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CHAPTER 17

THERAPY FOR ABNORMAL VOWELS IN CHILDREN WITH SPEECH DISORDERS

Fiona Gibbon

Introduction

There has been significant progress over the past decade in the range of interventions available for speech sound disorders and also in the quality of evidence supporting their benefits (Bernthal and Bankson, 2004; Bowen, 2009; Ruscello, 2007; Williams, McLeod and McCauley, 2010). Nevertheless, most approaches focus on identifying and remediating abnormal consonants – rather than vowels – in children’s speech. As a result, speech clinicians still have little evidence on which to base clinical decisions about therapy for children presenting with vowel errors in their speech. Although vowel difficulties are relatively infrequent, they should not be neglected in the hope that they will necessarily “look after themselves” (Gibbon, 2009). Indeed, based on extensive clinical experience, Hall, Jordon and Robin (1993) were of the view that children rarely self-correct vowel errors. The current chapter focuses on a range of therapy approaches that are of potential value for increasing the accuracy of vowel production in children with speech disorders. Included in this section are approaches that were developed originally to target consonant errors, but which clinicians could adapt to target vowel errors.

Speech disorders and vowel errors

The literature on interventions for speech sound disorders focuses almost entirely on abnormal consonant production (see review in Stoel-Gammon and Pollock, 2008). Not surprisingly, the overwhelming majority of therapy procedures have developed for the purpose of improving consonant error patterns, and there is a wide range of approaches in routine clinical use (Bernthal and Bankson, 2004; Gierut, 1998; Williams et al., 2010). The various approaches to therapy are based on diverse assumptions about underlying processing difficulties in children with speech disorders. As a result,

different approaches emphasize different therapy goals and employ different facilitative strategies.

Clinicians select one or more therapy approaches based on judgements about the most complementary matching between the assumed underlying speech processing difficulties experienced by the child and the orientation and strategies employed in a particular therapy approach.

Many diverse therapy approaches are reported as having positive effects on children's consonant systems (Bernthal and Bankson, 2004; Bowen, 2009; Ruscello, 2007; Williams et al., 2010). Examples of positive effects include greater accuracy in production of speech sounds, increased phonetic repertoires, more adult-like use of phonological contrasts, more complex syllable structures, and overall improved intelligibility. Although there is now a large body of evidence showing the benefits of therapy for speech disorders, treatment efficacy studies focus almost exclusively on improvements that occur in the consonant system as a result of therapy. In contrast to the extensive literature on therapy for consonant error patterns, relatively few approaches mention their application to vowel error patterns and few studies investigate the effects of therapy for vowel errors in speech disorders.

In Gierut's (1998) review of the literature on treatment efficacy, she specifically highlights the need for research into therapy programs for improving abnormal vowel systems in children with speech disorders. Despite the obvious need for further research, studies investigating the effectiveness of therapy for vowel errors in speech disorders remain sparse. A few small group studies have described direct therapy for vowel error patterns in the speech of children with speech disorders of unknown origin (Hargrove, Dauer and Montelibano, 1989; Gibbon, Shockey and Reid, 1992; Penney, Fee and Dowdle, 1994; Pollock, 1994). In these studies, therapy targeted a range of vowel error patterns and employed a range of previously described articulation and phonological therapy approaches. Despite an early study concluding that vowel errors "tend to be highly resistant to speech therapy" (Adler, et al., 1968, p. 55), these studies present a more optimistic picture of the outcome of therapy targeting vowel errors. Following a review of these studies, Gibbon and Beck (2002) concluded that direct therapy for

vowel errors can have a positive outcome with improvements in vowel production occurring over and above that expected from spontaneous development. These authors noted, however, that studies comparing the relative benefits of different approaches were lacking. As a result, it is not known which intervention approaches are the most effective for children presenting with vowel error patterns in their speech.

Why target vowels in therapy?

