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Using ultrasound visual feedback to remediate velar fronting in preschool children

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Abstract

Anecdotally, velar fronting can be difficult to remediate in some children. This pilot study examined the use of ultrasound visual feedback in remediating velar fronting in typically developing children. A single-case, multiple-baseline across-subjects experimental design was used to examine acquisition, retention and generalization of velar treatment targets. Two otherwise typically-developing children (P1, aged 4;0; P3, aged 4;11) completed the study. The productions of /k/ and /g/ at syllable-level were targeted during treatment. P1 improved her productions of /k/ and /g/ at syllable-level during the treatment period and achieved correct production at word-level during follow-up. P3 made no improvements in his productions of velar targets. This study suggests that ultrasound visual feedback may be an option for remediating velar fronting in some preschoolers. Further study is required.

Keywords

ultrasound; speech therapy; velar fronting; motor learning; children

In typically developing children, acquisition of /k/ occurs on average at about 3;6 years, while the acquisition of /g/ occurs at 3;6 years for females and 4;0 years for males (Smit, Hand, Freilinger, Bernthal, & Bird, 1990). Beyond these ages, few changes in /k/ and /g/ productions are observed (Smit et al., 1990). The most common error in the production of /k/ and /g/ is velar fronting (Smit, 1993), which refers to the substitution of velars /k/ and /g/ with alveolars /t/ and /d/ respectively (Gordon-Brannan & Weiss, 2007). Children presenting with velar fronting beyond their fourth birthday are considered to have disordered speech that warrants intervention (James, 2001).

Articulatorily, velar fronting may be a consequence of difficulty with tongue control. As summarized by McAllister Byun (2012), to produce velars, differential movement of the

tongue and jaw are required, as well as differentiated control of anterior and posterior aspects of the tongue. Gibbon (1999) also argued that velar fronting may be a consequence of a failure to dissociate different parts of the tongue, such as raising the tongue dorsum while keeping the tip/blade low. Although some linguistic approaches to therapy, such as minimal pairs, are often used to treat velar fronting, they require a minimal level of stimulability. Minimal pairs therapy is generally not recommended for children who are not stimuable and it is therefore necessary to consider approaches that would enhance a child's ability to correctly articulate the sound prior to implementing other linguistic approaches.

When using an articulation approach to speech remediation, the principles of motor learning can be applied to promote more effective and efficient acquisition and maintenance of new speech motor skills (Maas et al., 2008). Consistent with the Schema Theory framework (Schmidt, 1975), speech therapy that utilises the principles of motor learning involves two distinct stages; pre-practice and practice (e.g., Ballard, Robin, McCabe, & McDonald, 2010). The pre-practice (training) phase precedes and prepares the learner for the practice phase (Schmidt & Lee, 2011). The main goals of the pre-practice phase are for the learner to gain an internal reference-of-correctness and to achieve adequate stimulability for the production of the new motor task during practice (Maas et al., 2008).

The provision of feedback is crucial for the development of this internal reference-of-correctness (Swinnen, 1996). Augmented feedback allows the learner to validate the accuracy of their attempts (Sherwood & Lee, 2003) and encourages the learner to refine the execution of the motor task for learning to occur (Hodges & Frank, 2002). One form of augmented feedback used in speech therapy takes the form of "knowledge of results" (KR) feedback. KR refers to information on the outcome of the motor task, and is provided at the end of the movement execution (Schmidt & Lee, 2011). In the context of speech therapy, this refers to the auditory outcome of the motor task (i.e., how it sounds) (Adams & Page, 2000). That is, information to the learner on whether the production attempt sounded correct or incorrect according to the community standard. As suggested by Hodges and Frank (2002), it is expected that the provision of feedback specific to the outcome of the attempt encourages the learner to shape subsequent attempts accordingly for the execution of the speech target with increased perceptual accuracy. This is crucial as the gold standard of speech therapy outcome is the accurate auditory perception of speech targets by listeners (Kent, 1996).

