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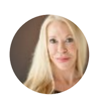

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Article

Treating Speech Subsystems in Childhood Apraxia of Speech With Tactual Input: The PROMPT Approach

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Purpose: Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT; Hayden, 2004; Hayden, Eigen, Walker, & Olsen, 2010)—a treatment approach for the improvement of speech sound disorders in children—uses tactile-kinesthetic-proprioceptive (TKP) cues to support and shape movements of the oral articulators. No research to date has systematically examined the efficacy of PROMPT for children with childhood apraxia of speech (CAS).
Method: Four children (ages 3;6 [years;months] to 4;8), all meeting the American Speech-Language-Hearing Association (2007) criteria for CAS, were treated using PROMPT. All children received 8 weeks of 2 × per week treatment, including at least 4 weeks of full PROMPT treatment that included TKP cues. During the first 4 weeks, 2 of the 4 children received treatment that included all PROMPT components except TKP cues. This design permitted both between-subjects and within-subjects comparisons to evaluate the effect of TKP cues. Gains in treatment were measured by standardized tests and by criterion-referenced measures based on the production of untreated probe words, reflecting change in speech movements and auditory perceptual accuracy.
Results: All 4 children made significant gains during treatment, but measures of motor speech control and untreated word probes provided evidence for more gain when TKP cues were included.
Conclusion: PROMPT as a whole appears to be effective for treating children with CAS, and the inclusion of TKP cues appears to facilitate greater effect.

Key Words: PROMPT, childhood apraxia of speech, developmental apraxia of speech, developmental motor speech disorders, speech sound disorders

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Childhood apraxia of speech (CAS) is a childhood speech sound disorder (SSD) in which the accuracy and consistency of the movements generating speech are compromised, resulting in errors in speech sound production and prosody. CAS is distinguished from dysarthria in that it appears to be the planning and programming of movements rather than their execution that is impaired (American Speech-Language-Hearing Association [ASHA], 2007). CAS may be a consequence of a known or unspecified neurological impairment or an isolated neurogenic SSD. Prevalence estimates for CAS range from as low as one occurrence per 1,000 children up to three or four per 100 children (ASHA, 2007). CAS places a child at risk for continuing difficulties in speech, expressive language, and the phonological foundations for literacy as well as wider impacts on the normal development of socioemotional skills.

Both diagnosis and intervention for CAS have proven challenging. The present study is an evaluation of the efficacy of one well-established treatment approach, Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT; Hayden, 2004; Hayden, Eigen, Walker, & Olsen, 2010), in changing motor behavior, articulation, and speech intelligibility in children with CAS. Specifically, we evaluated the efficacy of the PROMPT approach as a whole and conducted an initial evaluation of one distinctive component of PROMPT, the use of tactile-kinesthetic-proprioceptive (TKP) cues.

Diagnosis of CAS

Differential diagnosis of CAS is challenging because at present, there is no consensus on an empirically validated set of diagnostic features of CAS that differentiates it from other types of childhood SSDs, such as phonological disorders or those that are primarily neuromuscular in origin (e.g., dysarthria). However, the ASHA (2007) Ad Hoc Committee on CAS did note that

> Three segmental and suprasegmental features that are consistent with a deficit in the planning and

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> programming of movements for speech have gained some consensus among investigators in apraxia of speech in children: (a) inconsistent errors on consonants and vowels in repeated productions of syllables or words, (b) lengthened and disrupted coarticulatory transitions between sounds and syllables, and (c) inappropriate prosody, especially in the realization of lexical or phrasal stress. (para. 11)

Although these features cannot be considered necessary and sufficient to identify CAS, in part because the trajectory of the disorder may change relative to task complexity and age, they provide an initial foundation for research.

Treatment Approaches for CAS

A wide range of treatment approaches has been proposed for CAS (ASHA, 2007; Hall, 2000), although little rigorous evaluation research has been conducted (Square, Namasivayam, Bose, Goshulak, & Hayden, 2012; Strand & Debertine, 2000; Strand & Skinder, 1999) and no comparative studies have been reported. Three trends in recent decades are apparent, however, and all are exemplified by PROMPT. For children with suspected CAS or children who have been identified with planning and sequencing issues, approaches that target motor learning principles such as mass and distributed practice, concrete stepped learning with high intensity, and functional lexicons that have noncomplex motor movements are now being recommended (ASHA, 2007; Strand & Debertine, 2000; Strand & Skinder, 1999). These approaches consider speech production to be a motor skill like any other human (fine) motor skill; it is learned following repeated practice under certain conditions (Smith & Goffman, 1998).

Most of these approaches are grounded theoretically in the principles of sensory-motor skill learning and follow a framework that was derived from the development of speech motor control (Green, Moore, & Reilly, 2002; Hayden & Square, 1994; Maas et al., 2008; Strand, Stockel, & Bass, 2006). For example, PROMPT is based explicitly on a hierarchical interdependent bottom-up model of speech motor control and development, the Motor Speech Hierarchy (MSH; Hayden & Square, 1994). The MSH, described in more detail below, is based on the developmental and interactive nature of the speech subsystems. It graphically illustrates the hierarchical development, use, and independence of the laryngeal, mandibular, labial–facial, and lingual systems and their integration in sequencing, thereby providing a framework for the clinician to decide motor speech priorities for treatment. The goal of treatment is the learning of appropriate control and organization of movement patterns and syllable structures in varying linguistic contexts of increasing length and complexity (Hayden, 2006; Hayden et al., 2010).

A second major trend in the treatment of CAS has been to incorporate multimodality cueing such as auditory, visual, gestural, or TKP cues. Some current treatment programs of this type are PROMPT (Hayden & Square, 1994), Dynamic Temporal and Tactile Cueing (Strand & Skinder, 1999; Strand et al., 2006), Kaufman Speech Praxis Treatment for Children (Kaufman, 1995), Let's Start Talking (Hodge, 2007), Childhood Apraxia of Speech Program (Charnik, 2010), and Speech-EZ apraxia program (Carahaly, 2010). In some cases, such as PROMPT, TKP cueing has always been a core component since its initial presentation in Chumpelik (1984), whereas for others, such as Strand's Dynamic Temporal and Tactile Cueing (Strand et al., 2006) and Kaufman's Speech Praxis Treatment for Children, TKP cues either were added later or their role was greatly increased.

Current motor speech theories such as that of Guenther (2006) and empirical research now provide strong support for the use of TKP input in developing initial motor schemas and for establishing a solid phonetic–phonemic base that is later driven by phonological and linguistic feed-forward plans. In Guenther's model, early speech learning relies on sensory feedback from the proprioceptive system, which eventually gives way to the auditory modality as the primary source of feedback information. Based on this and similar work (Guenther, 2003; Hall, 2010), almost all treatment programs now being directed at CAS have changed to include some level of TKP support.

A third trend in the treatment of CAS is that many of these approaches embrace helping the child organize the temporal aspects of speech (Hayden et al., 2010; Strand et. al., 2006). These include slowing down the speech rate, emphasizing appropriate stress patterns and prosody, using tactile support for inaccurate movements, and using cues to help the child remember what is important (e.g., "Round your lips" or "Keep your jaw up," etc.). Generally, these approaches structure practice, enhance sensory learning, and practice syllables or words functionally. Timing, prosody, and rate are dealt with either in imitative activities, repetitive activities, or PROMPT—for example, by "mapping" in timing and stress aspects of a phrase (see Hayden et al., 2010). In summary, Williams, McLeod, and McCauley (2010) described these various similarities as "active ingredients" that are included in all treatment programs now being suggested for CAS.

PROMPT Treatment Outline

The PROMPT program was originally developed by Hayden in the 1980s and has been refined over the past 3 decades (Hayden, 2006, 2008). It is a tactile kinesthetic–based treatment method that has been effective in treating motor speech disorders in adults (Bose, Square, Schlosser, & van Lieshout, 2001; Freed, Marshal, & Frazier, 1997) and in children (Rogers et al., 2006; for a summary, see Hayden et al., 2010).

Although the PROMPT program is known for its use of tactile information, there are several other core elements that collectively distinguish it from other treatment programs (Hayden et al., 2010); they include the following, among others:

- Determination of a communication focus for treatment; that is, an aspect of development in which to embed and focus communication intervention, such as prelinguistic skills, speech subsystem development or rebalancing, activities of daily living, self-help skills, interactive communication routines, play skills, or preacademic or academic learning.

- Determination of the uses of PROMPT, such as to develop an interactive focus for oral communication; to map in cognitive–linguistic concepts; or to develop, balance, or restructure speech subsystems and determine sensory modalities most needed in treatment (TKP, visual–auditory).
- Development of goals and objectives that embody the communication focus and work toward motor, language, cognitive, and social function. This entails the use of reciprocal turn taking, including cognitively appropriate words, objects, actions, interactions, and social interaction and/or choice making in almost every interaction between the child and therapist.
- Ensuring within each session a high degree of motor-phoneme rehearsal (mass practice using prompts for accuracy of production) organized so that (a) these motor-phonemes are generalized across various vowel contexts and transitions (distributed practice) and are embedded into novel syllables and words within naturalistic activities, and (b) immediate use and transfer of the newly learned PROMPT lexicon is embedded in activities and the natural environment for use with parents, caregivers, or peers.