Although there are few studies that investigate intervention for vowel errors, there are a number of good reasons for targeting vowel errors as part of a therapy programme, such as to:

- *Improve intelligibility.* Vowel errors often have a significant and detrimental effect on intelligibility, and improving accuracy of vowels is likely to improve speech intelligibility.
- *Increase speech acceptability.* In mild-to-moderate vowel errors, the issue of acceptability of speech quality may arise. Even quite minor residual vowel errors that have little impact on intelligibility, may cause distress by making children's overall speech quality inappropriate for their accent group. Some children with vowel errors also have unusual prosodic patterns, further reducing speech acceptability. Therapy that improves abnormal vowels is likely to increase speech acceptability.
- *Accelerate progress.* There is evidence that children with vowel errors make slower progress in therapy than children with only consonant errors, and vowel errors can persist into the school years in some cases (Adler, Rees, Serwer and Stocker, 1968). Therapy that improves vowel errors is likely to accelerate progress in therapy and avoid problems associated with persisting vowel errors.
- *Restore a normal developmental pattern.* Children with typically developing speech master the vowel system earlier than the consonant system (cf. Donegan, this volume). A developmental perspective suggests, therefore, that vowel errors are a deviant aspect of phonological development and as such should be targeted before consonant errors to restore a normal developmental pattern.

Although these are good reasons for focusing therapy directly on vowel errors, one contraindication is where vowel errors are systematically conditioned by adjacent consonant errors (cf. Bates et al., this volume). In these cases it is logical to target the consonant error, and observe whether the vowel error improves spontaneously.

Vowel therapy: Principles and approaches

Although interventions specifically designed for vowel difficulties are lacking, clinicians are able to apply a variety of general principles and prerequisites when devising intervention for a child presenting with vowel difficulties. An assumption is that children with vowel errors do not form a subgroup separate from those with consonant errors. This assumption allows us to apply similar general principles and therapy approaches to both consonant and vowel errors. A proviso is that any approach requiring children to focus on their own articulatory activity may be somewhat more difficult with vowels than it is with consonants. The high degree of vocal tract constriction involved in consonant production generally results in high levels of tactile feedback which enhance awareness of articulatory placement. With the exception of close vowels, this tactile feedback is greatly decreased during vowel production. The section on principles is followed by descriptions of therapies that clinicians can adapt for use with vowel errors. These diverse approaches are not intended to be mutually exclusive. Rather, it is assumed that effective management of speech disorders involves the clinician selecting and sequencing different approaches to meet children's needs as therapy progresses (Dodd and Bradford, 2000). Although our understanding of the efficacy of different therapy approaches is limited, one approach for vowel errors that is not advocated is non-speech oral motor treatment because there is no evidence to suggest that these activities are effective (Lof and Watson, 2008; McCauley, Strand, Lof et al., 2009).

General principles

A prerequisite for effective identification and treatment of vowel errors is that clinicians themselves should have good auditory phonetic skills so that they can make an accurate perceptual transcription of the vowels used by the child. It is also important that clinicians relate the findings of the analysis to expected vowel production norms in the child's sociolinguistic group (McLeod, 2007). Clinicians need to formulate therapy goals in the light of a clear description of the adult target vowel system (i.e., if and how the target system differs from standard systems). Clinicians' own vowel production skills are also important, so that they can model a full range of vowel qualities during therapy activities. The need for vowel analysis and production skills is especially great in situations where a clinician and a child have different target accents. We return to the issue of developing clinicians' phonetic perceptual and production skills in relation to vowels towards the end of the chapter.

A second general principle is that clinicians need to select appropriate therapy goals and intervention strategies based on detailed phonetic and phonological analyses of the child's speech, an assessment of speech and language processing skills (e.g., Stackhouse and Wells, 1997), as well as relevant information gathered as part of routine clinical assessment. The phonetic and phonological analyses provide a descriptive account of speech error patterns, which the clinician can use to formulate therapy goals. Although an essential part of the assessment process, phonological analyses provide only a descriptive, rather than an explanatory, account of children's speech difficulties. A psycholinguistic profile will, however, suggest which aspect or aspects of speech processing to focus on in intervention and which approach is most likely to facilitate improvements in speech intelligibility. For example, some children may have perceptually-based difficulties in discriminating between similar vowels, whereas others may have difficulties learning how vowels function to convey linguistic meaning in speech. A third possibility is that children have motor difficulties in achieving the precise tongue, jaw and lip positions necessary for accurate vowel productions. These different levels of speech processing

form the rationale for the structure of the sections that follow, which describe a range of therapy approaches that develop processing skills at these three levels.