Another form of augmented feedback is "knowledge of performance" (KP) feedback. This refers to information pertaining to how the motor task has been executed (Schmidt & Lee, 2011). KP is especially important during the early stages of motor learning, when the learner is unfamiliar with the motor task (Schmidt & Lee, 2011; Maas et al., 2008). In the field of speech pathology, KP is often given in the form of verbal information provided by the therapist (e.g., Murray, McCabe, & Ballard, 2012) or visual information using tools such as surface electromyography (e.g., Craig et al., 1996), spectrography (e.g., Ballard et al., 2007; McAllister Byun & Hitchcock, 2012), electropalatography (e.g., Gibbon, McNeil, Wood, & Watson, 2003; Gibbon & Wood, 2003) or ultrasound (e.g., Bacsfalvi, 2010).

Specific to remediation of velar fronting, the influence of visual feedback via electropalatography (EPG) has been examined (e.g., Gibbon, McNeil, Wood, & Watson, 2003). Several EPG case studies report the treatment of velar fronting in children with cerebral palsy (Gibbon & Wood, 2003; 15 sessions in 4 months), Down Syndrome (Gibbon et al., 2003; 12 sessions in 14 weeks), and cochlear implant (Panteleimidou, Herman, & Thomas, 2003; twice per week for unknown duration) who were resistant to previous traditional articulation therapy. In these studies, the use of EPG resulted in significant changes in velar productions towards a more posterior tongue placement (Gibbon et al., 2003; Gibbon & Wood, 2003), as well as significant improvements in the intelligibility of the treated velar plosive target (Panteleimidou et al., 2003). However, the authors reported that further therapy was required for generalisation of treatment gains to occur (Gibbon et al., 2003; Gibbon & Wood, 2003; Panteleimidou et al., 2003). An alternate explanation for the lack of generalisation and retention contained in the papers by Gibbon and colleagues (Gibbon et al., 2003; Gibbon & Wood, 2003) may be that restructuring practice with EPG around PML is needed as it appears that 100% KP feedback and constant practice was used in both studies.

There are limitations to the use of EPG for remediation of velar production. In particular, velar plosives in open vowel contexts are formed with the tongue striking either the soft palate or the intersection of the hard and soft palate (Gibbon et al., 2003). The EPG plate is only located in the region of the hard palate and so may provide limited visual information (Liker & Gibbon, 2008). Moreover, EPG does not provide information on movements of the tongue prior to its contact with the hard palate (McAuliffe & Ward, 2006), or sections of the tongue with no contact with the palate. Consequently, a child may be forming seemingly correct posterior EPG contact patterns, but with an inappropriate movement of the tongue body (Gibbon & Paterson, 2006).

Considering the limitations with the use of EPG for the establishment of velars during articulation therapy with young children, it is of interest to explore an alternative and possibly more effective method for providing visual KP feedback for treating velar fronting. In recent years, researchers have begun investigating the effectiveness of using ultrasound visual feedback in articulation therapy. A number of studies have shown that ultrasound visual feedback may facilitate improved production of residual speech errors including /r/, /s/ and various vowels at single-word level in school-aged children and adolescents with long-standing, unresolved difficulties in articulation (Adler-Bock, Bernhardt, Gick, & Bacsfalvi, 2007; Bernhardt et al., 2008; Modha, Bernhardt, Church, & Bacsfalvi, 2008; Preston, Brick & Landi, 2013; Preston, McCabe, Rivera, Whittle, Landry & Maas, 2014). The use of ultrasound visual feedback appears to have positive effects on the acquisition of speech sounds at single-word level during articulation therapy.

However, most previous studies using ultrasound for articulation therapy (Adler-Bock, Bernhardt, Gick, & Bacsfalvi, 2007; Bernhardt et al., 2008; Modha, Bernhardt, Church, & Bacsfalvi, 2008) have not designed treatment with specific consideration of the principles of motor learning. Within these studies, there was, for example, no clear, specific distinction of pre-practice and practice conditions noted. This may be important, as different feedback conditions are used in pre-practice and practice phases (Maas et al., 2008). In particular,

while the pre-practice phase utilises both KP and KR feedback at high frequency, the practice phase involves the provision of KR feedback at reduced frequency (e.g., Ballard et al., 2010). While KP and KR feedback are crucial during the initial stage of learning (i.e. pre-practice), reducing the frequency of augmented feedback during practice is important for minimizing dependency on augmented feedback and for long-term learning to occur (Steinhauer & Grayhack, 2000; Swinnen, 1996). This lack of distinction in pre-practice and practice phases in all but one study of EPG visual feedback for velar fronting remediation (Panteleimidou, Herman, & Thomas, 2003) may suggest one reason why generalisation of targets was difficult.