Within the motor speech realm, PROMPT is based on the hierarchical establishment of movement parameters within speech subsystems (e.g., jaw, lip, and tongue), including the refinement and integration of normalized movements from preceding levels of motor control. Treatment generally proceeds in a systematic bottom-up fashion; for example, adequate physiological support for speech in the form of trunk, respiratory, and phonatory control is an essential foundation for the organization of the supralaryngeal articulatory systems. The MSH (Hayden, 2008; Hayden & Square, 1994) was developed to guide clinicians in evaluating and selecting movement parameters. The MSH is based on the interactive nature and development of control of seven key motor speech subsystems. The systems are Stage I: tone, Stage II: phonatory control, Stage III: mandibular control, Stage IV: labial–facial control, Stage V: lingual control, Stage VI: sequenced movements, and Stage VII: prosody. In treatment, speech production is facilitated by providing dynamic TKP cues that physically guide the child's speech movements with concurrent auditory and visual input. Cues are faded as speech movement patterns improve. Rather than working on nonspeech exercises or phonemic precision in nonsense syllables or word lists, PROMPT emphasizes the normalization of speech movement patterns in an age-appropriate, functional lexicon of words.

In PROMPT, auditory input is paired directly with TKP input to develop, organize, and execute movement for speech. In effect, the PROMPT clinician serves as an external programmer of speech movements while integrating these movements with appropriate cognitive and social tasks or interactions (see Hayden et al., 2010, for more detail). PROMPT is aligned with neuronal group selection theory (e.g., Sporns & Edelman, 1993) and the Directions into Velocities of Articulators speech production model (DIVA; Guenther, 2006) in that it emphasizes the role of auditory and somatosensory feedback required to adapt the neuronal networks to produce efficient task-specific motor solutions.

PROMPT differs from some current treatment approaches such as Moving Across Syllables (Kaufman, 1995) in that it does not focus on phonemes or phonological processes or use successive approximation to develop the motor plan; the focus is on normalization of dynamic speech movement productions that are contextually relevant and age appropriate with regard to the lexicon used for training. A set of phonemes may be identified for use in treatment due to the involvement of specific motor processes, but it is the latter that are the actual target. In this framework, the same phoneme might be used at different points in treatment for different purposes and grouped differently with other phonemes.

Because of PROMPT's commitment to embedding treatment within authentic communication across and within all domains to achieve the highest functioning level capable by an individual, it is consistent with the World Health Organization's (WHO's) *International Classification of Functioning, Disability and Health* (ICF) framework (WHO, 2001). Although various levels of TKP input are used to effect somatosensory change and promote development and/or speech accuracy, the linking of this information to cognitive and socially relevant information, materials, and activities is essential to communication proficiency and participation. PROMPT allows therapists to build functional, individualized lexicons for each child that can be instructed in natural contexts. In addition, there is a well-established program for training and certification of clinicians (www.promptinstitute.com).

Finally, the effectiveness of PROMPT has been demonstrated in a number of clinical populations. Freed et al. (1997) documented the acquisition and maintenance of the production of 30 words and phrases by a 24-year-old man with severe apraxia and aphasia who had been treated with PROMPT cueing techniques. Bose et al. (2001) showed that PROMPT treatment resulted in significant improvement in the precision and automaticity of functional phrases in a 30-year-old woman with severe apraxia and Broca's aphasia. Square and colleagues reported success in treating children with severe, persistent speech disorders with PROMPT (Square, Hayden, Ciolli, & Wilkins, 2001; Square et al., 2012). Rogers et al. (2006) successfully used PROMPT treatment to establish functional communication in several children with autism. Because of PROMPT's use of TKP cueing to establish normalized movements for speech and its focus on the production of functional words and phrases that are appropriate for a child's social environment, it is a viable program for treating children with developmental motor speech disorders (Hayden et al., 2010).

Despite these positive outcomes for PROMPT for individuals with a range of SSDs, there have been no published studies using PROMPT with children with CAS. In fact, a recent Cochrane review on the treatment of CAS concluded that there were no high-level treatment efficacy studies in the literature for this clinical population (Morgan & Vogel, 2009). Thus, there is a definite need for further research to improve the research foundations of PROMPT as a motor-based treatment approach for children with developmental motor speech disorders.

Goals of the Present Study

Although the most salient feature of PROMPT to most observers is the extensive use of TKP cues, it would be a mistake to equate PROMPT with the use of these cues and to equate the evaluation of PROMPT with evaluation of those cues. PROMPT treatment involves other features, such as the balance of massed versus distributed practice, cue fading, auditory cues, and more. And equally important with the intervention process as a whole is the diagnostic process that leads to the selection of target phonemes, words, and phrases. In most other treatment approaches, the selection of targets is based on error analysis of the child's speech combined with developmental information on phoneme development, such as the early/middle/late framework of Shriberg and Kwiatkowski (1982). Consequently, the selection of targets is relatively uniform for clients. In PROMPT, target selection is based on a hierarchical model of movement parameters within speech subsystems and the integration of normalized movements within preceding levels of motor control. Diagnosis is multi-dimensional, with a goal of identifying areas of strength and weakness. Consequently, it is much more individualized and does not always follow standard developmental patterns.

The purpose of the present study was to document changes in motor behavior, articulation, and speech intelligibility in children with CAS who undergo PROMPT treatment. An additional focus was to evaluate the efficacy of TKP cues within the PROMPT treatment framework. We chose to evaluate the use of TKP cues by comparing the effects of PROMPT treatment with and without those cues while holding constant all other key components of PROMPT, including target selection. The design included both a between-subjects and a within-subjects component. Following a baseline phase administered to all participants, two children received eight sessions of PROMPT without TKP cues (PWT) followed by eight sessions of full PROMPT (FP) treatment, and two other children received 16 sessions of FP treatment.

Given that PROMPT is based on principles of motor learning, it is important to demonstrate that the newly learned speech movement patterns can be generalized to different contexts; therefore, we identified rigorous and blind evaluation of untreated probe words as a core dependent variable. Most studies reviewing treatment efficacy have evaluated only single sounds or simple words that were targeted for treatment. When assessing the overall effectiveness of PROMPT for CAS, it was deemed necessary to look at overall intelligibility across words and phrases that were not targeted in treatment to see if underlying planning and organization were impacted and changed during PROMPT treatment.

Research Questions

In this study, we asked the following three questions:

1. In children identified with CAS, what is the effectiveness of 16 sessions (8 weeks) of FP treatment compared with the effectiveness of eight sessions (4 weeks) of PWT treatment followed by eight sessions (4 weeks) of FP with respect to …
   a. improved focal oromotor control and sequencing as evidenced in measures of articulation (Diagnostic Evaluation of Articulation and Phonology [DEAP]; Dodd, Hau, Crosbie, Holm, & Ozanne, 2002), intelligibility (Test of Children's Speech [TOCS+]; Hodge, Daniels, & Gotzke, 2009), and speech movements (Verbal Motor Production Assessment of Children [VMPAC]; Hayden & Square, 1999)?
   b. improved quality of speech movements in untrained words (generalization) as judged by a panel of certified speech-language pathologists (SLPs) who are blind to the experimental condition (untrained probes)?
   c. improved performance in the ICF (WHO, 2001) activity and participation domains (the Socialization subtest of the Vineland Adaptive Behavior Scales—Second Edition; Sparrow, Ciccheti, & Balla, 1984)?

2. Over the first eight sessions, what is the effectiveness of FP treatment compared with the effectiveness of PWT treatment with respect to …
   a. improved focal oromotor control and sequencing as evidenced in measures of articulation (DEAP) and intelligibility (TOCS+)?
   b. improved quality of speech movements in untrained words (generalization) as judged by a panel of certified SLPs who were blind to the experimental condition (untrained probes)?

3. For children who received PWT as their initial treatment, what is the effectiveness of the initiation of FP in the second 4 weeks with respect to …
   a. improved focal oromotor control and sequencing as evidenced in measures of articulation (DEAP) and intelligibility (TOCS+)?
   b. improved quality of speech movements in untrained words (generalization) as judged by a panel of certified SLPs who were blind to the experimental condition (untrained probes)?

Method

The design and methods of this study were approved by the University of New Mexico's Human Research Review Committee.

Participants

Four children (three males and one female, between the ages of 3;6 [years;months] and 6;0) who had previously been diagnosed by an SLP to have CAS were recruited from hospitals, schools, and agencies in the Albuquerque and Santa Fe, NM, area. As the precise operational definition of CAS remains controversial, we used criteria consistent with the guidelines proposed by ASHA (2007). Specifically, the inclusion criteria for participants included:

- Diagnosis of suspected CAS by a certified SLP.
- Performance criteria on two subtests of the VMPAC as determined on the basis of cutoff scores for children whose scores fell between the treatment-resistant and oromotor clinical groups in the validation research on the VMPAC. A minimum criterion of 85% for both 3- and 4-year-olds was set for the Global Motor subtest to confirm that there was no gross motor impairment, and performance below 43% (for 3-year-olds) or below 56% (for 4-year-olds) on the Sequencing subtest, which was judged most sensitive to core components of CAS.
- Impairment in articulation skills as evidenced by a score of at least –1.5 *SD*s below the mean standard score of 10 on the Articulation subtest of the DEAP and a TOCS+ word intelligibility score of less than 50%.
- Consistency of speech production below 50%, based on performance on the Word Inconsistency subtest of the DEAP.
- Receptive language skills no more than mildly impaired as evidenced by a standard score of no more than –1.5 *SD*s below the mean (i.e., at least 78) on the Auditory Comprehension scale of the Preschool Language Scale—Fourth Edition (PLS–4; Zimmerman, Steiner, & Pond, 2002).
- Hearing, vision, and orofacial structures within normal limits.

Table 1 presents a summary of the performance of the participants on the major inclusionary measures.