Approaches to vowel therapy

Altogether we outline six approaches to vowel therapy in the following sections. The first three approaches focus on (1) auditory perceptual skills; (2) linguistic abilities; and (3) motor skills. The final three approaches involve the use of computer-based instrumentation to (4) develop perceptual or phoneme awareness skills; (5) provide visual feedback of acoustic information; and (6) provide visual feedback of articulatory information. Examples are given of how different approaches could be adapted and applied to different vowel error patterns (cf. Bates et al., this volume; Pollock, this volume; Reynolds, this volume; for details of vowel error patterns in speech disorders).

1. Auditory perceptual approaches

The production of vowel errors may be associated with auditory perceptual difficulties, despite normal hearing acuity. There is now considerable evidence that a large proportion of children who present with speech disorders will have difficulties with speech perception to a greater or lesser extent (Maassen, Groenen and Crul, 2003; Rvachew and Brosseau-Lapre, 2010). Although some children have easily identifiable difficulties with auditory perceptual skills, others have more subtle (subclinical) auditory difficulties that co-occur the speech output disorders. Attention to these difficulties can be a beneficial component of speech therapy programmes. Examples of auditory perceptual approaches to therapy are auditory input therapy (Flynn and Lancaster, 1996) and auditory bombardment (Hodson and Paden, 1991). Flynn and Lancaster state that auditory input therapy “aims to enhance the auditory salience of target speech sounds and structures in a natural context” (p. 51). This approach is also called structured listening.

Auditory input therapy emphasizes the importance of children listening to adults producing well-formed utterances containing target sounds. The approach does not require children to produce target sounds. Flynn and Lancaster's view is that it is not necessary to include production practice because the increased opportunities to hear target speech sounds are sufficient to induce positive changes in output in many children. Auditory input therapy aims enhance the auditory salience of target speech sounds through children experiencing increased opportunities to hear well-formed adult productions during naturalistic contexts, such as structured stories and games. The approach maximizes auditory salience of target speech sounds by placing them in contexts that involve maximally clear productions. For example, target speech sounds are placed in words that have primary stress, that occur at the ends of phrases and that are nouns (as opposed to function words).

Auditory bombardment is a component of the Cycles approach to phonological therapy (Hodson and Paden, 1991). In auditory bombardment, children listen for a few minutes to a small set (12-15) of selected words containing the target sound using minimal amplification (called a mild gain assistive listening device). Bombardment takes place at the beginning and end of therapy sessions, and once a day at home. Like auditory input therapy, children are not required to produce target sounds during auditory bombardment activities. Although Hodson and Paden view amplification as an integral part of auditory bombardment, Flynn and Lancaster (1996) point out that no empirical research has compared the effects of amplification versus no amplification during bombardment activities. Flynn and Lancaster view structured auditory input without amplification as effective.

2. Linguistic approaches

Linguistic/phonological approaches emphasize the importance of contrasts and communicating meaning as integral components of the therapy process. In addition, therapy is typically directed towards targeting whole sound classes, rather than individual segments. Examples of phonological

approaches are minimal pair contrast therapy (Elbert, Rockman and Saltzman, 1980), maximal oppositions (Elbert and Gierut, 1986), Metaphon (Howell and Dean, 1994). Reynolds (1990) stated a phonological approach focuses on “awareness and discrimination of minimal differences and on the child's attempts to produce a difference of some kind in a case where they usually neutralised a distinctive opposition” (p. 145), and views phonological approaches as appropriate and useful particularly for younger children.

Minimal pairs therapy, also referred to as minimal pair contrast therapy, is probably the best known and most researched phonological therapy (Baker, 2010; Elbert et al., 1980). Therapy typically involves a game format presenting pairs of words that the child produces as identical (i.e., homophonous). For example, a child with vowel errors might neutralize the /E /, /İ / distinction, producing the minimal pair bed/bad as homophonous [bE d]. In relation to vowels minimal pairs can vary along the dimensions high/low; front/back; long/short and so on. A game format encourages children to produce the word pairs distinctly in order to communicate a message to the listener. The activities aim to engineer situations where communication breaks down if the child produces the word pair as homophonous because the confused listener cannot distinguish between the child's identical forms. In order to repair the breakdown, the child attempts to change his/her usual production in some way in order to get the message across. Through confrontation of minimal pairs, the child learns the communicative importance of producing the contrast distinctly. One limitation of minimal pairs therapy for some children is that success requires adequate motor or articulation skills to produce the target sound.