Despite the potential of ultrasound in providing a clear, sagittal view of the velar and alveolar contrast in tongue movement (Bernhardt, Gick, Bacsfalvi, & Adler-Bock, 2005), the potential benefits of using ultrasound in treating the specific speech error of velar fronting has been examined in only one study to date. Cleland, Scobie, and Wrench (2015) treated velar fronting in four children between the ages of 5 and 7 years using ultrasound. Results suggested relatively rapid increase in accuracy for all children, with each one achieving near 100% accuracy following 12 weekly therapy sessions. Cleland and colleagues used a head-stabilised ultrasound probe which provides for highly accurate recordings of tongue movement but is “heavy and uncomfortable over time” (p. 581).

Additionally, other than Cleland et al., (2015), the existing literature examines the effects of ultrasound in therapy with older school-aged children, adolescents and adults. Consequently, the effectiveness of using ultrasound in therapy with younger children is unknown.

Aim and hypothesis

This study aimed to explore the efficacy of using ultrasound visual feedback in remediating velar fronting during articulation therapy in preschool age children with otherwise typical development. Based on previous ultrasound studies, we hypothesised that:

1. Velar phonemes treated using an ultrasound visual feedback additional to articulation treatment in the pre-practice phase would change more than control phonemes, and
2. Any reported change in phoneme accuracy would generalise to untreated speech contexts.

Method

Recruitment

Participants for the study were recruited through private speech pathologists in the Sydney metropolitan area via email and parents interested in the treatment study were encouraged to contact the researchers. The inclusion criteria for the study were as follows: (a) English-speaking, (b) speech impairment involving velar fronting of /k/ and /g/, and within the normal range for chronological age for (c) hearing acuity, (d) receptive language, (e) oral-motor structures and functions, (f) speech perception, and (g) cognition. Results of speech,

hearing, receptive language and speech perception pre-treatment assessments are presented in Table 1 while results of the oral motor examination are presented in Table 2.

Participants

Two Australian children were recruited (Participant 1: female, age 4, 0; Participant 3: male, age 4, 11). Prior to this study, P1 had undergone speech therapy for 6 months, working primarily on lateralised /s/ and /s/ production during this study was within normal range. P1's production of her velars /k/ and /g/ was also targeted in this earlier therapy, albeit with parental report of no change in accuracy. P3 had completed 18 months of speech therapy which targeted /k, l, f/ and clusters. Similar to P1, parental report was of limited improvement in the production of /k/ with traditional speech therapy while his production of /l/ and /f/ was within the normal range at the time of assessment for this study. No further details were available about previous therapy for either child.

Note that P3's overall score for his oral/speech motor functions was affected by his poor score in diadochokinetic and single word repetition tasks. This was due to his difficulty with production of velar sounds in /pʔtʔkʔ/ and the presence of other speech sound errors. However, oral and speech functions for his lips, mandible, maxilla, tongue, velopharynx, larynx-respiration and his speech sample were within the normal range (see Table 2).

Study design and general procedures

The study utilised a single-case, multiple-baseline across-subjects experimental design (Kazdin, 2011). The children were randomly allocated to provide either three (P1) or four (P3) baselines over a two-week period as per current recommendations for this type of research (Kratochwill et al., 2012; Tate, McDonald, Perdices, Togher, Schultz, & Savage, 2008). Both received six treatment sessions over 3 weeks, followed by three follow-up sessions at 1, 2, and 3 weeks post-treatment as shown in Table 3. Each session was 50-minutes long. Parents observed all sessions in the room.