Design

The four participants were randomly divided into two groups of two each. The design of the study was a combination of an ABB design for the first group and an ACB design for the second group, where A = baseline, B = FP, and C = PWT. All of the participants received the FP diagnostic procedure, including selection of target phonemes. Approximately 15 target phonemes were identified for each participant, which were then combined to make words and phrases for use in the treatment sessions. Following the diagnostic procedure, there were two phases of treatment, each lasting ~4 weeks. In the first phase, participants in the first group received eight sessions of FP. The second group received eight sessions of PWT—that is, all components of PROMPT except for the use of TKP cues. Assessment of change during this first phase in the two groups provided a between-subjects comparison of the (added) effectiveness of using TKP cues. During the second phase, participants in Group PWT also received FP. A comparison of change in the two phases for this group enabled a within-subjects comparison of the two conditions. The FP group continued to receive FP.

Ideally, single-subject designs should include enough baseline sessions to demonstrate stability and to prevent spurious conclusions about effectiveness, which in fact represent maturation or random variation; five is often suggested as a guideline. The inconsistency that characterizes CAS may make it even more difficult to obtain a stable baseline. For the present study, however, we decided to conduct the entire study within the period of summer vacation from school, when school-related treatment is not provided, in order to avoid the need to withdraw current treatment. This mandated a limit of three baseline sessions. However, as will be seen later, there was little evidence overall for spontaneous improvement during the baseline period.

Measures and Timing

Several aspects of speech production were measured using both standardized tests and scoring of probes. The standardized tests were administered by four master's-level speech-language pathology graduate students who were

Table 1. Description of participants at study entry.

ID	Age (years;months)	Gender	DEAP SS	% Inconsistent	TOCS+ Words Intelligible	PLS–4 AC	Vineland Socialization SS	VMPAC Global Motor	VMPAC Sequencing
BS	3;8	M	4	65	36	88	103	95	20
CC	4;8	F	4	72	36	115	81	90	27
JS	4;1	M	3	82	22	89	89	85	0
UB	3;6	M	1	100	5	102	72	85	0

Note. ID = participant identifier; M = male; F = female; DEAP SS = standard score on the Diagnostic Evaluation of Articulation and Phonology; % Inconsistent = Word Inconsistency subtest of the DEAP; TOCS+ Words Intelligible = Word Intelligibility subtest of the Test of Children's Speech; PLS–4 AC = Auditory Comprehension subscale of the Preschool Language Scale—Fourth Edition; Vineland Socialization SS = standard score on the Socialization subtest of the Vineland Social–Emotional Early Childhood Scales; VMPAC Global Motor = Global Motor subtest of the Verbal Motor Production Assessment for Children; VMPAC Sequencing = Sequencing subtest of the VMPAC.

proficient in test administration and scoring but were blind to the study design. The same student did not administer the test each time to each child. No formal reliability testing of scoring of standardized tests was conducted, but the scoring was reviewed by senior staff of the project. The overall timing of assessments, probes, and phases of treatment is summarized in Table 2.

The Articulation subtest of the DEAP was administered three times as a measure of articulation. The Word Inconsistency subtest was administered at the outset only as a qualification measure for inclusion in the study. DEAP scores possess good to excellent reliability across time for all age bands; average corrected reliability coefficient for all ages was .93 and .96 for 3;0- to 5;11-year-olds and 6;0- to 8;11-year-olds, respectively. DEAP standard scores were used for analysis.

The TOCS+ was used as a measure of word and phrase intelligibility and was administered as a pretest, between the two phases of the intervention (midpoint), and at posttest. The TOCS+ was also administered ~3 months later as a measure of maintenance. Average percent correct, as determined independently by three graduate speech-language pathology students who were blind to the study, was used as the measure of change.

The VMPAC was used as a measure of quality of gross and fine motor movement, speech movements, and the ability to sequence these in connected speech. The VMPAC was also used to examine motor control in language and speech characteristics (i.e., prosody, rate, etc.). Test–retest correlations ranged from .56 to .90.

The Socialization scale is a subtest of the Vineland Adaptive Behavior Scales—Second Edition (Sparrow, Cicchetti, & Balla, 1984). The Socialization score was used as a measure of change in social participation. Test–retest correlations across all areas from Communication to Adaptive Behavior ranged from .78 to .89 for the 3;0–4;11 age group. Standard scores were used for analysis.

Untreated probe words. As described in the next section, three priority areas were identified for each participant, drawn from Stages III through VI of the MSH. In order to assess if improvement had occurred within the identified priority areas, as shown by transfer of motor actions and refinements to untreated words, four sets of probe words that would never be used in treatment were constructed to reflect the vertical plane of movement (mandibular), the horizontal plane of movement (labial–facial), the anterior–posterior plane (lingual), and a combination of all planes (sequenced movement). Ten words that reflected the properties of each subsystem (mandibular, labial–facial, lingual, and sequenced) and its primary movement actions were constructed (see Tables 3 and 4). For example, words reflecting gross mandibular movements (Stage III) and simple open-to-close, close-to-open, or close-to-open-to-close movements included *baaa, bob, pop, mom,* and *up* and were scored for appropriate jaw range, stability and grading, and closure movements.

Untreated probe word data were collected three times at baseline, two times in treatment phase one, two times in treatment phase two, at completion of treatment, and at 3 months post treatment, for a total of nine sets. The sets of 40 untrained probe words (10 per set) from each assessment point were randomized for video–motor and auditory–perceptual ratings by a panel of certified SLPs who were blind to the study. The panel rated the videotaped untrained words for adequacy of visual–auditory–motor performance on a 0 to 3 scale. To receive a score of 3, all three movement/auditory parameters associated with that stage had to be accurate. A score of 2 was given to words in which only two movement/auditory parameters were accurate, and a score of 1 was given when only one movement/auditory parameter was correct. A score of 0 was given when no parameters were correct.

Interobserver agreement checks were administered for the dependent measures (visual and auditory accuracy) for each complete untreated probe set of 40 words. Twelve completed, untreated word sets drawn from the entire 36 sets of probes were scored by all observers. Point-to-point reliability of judgments was 90% (range = 82%–100%). If a response did not have at least 90% agreement, all raters watched the video until 100% agreement was reached.

Table 2. Timing of all assessments, probes, and treatment phases.

Measures	Pretreatment inclusion	Pretreatment baseline	Intervention Phase I (4 weeks, 2 × week)	Mid-intervention assessment (end of Week 4)	Intervention Phase II (4 weeks, 2 × week)	Posttreatment	Follow-up (3 months posttreatment)
PLS–4	X						
Vineland	X					X	
VMPAC	X					X	
DEAP	X			X		X	
TOCS+		X		X		X	X
MSH		X					
Trained Probe Items			End of Weeks 1 & 3		End of Weeks 5 & 7	X	X
Untrained Probe Words		X	End of Weeks 2 & 4		End of Weeks 6 & 8	X	X

Note. MSH = Motor Speech Hierarchy.

Table 3. Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT) rules for choosing syllables and words for each stage.

Stage	Characteristics	Syllable structure	Categories assessed
III: Mandibular	Vertical plane movements, primarily mid-low vowels using extended jaw range, bilabials made through the jaw, some beginning diphthongs	VC, CV, CVC	Appropriate jaw range, appropriate jaw stability and midline control, appropriate open/close or close/open phrase
IV: Labial–facial	Horizontal plane movements, primarily high-mid vowels (mainly rounded or retracted) plus bilabials made through independent action of the lips, rounded or retracted facial movement	VC, CV, CVC	Appropriate jaw range with midline stability and control, appropriate rounded/retracted transitions, appropriate independent bilabial control
V: Lingual	Anterior to posterior plane movements, anterior to back independent linguals, with varying vowels and some blends	VC, CV, CVC	Appropriate lingual movements (anterior-to-posterior or posterior-to-anterior), appropriate timing between lingual movements, appropriate voicing within the CVC
VI: Sequenced	Polysyllabic words that cross multiple planes of movement	2 & 3 syllables	Appropriate lingual/labial transitions across syllables, appropriate timing across syllables, appropriate voicing across syllables

Intervention: Determination of Priorities, Treated and Untreated Probe Word Scoring, and Treatment

Determination of priorities. A spontaneous videotaped speech sample was obtained for each child. Using this sample, the Speech Analysis Observation (SAO; Hayden, 2006) was scored and was used to select three motor speech subsystems from the seven stages of the MSH as the beginning treatment priorities for change. Although the MSH contains seven stages, and the SAO assesses all of them, priorities for treatment are usually only chosen from Stages III–VI, where Stage III (mandibular control) represents movement of the jaw in the vertical plane; Stage IV (labial-facial control) focuses on horizontal movements of the lips and face; and Stage V (lingual control) requires independent movement of the jaw and tongue body with control of the anterior, middle, and back portions of the tongue. Stage VI (sequenced) combines Stages III–V in multisyllabic words.

Once the three priority stages were selected, several phonemes associated with those stages were selected for focus in treatment. These phonemes were then combined into 30 (10 for each of the three priorities) words and phrases (e.g., *me done* and *I want more*) that were in the child's vocabulary and would be functional for interactive social routines. The rules for choosing words for each stage and the criteria for judging movement accuracy are part of the PROMPT system and are summarized in Table 3. Table 5 presents the specific priority targets for each child. Information from measures used for qualification as CAS, and also from the DEAP, was used to confirm that appropriate targets had been selected. As an example of this process, a clinician might determine that Stages III, IV, and V should be selected as priority stages for treatment of a child. Words then that could be selected for that child might include *up, mom,* and *ya* for Stage III (mandibular); *peep, boy,* and *me* for Stage IV (labial–facial); and *juice, cookie,* and *phone* for Stage V (lingual). Note that although specific phonemes were identified for use in constructing target words and phrases for treatment, it is the motor patterns of the MSH that are the actual targets of treatment; depending on context, the same phoneme might be used at more than one level.