The maximal opposition contrast approach (Elbert and Gierut, 1986; Gierut 1989), like the minimal pair approach, presents a conceptual approach to phonological therapy. In minimal pairs, phonological oppositions typically vary in one feature, whereas in maximal opposition the phonological oppositions vary along multiple dimensions of voice, manner and place of articulation. In relation to

vowels, target vowels are selected on the basis that they also vary on a number of dimensions. For example, the vowels /i/, /A/ are maximally opposed (on the height and front/back dimension), as are /ī /, /u/. Gierut (1989) suggests that this approach is suitable for children with significant gaps in their phonological systems, or for those who find making the subtle distinctions in minimal pairs difficult. For these children, grosser distinctions may be easier for them to produce, so avoiding frustration particularly in the early stages of therapy. In a multiple oppositions approach (Williams, 2010), a greater number of treatment sets are used simultaneously than in other minimal pairs approaches. This means that in therapy several pairs are presented to the child at once. Thus, if a child produced *bet*, *bat*, *bit*, *boat*, *bite* homophonously as [bE t], then treatment sets would include bet~bat; bet~bit; bet~boat; and bet~bite. In this way, the approach directs treatment across the rule set by selecting a number of treatment targets, in this case four, from the phoneme collapse that are contrasted with the error substitute.

Another phonological approach is Metaphon (Howell and Dean, 1994, and see also the Imagery approach, Klein, 1996). Metaphon aims to increase children's ability to use phonological contrasts between sounds by building metaphonological and metacommunicative awareness and at the same time developing children's ability to use repair strategies. The approach has two phases. The first phase aims to build a shared vocabulary that the child and clinician can use subsequently to explore the phonetic properties of speech sound contrasts. Phase one capitalizes on children's naturally occurring interest in sounds. In phase one, children become increasingly aware of their own and the adult target system, are given opportunities to experiment with new articulatory gestures/configurations. Although there are few accounts of using Metaphon for vowel errors, the approach could be adapted easily for this purpose. For example, developing appropriate images and visual referents for vowel length; lip rounding versus spreading; perhaps tongue position and height; and movement for diphthongs (e.g., the Gibbon et al., 1992, study used a sliding analogy for the movement for diphthongs). Phase two of therapy builds on

the awareness of sounds that children have developed in phase one. Phase two encourages children to use new-found sound knowledge to make distinctions between minimal pairs and to repair errors where communication breaks down.

Reid (2003) devised the “Vowel House” as a child-friendly representational framework for spoken vowel contrasts that also incorporates links to written vowel patterns. The house is a visual representation that is designed to capture the conventional phonetic features of vowels, namely, the four vertical tongue heights (high, high-mid, low-mid, and low vowels) and three categories on a horizontal front-back dimension (front, central, and back vowels). The framework devised by Reid is particularly valuable in providing a principled approach to targeting children’s phonological awareness of vowels, for literacy teaching, and also for targeting persisting spoken vowel production difficulties. The approach has the advantage of supporting both conceptual and phonetic-linguistic aspects of working with vowels and the ‘house’ metaphor for tongue placement encourages children to explore the articulatory aspects of vowel production. Although the framework has been specifically devised for the vowels of Scottish English, it could be adapted for other varieties of English.

3. Motor approaches

Therapy to develop motor or articulatory skills follows general principles of motor learning, which emphasize the importance of providing repetitive, intensive and systematic drills. These drills are used to establish consistency in articulation and reduce variable performance. Motor approaches also emphasize the importance of knowledge of results in the form of verbal, visual, tactile, and/or kinaesthetic feedback on performance. Examples of articulatory approaches include the traditional method (Van Riper and Emerick, 1984), contextual facilitation (Kent, 1982), phonetic placement (Scripture and Jackson, 1925), and the use of tactile and gestural cues (e.g., Hayden, Eigen, Walker and Olsen, 2010; Passy, 1990).

Most approaches, including the traditional method, grade the motor complexity of tasks and this is incorporated into many approaches to treating articulation disorders. Another example of an approach that grades motor complexity, and which specifically includes vowels, is the Nuffield Dyspraxia Programme (Williams and Stephens, 2010). In this programme, each vowel target has an associated visual referent. For example, the diphthong /ɪ | / is associated with a picture of a parrot, and the vowel /i/ with a mouse. The programme provides numerous drill-play exercises building from sounds in isolation to simple alternating sequences and gradually to phrases. The programme has been used with children from 3 years and upwards who have been diagnosed with developmental apraxia of speech.