Equipment and data recording

All assessment, baseline, treatment and follow-up sessions were audio and video-recorded. Audio recordings were made using an Olympus VN-8600PC digital voice recorder. Video recordings were made using a Sony DCR-SR60E digital video camera recorder on a tripod. The screen of the ultrasound machine was included in the scope of the video-recording when the ultrasound machine was in use during the pre-practice phase. The ultrasound machine used was a Philips ATL HDI 5000 (ATL ultrasound, Bothell, WA, USA) unit with a curvilinear 2.0-4.0 MHz transducer. Ultrasound images were obtained by placing the transducer under the child's chin to obtain an image of the tongue in sagittal section. These images were not recorded onto the ultrasound machine itself.

Baseline and follow-up data collection

Following initial assessment, probes assessments were devised. At each probe session (baseline, within therapy probes before sessions 2, 4 and 6 or follow up) a set of 30 single-words containing treated and untreated /k/ and /g/ and control phoneme(s) and a connected speech sample on the production of velar targets /k/ and /g/ and control phonemes were

collected. Fifteen single words for each velar target were examined. The targets included velars as singletons in initial, medial, and final word positions, and in clusters. Ten of the single words in each category were randomly selected for treatment and the remaining five were included to demonstrate generalisation of any treatment effect. A picture-naming task was used to elicit the single-word targets. The color picture cards were created using the Boardmaker® software (Boardmaker®, Version 5.1.3, 2002). To elicit the single-word targets, a picture was selected at random and the child was asked, “What’s this?” When required, cues were given in the order of: (a) semantic (e.g., “Dogs do this with their tails when they are happy.”), (b) binary choice (e.g., “Is it wag or table?”), and (c) delayed imitation (e.g., “It’s ‘wag’. What is it?”) (McLeod, 1997). Additionally, the production of /ŋ/ in single words was collected from both children as a control behaviors. Generalisation of treatment to production of /ŋ/ was not expected due to the difference in manner of articulation.

Treatment

The production of velars /k/ and /g/ were both targeted during treatment for each participant. Treatment was designed to progress in the following order: (a) /k/ and /g/ in a syllable, (b) /k/ and /g/ in single words, and (c) /k/ and /g/ words in connected speech. The criterion of 80% accuracy of the target sound in production during the practice phase was required for the participant to progress to the next level of complexity. When treatment targeted the production of velars in a syllable, the velars were paired with a central-mid vowel (i.e. [ʔ]). The syllables were then elicited using individual cards printed with the letter ‘k’ or ‘g’. The single words used in treatment were the 20 single words (10 /k/ and 10 /g/) randomly preselected from the 30 single words used for baseline and follow-up measures. The same procedure used for eliciting baseline and follow-up data was used to elicit single words during treatment. No home practice was required during the study period and parents were specifically requested to refrain from other speech therapy.

Pre-practice—Each treatment session began with a pre-practice phase for the production of targets. Ultrasound imaging in real-time was used to provide visual KP feedback on every trial in the pre-practice phase. At the start of each treatment session pre-practice phase, the researcher modeled the production of a velar and an alveolar contrast (i.e. /k/ and /t/) while visual feedback of the clinician’s tongue movement was provided with the ultrasound machine. The differences in place (i.e. front vs. back) and auditory perception of the velar and alveolar contrast were emphasised and established with the children. An arrow was placed on the screen of the ultrasound machine to remind children of the position of the back of the tongue. The children were also given a cue to move their tongues while the ultrasound visual feedback was provided to increase their awareness of the tongue movement required to produce the velars (e.g., “Play around with your tongue. Make the back part of your tongue move.”). In addition to real-time visual ultrasound KP feedback, the researcher provided both verbal KP and KR feedback on all pre-practice trials. As we aimed for a minimal reference of correctness, the criterion for progression from the pre-practice phase to the practice phase was 3 correct productions of the target (i.e. /k/ and/or /g/ with a schwa). These did not have to be consecutive productions. Once this criterion was met, the ultrasound feedback was removed and the practice phase was initiated. P1 received a mean

of 65.8 (SD 11) trials per session during pre-practice (12, 98, 78, 69, 63 and 75 trials from sessions 1 – 6 respectively). P3 received a mean of 52.8 trials (SD 7) during pre-practice per session (40, 43, 51, 45, 88 and 50 trials from sessions 1 – 6 respectively). Prepractice lasted until the predetermined number of correct productions were achieved. This varied from 10 to 45 minutes (out of a 50 minute session) across the sessions for P1 and consisted of the whole session for all of P3's sessions, that is P3 was provided with the ultrasound biofeedback on all trials.