Table 4. Untreated word probe sets.

Stage III: Mandibular	Stage IV: Labial–facial	Stage V: Lingual	Stage VI: Sequenced
um	*boy*	*tan*	*robot*
eye	*bee*	*dog*	*cupcake*
map	*peep*	*log*	*toothbrush*
meow	*bush*	*owl*	*ice cream*
home	*moon*	*sun*	*ladybug*
bam	*phone*	*snake*	*marshmallow*
Bob	*feet*	*juice*	*umbrella*
Pam	*fish*	*clown*	*birthday cake*
pup	*wash*	*crib*	*hamburger*
pie	*show*	*grape*	*strawberry*

Note. All four sets were administered to all participants at each assessment point, although only three sets were priorities for each participant.

Scoring of treated words. To determine how each child was progressing with his or her chosen priorities (e.g., targeted treatment words) or if these priorities should be changed, treated word probes were administered and scored by the treating clinician at the beginning of every other session after baseline, or six times (three times in each treatment block) over the 16 treatment sessions. Given the focus on a limited set of sounds, severe inconsistency of production by children with CAS, and use of nonpicturable words, direct imitation was used to elicit each word in each priority area, for example, "This is a watermelon, say *watermelon.*" Each production was scored online by the treating clinician using a 0–2 point scale. Both auditory and visual aspects of the production were assessed. Both needed to be free of error or totally typical for a child's age for a score of 2; 1 was scored if only the auditory or visual aspect was correct, and 0 was scored when neither the auditory or visual aspect was correct. If the child

Table 5. Treatment priority targets for each participant.

Participant, condition, and 3 priorities	Category	Phonemes	Sample words
BS, PWT			
Priority #1	Labial–facial	/ʊ/, /i/, /p/, /v/, /ʃ/	*Sheep, shut, five, you, me, wash, phone*
Priority #2	Lingual	/z/, /ɵ/, /ð/, /l/, /tʃ/, /dʒ/, /g/, /k/	*Go, jump, match, watch, clock, that, yellow*
Priority #3	Sequenced		*Baseball bat, football, hula hoop, chewing gum, peanut butter*
CC, PWT			
Priority #1	Lingual	/l/, /s/, /i/, /ə/, /ʃ/, /k/, /g/	*Cup, cow, keep, ship some, sock, luck, legs, car, green*
Priority #2	Labial–facial	/p/, /f/, /o/, /ʃ/, /tʃ/, /ʊ/	*Push, food, go, shoot*
Priority #3	Sequenced		*Watermelon, hamburger, telephone, computer*
JS, FP			
Priority #1	Mandibular	/o/, /ɑ/, /i/, /ə/, /ʌ/	*Pop, mom, on, up*
Priority #2	Lingual	/k/, /g/, /ʃ/, /sn/, /sl/	*Keep, shot, slide, to, slip*
Priority #3	Labial–facial	/p/, /f/, /ʃ/, /v/	*Foot, push, shoe, feed, shut, five*
UB, FP			
Priority #1	Mandibular	/iɑ/, /ɑi/, /ɑ/, /m/, /b/, /p/	*Ya, hop, mom, bam, bump*
Priority #2	Labial–facial	/o/, /u/, /uə/, /i/, /iu/, /p/	*No, one, two, me, you, push*
Priority #3	Lingual	/t/, /d/, /n/, /s/, /l/, /ɹ/, /g/, /k/, /tʃ/	*Match, put, hit, done, not, need*

Note. PWT = PROMPT without tactile-kinesthetic-proprioceptive (TKP) cues; FP = full PROMPT with TKP cues.

achieved 80% accuracy on the set of words for a priority over three consecutive sessions, a new priority or speech subsystem stage was chosen from the MSH. Because the purpose of the treated word probes was primarily to guide the course of intervention, and because the scoring was necessarily done by the clinician during the treatment session, the treated word data were not analyzed as a dependent variable.

Treatment. Treatment sessions were conducted by two certified SLPs with extensive experience using PROMPT. An unobtrusive video camera and separate microphone were used to record all testing, treatment, and probe sessions for future scoring. Treatment included 16 individual, biweekly sessions lasting 50 min each (illness, vacations, and other factors sometimes caused the sequence to be extended in time) over an 8-week period (two 4-week segments). All sessions were videotaped for probe data and fidelity. After a 5-min warm-up drill (mass practice of trained phonemes or words, phrases), there were three 15-min treatment activities during which distributed and random practice occurred in functional situations including constructive play (i.e., "Sort and Say" game, puzzle, or building blocks, etc.), symbolic play (i.e., farm and truck activity, imaginary play with dolls, etc.), and a social routine or game where each participant takes turns and furthers the game objective, (i.e., "Cariboo" game or a bowling game, etc.). Each activity was designed to present the child with 15–20 opportunities to produce each trained target word. The activities were also chosen for their ability to be expanded and made more complex over the treatment period; for example, simple forms such as *mo* (*more*) were expanded to *I want more.* Changes in position between the child and therapist were provided in almost every activity, such as working at a small table or moving to the floor.

As described earlier, there were two conditions during treatment: FP, where specific TKP cues paired with auditory input were used, and PWT, where only auditory–visual reinforcement was used. The same treatment protocol was followed in each group in all other respects. (See the Appendix for an example of PROMPT and auditory–visual protocols at the single sound level.) In both groups, as the speech motor behaviors became better established, the clinician faded the cues and reduced the frequency and immediacy of feedback.

Some prompts (*parameter* prompts) are large, organizing postures or cues that focus TKP input to the skeletal, muscular, or neurological system. They provide base support for the more complex and intricately timed postures and muscular contraction needed for accurate speech production. Other (*surface*) prompts focus TKP input on specific articulators and generally signal the components of place, timing, or transition. As an example, for /o/, the middle three fingers of the hand are equally distributed on the top lip margin while the thumb and little finger are placed equally on the bottom lip margin and all are slightly pulled forward. Still other (*syllable*) prompts are designed to holistically shape muscle groups for CV syllable productions such as *bee, toe,* and *bow.* For example, in *bee,* the two sounds are prompted and *mapped in*; first, for /b/, the back of the first two fingers are placed on the medial third of the upper and lower lip margins and slightly pressed in; for /i/, the thumb and first fingers are placed at the intersection of the upper obicularis oris and the zygomatic and with very gentle and slight action move upward and backward. Then, the third finger is curled in and placed under the mandible to support the jaw in an almost fully closed position while the first finger and thumb are placed at the intersection of the upper obicularis oris and zygomatic muscles and slightly pulled up and backward while the child repeats the syllable. Finally, *complex* prompts are used to construct single motor-phonemes by integrating two planes of movement. For example, in the production of /i/, where anterior tongue tip contraction and lip retraction are both needed, the clinician uses a cupped middle finger behind the mandible in the soft tissue and applies firm pressure upward and forward on the mylohyoid muscle while the thumb and first finger are used as described above at the intersection of the obicularis oris and zygomatic muscles.

In PROMPT treatment, the frequency, timing, and type(s) of prompts are determined by the clinician. In general, at the beginning of treatment and where the child is aware of why prompting is occurring, frequency is high and may occur every 5–10 s within the attempt. Later, both the timing between the error and the prompt may be lengthened to allow the child "recall of the movement," or additional prompt supports may be added. As control at each level is established, prompting is systematically reduced until the child is producing all actions on his or her own. For example, for participant UB, primarily parameter and surface prompts were used initially to develop a typical jaw range in the horizontal plane of movement and provide boundaries and reduced degrees of freedom through the jaw. As UB's range normalized, only surface prompts were used to signal changes in bilabials and jaw closure. After this was established, surface and syllable prompts were used to establish early syllables and movement in the vertical plane for words such as *me* or *you* where the jaw movement must stay reduced. Then, mainly surface prompts were used to establish short phrases and to impact early linga-aveolar productions such as /d/ and /n/.

To verify the clinician's adherence to the PROMPT protocol and technique, we took fidelity measures twice during the treatment phase. The videotapes were reviewed by an independent PROMPT instructor who had been trained to assess fidelity. Using the standard PROMPT fidelity score sheet that is used in PROMPT training (available on request from the second author), the examiner rates a clinician on a series of thirty-six 4-point scales; a score of 4 denotes that a behavior has *always been observed,* and a score of 1 that the behavior is *rarely observed*. The clinician is rated across four areas: physical–sensory (e.g., appropriate prompting is given at the right time and for the right purpose; clinician states, asks, and models expected response if child does not automatically produce it), cognitive–linguistic (e.g., chosen activities are at the appropriate cognitive level to engage the child; clinician uses language that matches or just slightly exceeds the receptive language of the child), social–emotional (e.g., clinician interaction optimizes child arousal and joint attention; clinician consistently reinforces positive behavior), and treatment setup and strategies (e.g., work areas are clearly and visually delineated; space is used appropriately given the nature of the activity). On all fidelity measures, ratings (sum of scores across all 36 items) were above 95% of the maximum possible score of 144.

Results

The performance on each of the standardized measures, for each participant, is provided in Table 6. For the DEAP and the Vineland Socialization subtest, the test manuals provide confidence intervals for scores that can be used to determine if the improvement observed is greater than that due to chance variation across administrations. Significance in the table for those measures represents nonoverlapping confidence intervals. Based on information in Hodge and Gotzke (2010) and personal communication with the TOCS+ developer (M. Hodge, personal communication, March 20, 2012), a criterion of at least 16.7% change was set for significant improvement on that measure. No formal means of evaluating change on the VMPAC is currently available.