Some articulatory approaches emphasize the role of phonetic context surrounding target vowels in facilitating correct sound production (e.g., Contextual Facilitation, Kent, 1982). In children with variable productions of vowels, some phonetic environments or linguistic conditions may be more likely to facilitate correct vowel production than others. An awareness of the impact of context on production accuracy is useful, because during therapy, clinicians will want to proceed through a hierarchy from maximally facilitative contexts, to less- or non-facilitative contexts. Kent (1982) identified stress as a factor that could influence accuracy of sound production. For example, stress helps to “assure distinctive and well-formed (non-reduced) articulations” (Kent, 1982, p. 67). In addition, vowel durations are longer in stressed syllables, and more extreme is their articulatory placement than sounds in unstressed syllables. Consequently, the increased acoustic information available in stressed syllables means that sounds are more perceptually distinct to the listener and may supply children with enhanced motor and auditory feedback. In other words, in initial stages of therapy, there are good reasons for selecting words that have target vowels in stressed syllables.

Contextual factors can act to either facilitate or hinder correct sound production and phonetic similarity between adjacent sounds may also have a facilitative effect. Gallagher and Shriner (1975) stated that “large articulatory adjustments seem to place more constraints on the speech production

mechanism, and correspondingly, the chance of error for segments within the motoric unit is increased” (p. 631). In addition to the inherently facilitative phonetic contexts for vowels, correct vowel production will be further assisted by careful choice of consonants surrounding vowels selected on the basis of the phonological analysis of the child’s consonant system and the constraints operating on it. Crystal (1985) reminds clinicians to “teach one thing at a time” (p. 5). When applied to vowel therapy, the implication is that correct vowel production is facilitated in contexts that involve well established, correctly produced consonants and syllable structures. The application of this principle will in almost all cases limit the choice of words available for use in therapy because most children with vowel errors also have reduced consonant inventories and syllable shapes.

Different therapy approaches for speech disorders have used tactile and gestural cues for vowel errors. Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT, Hayden et al., 2010) is an approach that involves the clinician applying a system of external tactile cues (using the clinician's hands) to the external regions of the child's vocal tract. The application of these tactile cues, or “prompts”, are altered in terms of degree of pressure and tension applied to specific muscle groups, and also in terms of the duration of the prompt and speed of application. These tactile cues are applied to the vocal tract structures associated with voicing, nasality and jaw opening. There is a different prompt for each phoneme, including vowels. Some techniques use gestural cues for vowels, for example Cued Vowels (Passy, 1990). Cued Vowels (Passy 1990) include the standard English vowel sounds with hand signs representing where each vowel is made in the mouth, whether there is lip rounding or not and whether they are long, or short monophthongs, or diphthongs.

4. Using computers to develop sound awareness skills

Computers offer new possibilities for engaging children in auditory discrimination and identification tasks. Rvachew and colleagues have conducted a series of studies investigating a procedure known as

Speech Assessment and Interactive Learning System (SAILS, see Rvachew and Brosseau-Lapre, 2010). SAILS is a computer game developed for children aged 3-9 years for the assessment and treatment of phonemic perception, phoneme identification and to establish appropriate phonemic boundaries. The basis for the programme is a series of auditory stimuli, which represent correct and incorrect productions of words. The child identifies whether a production they hear is correct or incorrect. Rvachew's studies have found that children with speech disorders aged 4-5 years who received this auditory/perceptual programme in combination with therapy that focused directly on production, made twice as much progress in achieving articulation accuracy than children whose intervention programmes did not include a speech perception component.

5. Visual feedback of vowels using acoustic analysis

The use of computer assisted visual feedback in therapy derives its effectiveness from making ambiguous internal cues explicit, and enabling conscious control of such cues to develop. In relation to therapy for speech disorders, biofeedback is particularly effective where details of target sound production are difficult to describe to clients. This applies particularly to movement of the visually inaccessible articulators, such as the tongue during production of vowels. Through real-time feedback, the speaker has the opportunity to monitor and change tongue behaviour using techniques that provide feedback using visual displays.