Practice—During the practice phase, the children were required to produce the targets (i.e. /k/ and /g/ in a syllable) without the ultrasound visual feedback. This approach allows for reduction of the ultrasound based KP feedback, which is thought ensure maintenance of any treatment gains. KR feedback was given for an average of 50% of all trials. This was scheduled on the data collection sheet prepared for each session with more frequent feedback at the start of practice and a diminishing schedule subsequently. A 3-minute rest break was provided after every 25 trials. The participant played a short game with the researcher or interacted with their parents during each rest break. For P1, an average of 61.7 practice trials (SD = 10) were conducted per treatment session (20, 80, 80, 80, 40 and 70 trials from sessions 1 – 6 respectively). P3 never progressed to this phase.

Data analysis

The first author (QWH) conducted all sessions and transcribed all baseline, treatment and follow-up data phonemically. QWH rescored a randomly selected 10% of the data with point-to-point intra-rater agreement of 96%. Inter-rater agreement with a speech pathology clinician unfamiliar with the children or study hypotheses was calculated on the same 10% of the data and was acceptable at 80%. Adherence to the treatment protocol (fidelity) was examined on two randomly selected sessions for each child. This fidelity ranged between 88% and 94%. Errors in adherence to the protocol were primarily (1) provision of KR feedback more frequently in practice than required and (2) provision of only KR feedback rather than KR and KP feedback for correct trials in practice for both children.

Production accuracy during baseline, treatment and follow-up was graphed for visual inspection of treatment, maintenance and generalization effects. Visual inspection is the prevailing form of data analysis for single-case research (Kahng et al., 2010). Moreover, considering the generally stable baseline and the clear change found in follow-up for one participant, it is believed that visual inspection is a reliable tool for data analysis in this current study. Direct examination of the recorded ultrasound images was not undertaken in this study as we were focused on using data that is available to practicing clinicians, is ecologically valid, and is the gold standard for speech production: perceptual speech accuracy (Kent, Miolo & Bloedel, 1994).

Results

Participant 1

Performance during treatment—In each of the 6 treatment sessions, P1 achieved the accuracy criterion of 3 correct responses during the pre-practice phase for progression to the

practice phase. P1 improved her productions of /k/ and /g/ during the practice phase over the course of the 6 treatment sessions from 0% in sessions 1 and 2 to 17-20% over sessions 5 and 6 (Figure 1). As P1 did not reach the 80% correct criterion for progression to higher levels of complexity, single words and connected speech were not treated. Similarly, as P1 did not receive treatment at the single word level, the data from baseline and experimental probes represents generalisation of treatment effects.

Generalisation of treatment effects—Potential generalisation of treatment effects for both /k/ and /g/ was noted during follow-up for P1 (Figure 1), even though P1 only received treatment at syllable level. Visual inspection of figure 2 suggests a low and stable baseline prior to the treatment phase. In contrast, there is a higher level of production accuracy of both /k/ and /g/ in single words with an increasing trend during follow-up (Figure 2). More specifically, P1 showed an increase in the accuracy of production of /k/ at word level from 0% in the first follow-up session to 20% at post-treatment. In addition, P1 accurately produced /k/ in connected speech on 2 out of 19 occasions during the 50-utterance connected speech sample in the final follow-up session. The words were ‘cup’ and ‘carrot’.

Additionally, P1 showed a gradual and greater increase in the production of /g/ at word level during the follow-up period. She improved the production of /g/ at word level from 6.67% to 33% (Figure 2). However, no correct production of /g/ was noted in connected speech in the 50-utterance connected speech sample.

Experimental control—P1’s production of /ŋ/ in single words remained consistently low throughout the study with no clear rising trend (Figure 2).

Participant 3

In none of the 6 treatment sessions, did P3 achieve the accuracy criterion of 3 correct responses during the pre-practice phase for progression to the practice phase (Figure 3).