Figures 1 through 4 present the results of the scoring of the untreated word probes for each child individually. These are the most detailed measures, both in aspect of speech being measured and in time scale. They provide evidence of the acquisition, generalization, and maintenance effects of PROMPT treatment for each child. For each of the three targets for each child, the three baseline measures were used to compute a mean and standard deviation. Performance during and after treatment that was at least 2 *SD*s above that baseline mean was taken as evidence of significant change and was marked with larger markers in the graph. In addition to this criterion for judging statistical reliability of change between the periods of the study, it is useful to have a measure of effect size for each change. Table 7 presents the Nonoverlap of All Pairs (NAP) index proposed by Parker and Vannest (2009). NAP makes no assumption about distribution or measurement scale beyond ordinality. Parker and Vannest suggested the following guidelines for evaluating NAP values: 0.00–0.65, weak effect; 0.66–0.92, medium effect; 0.93–1.00, large or strong effect. Due to the small number of data points in each phase (2 or 3), these effect sizes should only be considered suggestive.

Below, we first address each of the research questions on the basis of the results in Table 6 and the figures, looking across all participants. Because one of the hallmark features of CAS is variability both across children and within a given child's performance, we then examine the results from each child separately.

Effectiveness of 16 Sessions of FP Treatment Versus Eight Sessions of PWT and Eight Sessions of FP

Our first question asked how 16 sessions (8 weeks) of FP treatment would compare to eight sessions (4 weeks) of PWT followed by eight sessions (4 weeks) of FP. As shown in Table 6, three of the four participants improved their DEAP Error score from pretest to posttest; for participants BS (PWT) and UB (FP), the increase was significant based on confidence intervals provided in the test manuals. Converging evidence for improvement in production is provided by the results for word intelligibility and phrase intelligibility on the TOCS+. (One child's speech was not sufficiently advanced to justify administering the latter.) All four participants improved their TOCS+ intelligibility score from pretest to posttest. All four participants met that criterion for both words and phrases; change was comparable for the two groups of participants. More focused information on change is provided by the results on the VMPAC. Although change

Table 6. Change in structured measures over the phases of the study.

Measure	BS (PWT)	CC (PWT)	JS (FP)	UB (FP)
DEAP Articulation Error SS (*M* = 10, *SD* = 3)				
Pretest	4 [3–5]	4 [3–5]	3 [1–5]	1 [0–2]
Midpoint	4 [3–5]	5 [4–6]	5 [3–7]	3 [2–4]
Posttest	9 [8–10][a]	4 [3–5]	5 [3–7]	5 [4–6][b]
TOCS+ % Words Intelligible				
Pretest	35.5	36.6	22.1	5.3
Midpoint	65.5[a]	50.6	49[a]	19
Posttest	58[b]	55[b]	53[b]	24[b]
Follow-up	75[a]	62[b]	40[b]	37[b]
TOCS+ % Phrases Intelligible				
Pretest	34	27.3	17.7	—
Midpoint	64.3[a]	40.3	40[a]	—
Posttest	60[b]	59[b]	47[b]	—
Follow-up	80[a]	60[b]	53[b]	—
VMPAC Focal Oromotor Control %				
Pretest	69	72	61	58
Posttest	80	82	78	63
VMPAC Sequencing %				
Pretest	19.6	27	0	0
Posttest	41	67	43	35
Vineland Socialization SS (*M* = 100, *SD* = 15)				
Pretest	103 [93–113]	81 [73–89]	89 [81–97]	72 [62–82]
Posttest	113 [103–123]	108 [100–116][a]	114 [106–122][a]	83 [73–93]

Note. Confidence intervals (CIs) are provided in brackets, where available. For the DEAP, 95% CIs are based on Table C of Dodd et al. (2002); for the Vineland Socialization subtest, 95% CIs are based on Table B.3 of Sparrow et al. (1984); and for the TOCS+, judgment of significant change is based on consultation with M. Hodge (see text). Dashes indicate testing could not be administered due to severity of the child's impairment. [a]Significantly higher than previous time point. [b]Not significantly higher than previous time point, but significantly higher than at pretest.

occurred on both the Focal Oromotor Control and Sequencing subtests of the VMPAC, a greater change was seen for sequencing, the area of greatest impairment and the most central to the definition of CAS. For both measures, changes were comparable for the two groups. Regarding the Socialization subtest of the Vineland, all four participants increased their scores; for participants JS (FP) and CC (PWT), the changes were significant based on confidence intervals provided in

Figure 1. Performance of participant BS (Prompts for Restructuring Oral Muscular Phonetic Targets [PROMPT] without tactile-kinesthetic-proprioceptive cues [PWT] in first phase) on untreated word probes. Larger markers indicate performance at least 2 *SD*s above baseline. Scores on the *y*-axis are the percentage of the maximum score (30 = 10 words × 3 points/word) achieved by the child. Base-1, -2, -3 = the three baseline measures; Tx-1, -2, -3, -4 = the four measures taken during treatment; Final = the measurement taken at the end of treatment; Fol-up = the follow-up measure taken 3 months after treatment (see Table 2).

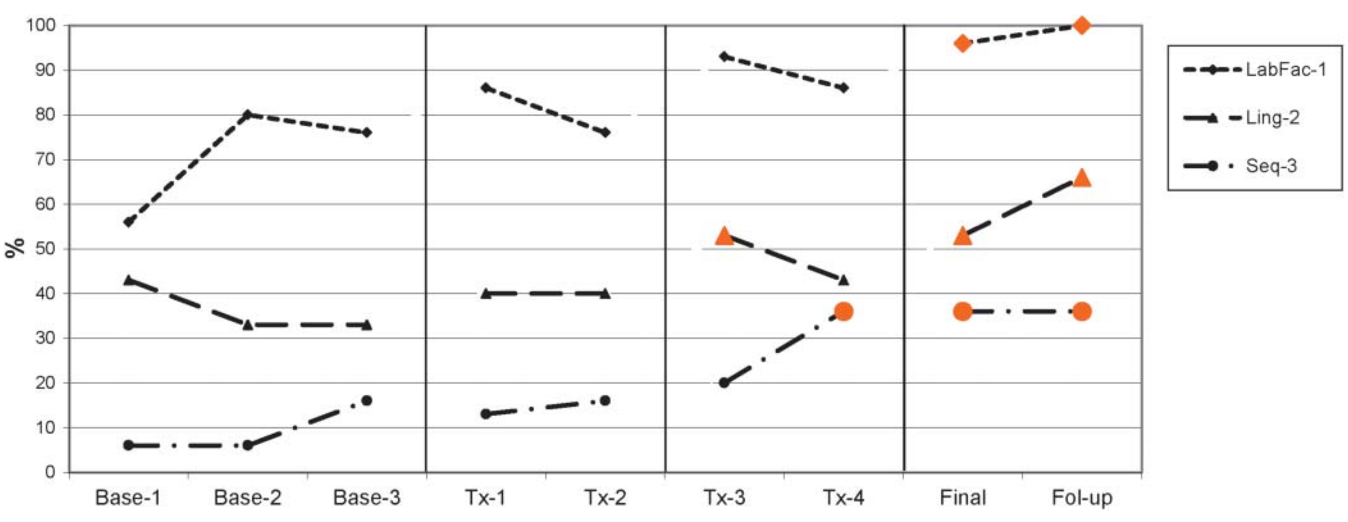
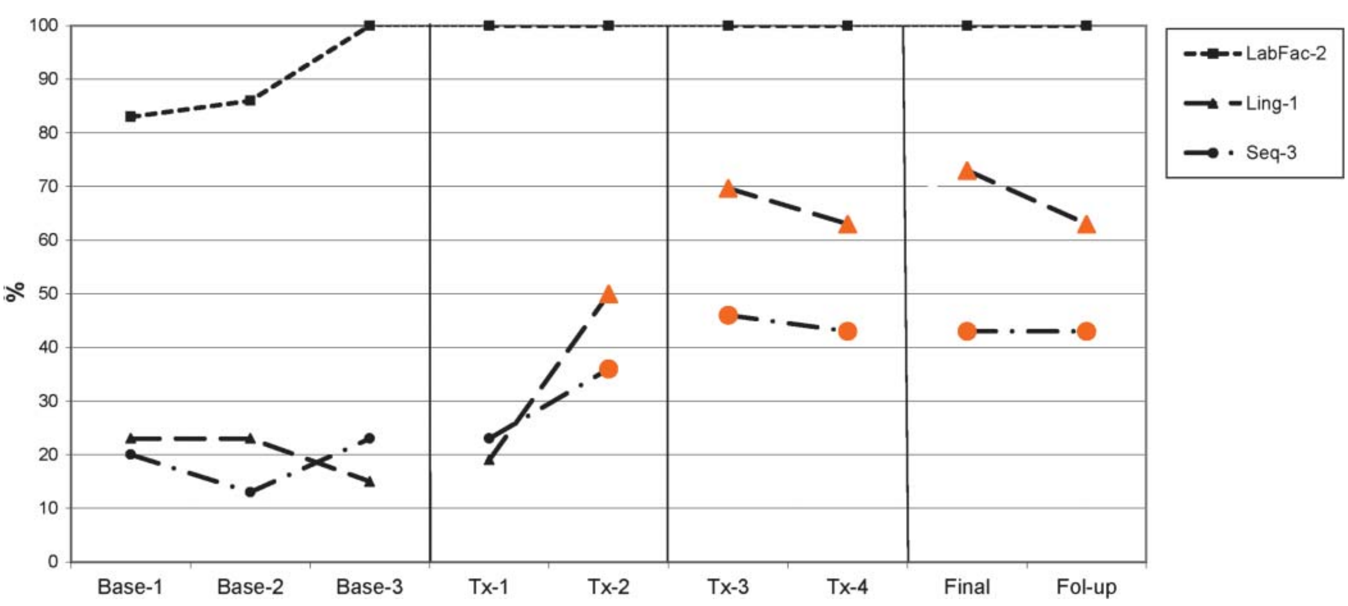


Figure 2. Performance of participant CC (PWT in first phase) on the untreated word probes. Larger markers indicate performance at least 2 *SD*s above baseline. Scores on the *y*-axis are the percentage of the maximum score (30 = 10 words × 3 points/word) achieved by the child.



the test manual. Again, the changes were comparable for the two groups. Thus, taken together, the results of the structured tests showed that all four participants made substantial advances over the 16 sessions, and they were comparable for the two groups.

