, blends, and diagraphs can themselves be a subject for several studies.

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Compliance with Ethical Standards

Conflict of interest The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Ethical approval All procedures performed in this study involving a human participant were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from the parents of the child with ASD who participated in this study.

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