Experimental control—P3’s production of /ŋ/ at word-level remained consistently low (Figure 4).

Discussion

The aim of the study was to examine the effects of using ultrasound KP visual feedback in articulation therapy to remediate velar fronting in young children. Previous studies on the use of ultrasound with older children, primarily on different phonemes, showed positive treatment effects.

The first case (P1) supported our primary hypothesis and these results suggest that the provision of ultrasound visual KP feedback in articulation treatment facilitates the remediation of velar fronting in young children. This is supported by the presence of a stable baseline prior to the commencement of treatment and the relatively stable production accuracy of the control /ŋ/ throughout the study period (Figure 2). Moreover, P1 had previously received therapy on the production of velars with no success. More importantly, generalisation of treatment effects to the productions of /k/ and /g/ in words was seen and

accurate production of /k/ in connected speech level was emerging in the final follow-up session. This is an important finding, as P1 was unable to reach criterion level for progression to production at word-level during the treatment period and treatment therefore focused only on production at syllable-level. Additionally, P1 never achieved the predetermined criterion of more than 80% for the production of either /k/ or /g/ at syllable-level. This may be evidence that the use of principles of motor learning, which includes the provision of KP feedback, facilitates the acquisition, maintenance and generalisation of speech motor skills. It is possible that P1's changes were due to maturation but we believe that, given the reported persistence of her impairment and the improvement that coincides with the therapy program, this is unlikely.

The second case (P3) did not show any progress in production of either /k/ or /g/. In fact, across all 6 treatment sessions, P3 did not achieve the criterion of 3 accurate productions of velar plosives at syllable-level during pre-practice for him to progress to the practice phase. Thus the results from P3 do not mirror findings from P1 and therefore this participant's data fails to support our primary hypothesis. We speculate that this may be partly due to two subject-specific variables. Firstly, P3 had limited motivation to change his speech. He frequently cried during therapy and required encouragement from both his mother and the clinician to take part in the therapy. On some occasions, he stated a preference to work on his production of [tʔ] rather than [kʔ]. Motivation is an important component of the pre-practice phase that can have an impact on treatment success (McIlwaine et al., 2010). Importantly, according to the Capability-Focus framework, motivation is a crucial variable for progress in speech therapy for children (Kwiatkowski & Shriberg, 1998). Indeed, previous ultrasound studies have also noted lack of motivation as a contributing factor to poor progress in therapy (e.g., Bernhardt et al., 2008).

Another area of consideration from this study is P1's achievement of accurate productions of /k, g/ at word-level at follow-up, suggesting partial support for our second hypothesis. This occurred despite therapy only working on production at syllable-level. While this observation suggests the maintenance and generalisation of speech motor skills facilitated by the use of ultrasound visual KP feedback and the application of principles of motor learning, it also suggests that the accuracy criterion of 80% for progression to complex targets may be too high.

It is important to note that no studies have actually investigated the minimum or optimal percentage accuracy required for progressing to complex targets during articulation therapy. The accuracy criterion of 80% correct responses was an arbitrary decision made in reference to previous speech pathology studies that also utilized the principles of motor learning in designing the treatment protocol (e.g., Ballard et al., 2010). According to the challenge-point framework for motor learning, learning is closely related to the functional difficulty of a task and optimal learning occurs when the learner is correctly challenged by an increase in functional task difficulty (Guadagnoli & Lee, 2004). Therefore, to ensure that learning is optimized, practice should progress to tasks that are relatively difficult (i.e. challenging) for the learner at the appropriate time.

The present study differs in a number of ways from prior research. For example, Cleland et al. (2015) treated velar fronting in children who were slightly older (5-7 years) than the children in this study, and those children also received twice as many therapy sessions. The current study involved a smaller number of treatment sessions and therefore potentially a relatively lower dose of therapy compared to previous ultrasound studies. Specifically, previous ultrasound studies included therapy sessions ranging from 9 – 19 sessions in total (e.g., Bernhardt et al., 2008). Therefore, the 6 therapy sessions in the current study may have reduced the potential to observe measurable progress. However, what is unknown about most of the previous studies is the total number of trials, both per session and in total, and therefore discussion of the impact of total dose or dose frequency is of interest but somewhat speculative.