With respect to the untreated word probe data, the most relevant data points are the seventh, eighth, and ninth ones on the lines for each of the three targets for each child; they came from the end of the treatment phase, a follow-up assessment, and a delayed posttest. Twenty-four of these 36 points represent performances that were at least 2 *SD*s above baseline. The majority of the exceptions (7 out of 12) were cases where initial performance was quite high, making it difficult to register much improvement. Again, there was little difference between the two groups: 13/18 for PWT and 11/18 for FP. The effect sizes in the last column of Table 7 confirm a strong effect from baseline to the final two assessments, which was comparable for the two conditions.

Figure 3. Performance of participant JS (full PROMPT [FP] throughout) on the untreated word probes. Larger markers indicate performance at least 2 *SD*s above baseline. Scores on the *y*-axis are the percentage of the maximum score (30 = 10 words × 3 points/word) achieved by the child.

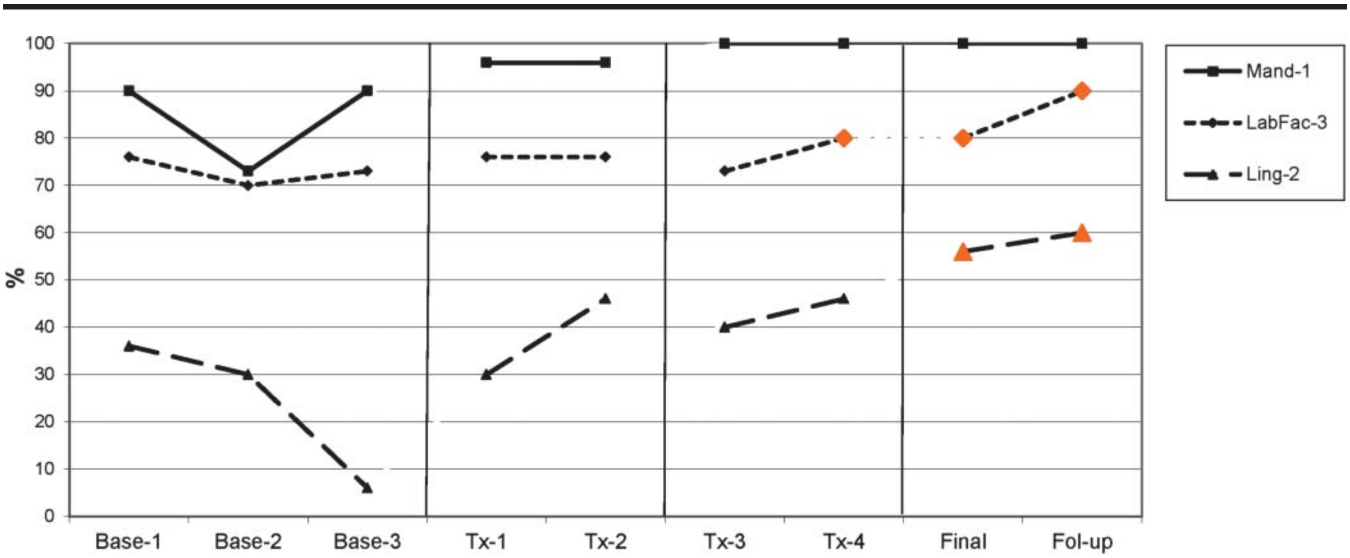
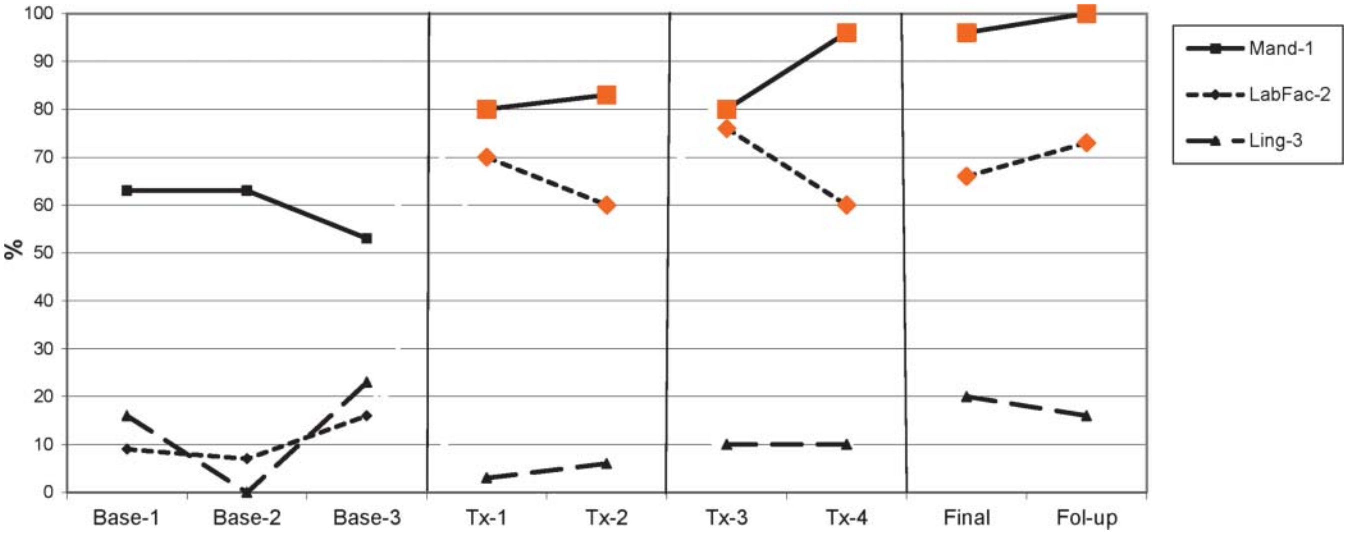


Figure 4. Performance of participant UB (FP throughout) on the untreated word probes. Larger markers indicate performance at least 2 *SD*s above baseline. Scores on the *y*-axis are the percentage of the maximum score (30 = 10 words × 3 points/word) achieved by the child.



In sum, both treatment regimes appear to provide comparable, substantial improvement. However, in the present design, it is possible that PWT is less effective on its own, but the provision of FP later makes up for this. For that reason, we turn to the second question.

Effectiveness of FP Treatment Over First Eight Sessions Versus PWT

The second question asked how effective FP treatment over the first eight sessions was compared to PWT during the same time frame. For this question, we compared pretest and midpoint structured assessments after the first eight sessions. On the DEAP, although the two FP participants made more improvement than the two PWT participants over the first eight sessions (0 and 1 vs. 2 and 2), in neither case was the change significant. On the TOCS+ words and phrases intelligibility scores, the improvements over the first eight sessions were comparable for the two groups (30 and 14 vs. 27 and 14).

With respect to the untreated word probe data, the most relevant data points are the two that occur during the first treatment phase (the fourth and fifth). For the two children in PWT, two of the six points reached the 2-*SD* criterion; for the two in FP, four of the six points did. However, in both cases, it was one of the two children in the group

Table 7. Effect sizes (NAP) for changes in the production of untreated words between study phases, based on data in Figures 1–4.

Participant, condition, and target	Change from baseline to 1st 4 weeks treatment	Change from 1st 4 weeks treatment to 2nd 4 weeks	Change from 2nd 4 weeks treatment to post + follow-up	Change from baseline to post + follow-up
BS, PWT				
Labial–facial	.75	.88	1.0	1.0
Lingual	.67	1.0	.88	1.0
Sequenced	.75	1.0	.75	1.0
CC, PWT				
Lingual	.75	1.0	.63	.83
Labial–facial	.83	.50	.50	1.0
Sequenced	.92	1.0	.75	1.0
JS, FP				
Mandibular	1.0	1.0	.50	1.0
Lingual	.75	.63	1.0	1.0
Labial–facial	.83	.50	.88	1.0
UB, FP				
Mandibular	1.0	.63	.88	1.0
Labial–facial	1.0	.63	.50	1.0
Lingual	.75	1.0	1.0	.58

Note. NAP = Nonoverlap of All Pairs.

who was responsible for these points. The effect sizes reported in the first column of Table 7 depict medium to strong effects of the first treatment phase. There is a small tendency for the effects to be larger for the children in FP than for the children in PWT.

In sum, there was little evidence for a difference in effectiveness between the two treatment conditions. There was substantial variation in response to intervention by individual children.

Effectiveness of FP in Second 4 Weeks of Treatment

The third question asked how effective the initiation of FP treatment in the second 4 weeks was for the children who received PWT as their initial treatment. For this question, we examined the change that occurred from midpoint to posttest for the participants who received PWT initially. On changing from PWT to FP, BS made a significant improvement on the DEAP but no improvement on either TOCS+ score. In contrast, CC made no improvement on the DEAP, along with improvements on both the TOCS+ words and TOCS+ phrases intelligibility measures, which did not meet the criterion for significant change. Taken together, the structured tests provided little evidence for a significant "boost" from the introduction of FP after PWT.