This research has supported the use of a hand-held ultrasound probe in the use of ultrasound biofeedback which may have higher ecological validity and may aid compliance for younger children rather than using the head stabilised version as reported in Cleland et al., (2015).

Finally, the physiological inability of the children to separately elevate the posterior tongue dorsum while holding the anterior tongue low in the mouth must be a contributing factor in the success or failure of any interventions for velar fronting. As McAllister Byun (2012) and Gibbon (1999) suggest, accurate production requires differentiated neurological control and more research is required to understand the underlying processes which contribute to such control.

Limitations

The current study had a number of limitations. In particular, this study involved a small number of treatment sessions and employed a high accuracy criterion for progression to complex targets during therapy. These factors may have had an impact on the treatment gains observed in the study. Additionally, maintenance and generalisation of treatment effects beyond 3 weeks post treatment could not be established as P1 resumed therapy with a private speech pathologist after the completion of the final follow-up session of the study. An investigation of the long-term maintenance and generalization of speech motor skills could provide greater insights into the effectiveness of using ultrasound visual KP feedback and principles of motor learning in the area of speech therapy.

Future research and clinical implications

This pilot study provides preliminary evidence for the efficacy of using ultrasound visual KP feedback as one option for the remediation of velar fronting in some young children. The results from P1 are consistent with the findings from previous studies from older children with other speech errors, providing further evidence that the use of ultrasound KP feedback facilitates the acquisition of new speech motor skills. More importantly, the findings from P1 suggest that ultrasound visual KP feedback is a possible alternative in speech therapy when traditional methods of therapy have failed, since P1 previously received therapy to remediate her velar fronting with no success. Indeed, should further treatment be required, P1 may have now had the required motor skills to benefit from a linguistic intervention such as

minimal pairs. While the results from P3 are inconsistent with the findings from P1, this may be due to various participant-specific factors such as motivation.

Considering these pilot findings, it appears that further investigation is warranted to provide more evidence for the effectiveness of using ultrasound in providing visual KP feedback during therapy with preschool aged children. Future studies could recruit a larger group of children to explore whether findings from this study can be generalised to other children (and perhaps to reduce the impacts of participant-specific factors on treatment effects). Investigation of longer duration of treatment and long-term maintenance of treatment effects would also be beneficial.

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Declaration of Interest

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Figure 1.
P1's Production accuracy (%) of /k/ and /g/ at syllable-level in treatment sessions

Figure 2.

P1's production accuracy (%) of /k/, /g/ and control /ŋ/ at single-word level during baseline and follow-up sessions.

Figure 3.
P3's production accuracy (%) of /k/ and /g/ at syllable-level in treatment sessions

Figure 4.

P3's production accuracy (%) of /k/, /g/ and control /ŋ/ at single-word level during baseline and follow-up sessions

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Table 2

Results of oral-motor structures and functions assessment for P1 and P3

Oral/Speech Motor Control Protocol (Robbins & Klee, 1987)	P1		P3	
	Raw result	Interpretation	Raw result	Interpretation
Structure	24	WNL	24	WNL
Function	104	WNL	97	<NL
Rate and duration				
/pa/	5 per second	WNL	4 per sec.	WNL
/ta/	4.3 per sec.	WNL	4 per sec.	WNL
/ka/	*	-	*	-
/pətəkə/	1.3 per sec.	WNL	2 per sec.	WNL
pattycake	1.3 per sec.	WNL	1.7 per sec.	WNL
Maximum phonation time	7 sec	WNL	9 sec.	WNL

Note. WNL = within normal limits; NL = normal limits. Dash indicates data not appropriate under the corresponding heading. Asterisk indicates results not found as participant was fronting on all occasions and not stimuable for the production of /ka/ during the assessment.

Table 3

Number and type of sessions received by each participant

	Baseline	Treatment	Follow-up
P1	3	6	3
P3	4	6	3

Table 4
Average production accuracy of control and treated targets across baseline and follow-up sessions for P1

	Treated targets				Control	
	/k/		/g/		/ŋ/	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
P1	0%	13.3%	2.2%	22.1%	0%	4.4%