With respect to the untreated word probe data, the relevant comparisons are between the data points during the first treatment phase (#4 and #5) and those from the second phase (#6 and #7). For BS, there was evidence of greater gain during the second phase; there was little evidence of change during the first treatment phase, and his only two data points meeting the 2-*SD* criterion occurred during the second phase. For CC, performance was also higher during the second phase (four points met the criterion). However, performance was also improved in the latter part of the first phase (two positive points); therefore, the high performance later may represent only continued benefit from the PWT experience. The effect size for BS was strong for all three priorities, as it was for CC for two of the three priorities.

In sum, BS responded to the change in treatment with significant improvement on both the DEAP and the untreated word probes. CC also improved, especially on the untreated word probes, but this result is ambiguous due to the increase in performance that began before the transition.

Individual Child Responses to Treatment

Participant 1 (PWT). BS (male) was age 3;8 at initiation of the study. His qualifying data revealed a severe articulation deficit (DEAP standard score [SS] of 4) that was highly inconsistent (65% of the time), with breakdowns in verbal language and sequencing tasks. He was only partially intelligible to the naive listener in spite of typical receptive language, cognition, and motor ability. BS was excessively verbal, with extremely poor prosody and stress. He was outgoing and cooperative, and he appeared to use his excessive speech as a way to try to engage the listener. He worked hard to get his point across even if it took several repetitions. BS was the most developmentally typical child in the study, overall (e.g., in physical–sensory, cognitive–linguistic, and social–emotional aspects). He had the most engaged family throughout the study. Almost all of his family members attended each session, reviewed his homework, and promoted the use of his treatment lexicon in everyday situations.

As noted above, BS's DEAP Error score and TOCS+ word and phrase intelligibility scores improved significantly from pretest to posttest. On the DEAP, this advance occurred during the second treatment phase, after FP was introduced. On the TOCS+, however, the change occurred during the first treatment phase. On the VMPAC, BS's focal oromotor control score went from 69 at pretest (below the 5th percentile) to 41 (just below the mean), and his sequencing score went from below the 5th percentile to just below the mean. As shown in Figure 1, all three of BS's priority areas improved over the study, with more substantial changes occurring in the second half of treatment in all three priorities, including continuing changes into follow-up.

In summary, BS showed a strong response to treatment, with a general pattern of larger change during the second phase of treatment, when FP was introduced.

Participant 2 (PWT). CC (female) was age 4;8 at study initiation. Her qualifying data revealed a severe articulation deficit (DEAP SS of 4) that was highly inconsistent (72% of the time), with breakdowns in verbal language and sequencing tasks. She was only partially intelligible to the naive listener in spite of typical receptive language, cognition, and motor ability. CC was quiet, often withdrawn, and very sensitive to any perceived correction. At times, she was completely cooperative and engaged; at other times, she was moody, sullen, and uncooperative. Although CC was the highest performing child in receptive language and motor ability, she had difficulties making friends and interacting with others. CC's home situation was in flux as the family was having financial difficulties and was downsizing and restructuring some businesses they owned. Her mother attended her treatment sessions regularly and was supportive of the treatment process and transfer of CC's lexicon into everyday activities.

CC's DEAP Error score did not improve over the course of the study, whereas her TOCS+ word and phrase intelligibility scores improved significantly, with her word intelligibility score improving primarily in the first phase and her phrase intelligibility score improving in both phases. Her sequencing score on the VMPAC went from well below the 5th percentile to just below the mean. Her Vineland Socialization score improved significantly from pretest to posttest. Changes were observed on the untreated word probes for both lingual and sequencing priorities in the last treatment session of the first half of treatment, which then continued to show increased significance from baseline, continuing into and through the second half of treatment. In general, CC's results indicate that improvement began to occur in the first phase but began to consolidate in the second phase, when TKP was introduced.

In summary, CC showed a substantial response to treatment, although it is difficult to know if there was a differential response to FP when it was introduced in the second phase.

Participant 4 (FP). JS (male) was age 4;1 at study initiation. His qualifying data revealed a severe articulation deficit (DEAP SS of 3) that was highly inconsistent (82% of the time), with breakdowns in verbal language sequencing tasks. He was only partially intelligible to the naive listener in spite of typical receptive language, cognition, and motor ability. JS had the most chaotic family life of all of the children and was living in at least two and often three different homes. During treatment, his mother was hospitalized and then died, and he began living with his grandmother. There was a period of 1 month during which JS's treatment was interrupted completely. In order to finish the treatment, the remaining sessions were completed in the school setting. JS appeared often as a sweet and engaging child but then would withdraw and become uncooperative. He appeared very aware of his own unintelligibility and would often try to distract the listener with clownish behavior. When unable to change the subject, JS would then resort to "acting out" or withdrawal.

JS's DEAP Error score improved in the first phase, but not quite significantly. His TOCS+ word and phrase intelligibility scores improved significantly, and the major change in both occurred during the first, FP, phase. JS's sequencing score on the VMPAC went from 0—significantly below the 5th percentile—to 43, or just below the 5th percentile (47) for his age. His Vineland Socialization score improved significantly, from 89 to 114. His initial priorities for treatment were (a) mandibular, (b) labial-facial, and (c) lingual. After the second session, with mandibular stabilization, these were changed to (a) lingual, (b) labial-facial, and (c) mandibular. On the untreated word probes, some significant change was seen in the second half of treatment, and this continued into follow-up in both labial–facial and lingual priorities. Although JS received FP, his organization and integration of these subsystems was slow to emerge. Issues with his home and family, performance anxiety, and his extremely poor ability to sequence verbal tasks for his age were complicating factors.

In summary, the structured measures for JS evidenced some growth beginning in the first (FP) phase of the treatment, although the untreated word probe measures did not show significant change until the second phase. This delayed response may reflect family and personality issues.

Participant 3 (FP). UB (male) was age 3;6 at study initiation. His qualifying data revealed a profound articulation deficit (DEAP SS of 1) that was highly inconsistent (100% of the time). UB used approximately three vowels and occasional bilabials /b/, /m/. He appeared to have no idea how to produce sounds on imitation. In spontaneous production, UB produced a string of vowels occasionally occluded by a bilabial. He was the only child in the study who could not be given the TOCS+ intelligibility phrases. He was totally unintelligible to the naive listener in spite of typical receptive language, cognition, and motor ability. UB most often used gestures to get his needs met and ranged from emotionally labile (crying, escape behaviors, unable to separate from his mother) to totally engaged with the clinician, happy, and not wanting to leave the treatment session. Overall, UB was the most immature child in the study and the most dependent on his mother. His mother attended all treatment sessions and over the treatment period developed a different style of relating to him. She developed better boundaries and encouraged his separation and independence. Transfer of his treated word lexicon was encouraged but not consistent.

UB's DEAP Error score and his word intelligibility score on the TOCS+ improved significantly from pretest to posttest, with change occurring during both treatment phases. On the VMPAC, UB's initial testing score in sequencing was 0 or significantly below the 5th percentile, and by the posttest, he had improved to above the 5th percentile. Most of UB's treatment time was spent in organizing, grading, and integrating the mandibular and labial–facial speech subsystems. On the untreated word probes, significance was achieved in both the mandibular and labial–facial priorities almost from the first treatment session using TKP, whereas the lingual priority (which was only minimally targeted due to his substantial issues with mandibular and labial–facial organization) made no change. The emphasis in treatment was placed on developing simple syllables and words that could be used to communicate his needs and develop interaction within his family.

In summary, both the structured measures and the untreated word probe results showed a strong response to treatment for UB that clearly began in the first phase of treatment.

Discussion

Effectiveness of 8 Weeks of FP Treatment Versus 4 Weeks of PWT and 4 Weeks of FP

All four participants in this study received 16 sessions of treatment that included all or almost all of the core components of PROMPT. For two of the participants, half of the sessions omitted the TKP cues only. An examination of change over the full course of treatment, pretest to posttest, revealed substantial change on a variety of structured and unstructured measures that, in many cases, was statistically significant. Of particular note, all four participants improved their performance on untrained probe words significantly, as judged by a panel of SLPs who were blind both to experimental condition and to the point in the study at which the video recording was made. In every case but one of the 12, the NAP effect size measure for the intervention as a whole was large. Together, the results provide considerable evidence for the overall effectiveness of PROMPT for treating children with CAS. The advances were comparable for the two groups of children.

Effectiveness of FP Treatment Over First Eight Sessions Versus PWT

Beyond this overall evaluation of the effectiveness of PROMPT for children with CAS, we sought to evaluate the extent to which providing TKP cues added to the effect of all other components of PROMPT. For this, it was necessary to examine the two phases of intervention separately. For this research question, we compared the effect of the first eight sessions for the children who received PWT and those who received FP. On the DEAP Error score, there was a trend for children receiving FP to improve more, but it did not reach significance. With respect to untreated probe word production, there was little difference, as one of the two children receiving PWT (CC) and one of the two children receiving FP (UB) showed a strong response to treatment in the first phase, and the other two showed more change in the second phase. The effect size results, however, did show a trend for larger change for children in FP than PWT. Thus, taken together, these results provide some evidence for a differential effectiveness of FP. This conclusion, however, must be qualified by the possibility that the relatively short treatment phase (eight sessions) may not have been long enough to reveal the full effect of the treatment condition experienced. This is particularly likely given our focus on generalization of motor patterns to untreated words as the primary dependent measure—a process that is likely to take more time than other measures.

Effectiveness of FP in Second 4 Weeks of Treatment

The third research question also focused on the comparison of PWT with FP by examining change in the second treatment phase for the two children who were transitioned from PWT to FP at that point. For one participant (BS), this transition was followed by a larger change than during the first phase. For the other (CC), change began at the end of the first phase and continued into the second phase. As was the case for the second research question, the results based on the 2-*SD* criterion provide only limited evidence for differential effectiveness. However, the NAP effect size results are more positive about the effect of including TKP cues: they were of large magnitude for five of the six priorities and were larger than the changes seen between the first and second treatment phase for the children receiving FP throughout.

Taken together, the results for the second and third questions on the DEAP and the untreated word probes for three of the four participants (BS, JS, UB) provide some modest evidence for an additional effect for TKP cues. The exceptions to this pattern (participant CC, and the TOCS+ intelligibility measure) are interesting in their own right. CC was the highest functioning participant at pretest; her motor speech control may have been harder to affect because there was already a more extensive set of lexical and grammatical forms with their own established motor patterns. She was also the most challenging participant interpersonally. In addition, between the midpoint assessment and the posttest (when she first experienced FP), CC passed into the next older age category, which reduced her standard score. The TOCS+ intelligibility measures failed to show a consistent difference between PWT and FP. We believe that intelligibility is sensitive to additional factors beyond motor speech control; in particular, prosodic factors may play a substantial role in clarifying meaning. In this regard, it is notable that for BS, one focus of treatment was a general slowing of speech, and his intelligibility increased dramatically in the first, PWT, phase, whereas his DEAP Error score did not improve until the second, FP, stage.

Why Is PROMPT Effective?

All four children benefited from the 16 treatment sessions with respect to multiple outcome measures. The most consistent results were found in the TOCS+ measure of intelligibility and the measure of generalization of targeted motor movements and coordinative actions to new single-syllable words, polysyllabic words, and short phrases, rigorously based on blind evaluation of the untreated word probes. Gains were also impressive in a measure of generalization to social interaction outside the clinical setting, which we assessed in a very modest way using the Vineland Socialization scale. It is important to keep in mind that throughout the intervention, every child was receiving at least all but one of the core elements of PROMPT treatment as described in the introduction. We feel strongly that these core elements, independent of the provision of TKP, are critical to its success or to achieving the treatment goals in the most expedient time frame. Thus, the present study, along with others, provides substantial support for the ability of the entire PROMPT program to promote change. However, each of the core elements of the PROMPT program needs to be evaluated, as we do not yet have evidence of the impact of individual components or combinations of them. We suspect that the domain analysis, selecting priorities based on the MSH, turn-taking interaction, and functionality are the major contributing factors to the effect of PROMPT. These need to be investigated separately—ideally with a much larger research sample and using a broader range of measures including kinematics.

Scores on the untreated probe words and on the DEAP provide some modest evidence that including TKP in the FP program resulted in more success than the PWT condition. We interpret this result in light of the hypothesis of Sporns and Edelman (1993) that neuronal groups are the basic functional units of selection and are arranged in maps representing the body surface or visual space. These maps are anatomically coupled by connections throughout the cortex, and after several successful attempts at a task, modified pathways are formed and reorganization of previous neuronal maps occurs. The fundamental rationale for the use of TKP in PROMPT is that TKP acts to substantiate the neuronal group premise and provides a consistent framework for the changes evidenced in PROMPT treatment. All inputs directly correspond to the motor contractions required for that sound or word. These prompts are always systematically applied and reinforced. If this hypothesis is correct, another reason for the effectiveness of PROMPT is the high number of productions that are elicited for each target in each activity.

On the basis of this first study to distinguish the impact of TKP, several issues have become apparent. One is that with higher functioning children (speaking at phrase level and above), it may take more time, especially if incorrect lingual actions are highly inconsistent (e.g., /t/ for /k/), to produce permanent change. In the current study, one of the two children who received FP in the second phase (BS) demonstrated marked changes in his articulation after prompts were given. In the other child (CC), subsystem control and integration, especially in sequencing words and phonemes, was seen to begin changing during the last session of PWT. Once FP was added, refinements of lingual actions developed and then continued rapidly to generalize to untreated words through follow-up. More generally, it may take more time than this study allowed to make significant changes in movement patterns and therefore linguistic changes to new productions. Additional treatment sessions might allow us to see the interaction between the physical prompting and the other components and confirm that all PROMPT components including TKP are necessary to produce optimal change. Finally, we postulate that changing/developing the lower speech subsystems (i.e., mandibular and labial–facial) may happen more quickly because they require more gross muscle activation rather than fine muscular control (e.g., see UB). Lingual actions, however, are more refined and take more time, intramuscular input, and more sensory recognition.

A final implication of these results may be among the most important. In the current study, variation in the form of PROMPT—whether TKP was included or not—appeared to have less of an influence than individual child characteristics (compare BS and UB with CC and JS). Because TKP and other components of PROMPT are embedded in functional communication (as opposed to, for example, drill), the child must be available for engagement in the PROMPT process. The crux of this requirement is intention to communicate and associated skills such as turn-taking. Both affective and cognitive factors may impact engagement, either positively or negatively. To explore this conclusively, a larger number of participants will need to be studied in a group design correlating child characteristics with response to treatment.

Limitations and Future Directions

Several aspects of the design of the present study limit the generalizability of the conclusions from this examination of the general effect of PROMPT and the specific effect of TKP cues, and suggest important directions for future research. First, although considerable attention was paid to the selection of participants who fit the current consensus definition of CAS, there were only four of them. Second, only three baseline assessments were made of the untreated word probes, although it is increasingly common to obtain five or more. A stable baseline would provide increased validity for testing significant change over the course of the study. Third, it would have been useful to have VMPAC and Vineland measures obtained at midpoint, as was done for the DEAP and the untreated word probes, to further evaluate the impact of the TKP cues. Fourth, each treatment phase included only eight sessions, typically over 4 weeks, and consequently, the response to treatment may not have stabilized before the next phase. This is part of a larger need for more information on the role of intensity and duration in treatment. From a motor perspective, we hypothesize that increased intensity (e.g., 5×/week rather than 2×/week) would be less effective than increased duration, as increased practice in the natural setting is required to stabilize skills and generalize to everyday communication.

It would be illuminating to compare the time course of change on the treated words and the untreated words to understand the conditions that facilitate generalization. In the present study, the two types of assessment were not synchronized sufficiently in the design to make this possible. However, it must be recognized that there will always be qualitative differences between the two sets because the treated words are necessarily personal to each participant, whereas the untreated words are used as a general rubric. Thus, the extent of delay between the two types of advance will be somewhat ambiguous.

Finally, as discussed above, other core elements of PROMPT beyond the use of TKP cues, such as the use of the MSH for selection of priorities for treatment, also merit investigation of the effectiveness they bring to treating children with CAS and other SSDs.

Conclusion

In the present study, a relatively brief (16-session) program of PROMPT-based treatment resulted in significant gains for children with CAS on both standardized tests and the production of untreated words, as evaluated by scorers who were blind to condition and time of assessment. Complex impairments such as CAS require complex programs of intervention. Consequently, progress in clinical science will require going beyond evaluation of the effectiveness of programs as a whole to determine the contribution of specific components. The present study represents a first step in this direction. The results provide some modest evidence that although the components of PROMPT other than TKP cues are effective in themselves, TKP cues add to their effectiveness. More definitive evaluation will require a larger number of children and a longer period of treatment.

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Appendix

Example of Full Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT) and PROMPT Without Tactile-Kinesthetic-Proprioreceptive (TKP) Cues Protocols at the Single Sound Level

Group FP: Full PROMPT

Therapist says, "First, we will practice saying the sound by itself. I will say it while I show you how it feels, and then I want you to say it."

Therapist action	Child response	If correct…	If not correct…
1. Say sound, giving first prompt.	Child repeats.	Go to next sound.	Go to Trial 2.
2. Say sound, giving same or alternative prompt as required (e.g., parameter, surface, syllable, complex).	Child repeats.	Go to next sound.	Say, "And again," and go to Trial 3.
3. Say sound, giving same or alternative prompt as required (e.g., parameter, surface, syllable, complex).	Child repeats.	Go to next sound.	Say, "Let's try that one more time," and go to Trial 4.
4. Say sound, giving same or alternative prompt as required (e.g., parameter, surface, syllable, complex).	Child repeats.	Go to next sound.	Go to next sound.

Brief Definition of PROMPT Types

PROMPT type	Definition
Parameter	Broad-based support for one parameter (e.g., jaw support, broad facial rounding/retraction)
Surface	Information in one dimension to an articulator to signal place, timing, and transition
Syllable	Combination of parameter and surface
Complex	Information in more than one plane of movement in order to construct a holistic representation of a motor-phoneme

Group PWT: PROMPT Without TKP Cues but Including Auditory–Visual Cues

Therapist says, "First we will practice saying the sound by itself. I will say the sound, and then I want you to say it after me. Look at me, listen to the sound, do what I do."

Therapist action	Child response	If correct…	If not correct…
1. Say sound, looking at the child.	Child repeats.	Go to next sound.	Go to Trial 2.
2. Have the child focus on the therapist's mouth. Give a verbal description of where to place, or how to move, the articulators.	Child repeats.	Go to next sound.	Go to Trial 3.
3. Repeat Step 2.	Child repeats.	Go to next sound.	Go to Trial 4.
4. Repeat Step 2.	Child repeats.	Go to next sound.	Go to next sound.