Several systems been available in the past that provide visual feedback of vowel production, based on acoustic analysis, although there has been little research aimed at discovering what type of visual feedback is likely to be of most value to children at particular ages. One issue concerns the timing of the feedback. For feedback to be effective, it needs to follow speech output as quickly as possible, but the dynamic nature of speech means that continuous real-time displays may be too transitory to allow children to interpret the feedback. Moreover, the delayed nature of the clinician's

feedback may not allow children to recognize tactile and kinaesthetic cues and associate them with correct tongue placement and posture as they occur. Many feedback systems therefore involve some mechanism for “freezing” the visual image. Another issue concerns the nature of the visual display. Some feedback displays attempt a visual representation of the articulators, which can support a direct articulatory approach to therapy. Others use abstract displays or games where the visual display is unrelated to the mechanism of speech production and the aim is to maintain children’s attention and reward success.

The use of spectrographic displays for improving vowel production in children with speech disorders has received limited research attention, although there are reports of positive responses with vowel errors associated with other speech pathologies. Spectrograms provide cues for important speech features associated with vowels, with the location and shape of formant bands being the most visually salient cues for vowel identification. Ertmer, Stark and Karlan (1996) used spectrographic displays to improve vowel production in two 9-year-old children. These authors found that both children showed improvement in at least some of the vowels targeted, and there was some evidence of carryover of practised vowel targets to untrained words. The authors viewed one child’s rapid progress in production of some vowels to be due to a sudden insight into the relationship between spectrographic patterns and positioning of the articulators for vowels. The authors stated that the relatively concrete, consistent and immediate feedback provided by the displays allowed the children to be active learners through interaction with the visual displays.

Shuster, Ruscello and Toth (1995) used visual feedback with a 10-year-old boy and a 14-year-old girl with articulation disorders who had been unable to attain correct production of /r/ or /ä ± / despite years of unsuccessful treatment. Intervention used a real-time spectrograph to display a correct /ä ± / produced by the investigator located beside an incorrect /ä ± / produced by the child on a computer screen. The two versions displayed at the same time made visual inspection of differences possible, and

allowed discussions about these differences to take place. Acoustic measures made of the clients' productions before and after treatment indicated that older children and adolescents are able to use this type of visual feedback to attain correct production when other methods have failed.

6. Visual feedback of tongue position during vowels

Visual feedback about tongue position can be achieved using techniques such as glossometry (Fletcher, Dagenais and Critz-Crosby, 1991), electropalatography (Dagenais, Critz-Crosby, Fletcher and McCutcheon, 1994; Gibbon and Wood, 2010) and ultrasound (Bernhardt, Stemberger and Bacsfalvi, 2010). Physiological techniques can provide feedback about articulatory features such as tongue height and its relative position in the front/back dimension. An important advantage of these techniques over indirect acoustic information is that the visual feedback provided is both evaluative and informative with direct articulatory information given about why mismatches occur and how to correct errors.

Electropalatography (EPG) is a technique for recording, visually observing and analysing the tongue's contact with the hard palate during continuous speech (Gibbon and Wood, 2010). EPG has a facility for providing direct visual feedback of tongue-palate contact patterns. An essential component of EPG is a thin custom-made artificial plate moulded to fit the speaker's hard palate. Embedded in the artificial plate are a number of sensors, which are exposed to the lingual surface and detect the presence of contact between the tongue and the hard palate. EPG can be used to provide visual feedback for abnormal production of the relatively close front vowels /i /, /ɪ /, /E / and diphthongs with a close front vowel component such as /eɪ /, /aɪ /, /ɔɪ /. A recent study by Gibbon, Lee and Yuen (2010) has described EPG patterns in typical adults for selected vowels, and McLeod and Singh (2009) provide further information about typical contact patterns for a wider range of vowel. EPG has revealed abnormal contact patterns for vowels in children with cleft palate (Gibbon, Smeaton-Ewins

and Crampin, 2005), although this study did not use the technique to provide visual feedback for abnormal vowel production.

Ultrasound is a non-invasive procedure that can be used to display tongue position during normal and abnormal vowel production. Ultrasound uses the reflective properties of sound waves, with a piezoelectric crystal emitting an ultra high-frequency sound wave and receiving the reflected echo. When the sound reaches the air at the surface of the tongue, it reflects back thereby creating an image of the tongue consisting of a bright white line. It is possible to gain an image of the tongue by placing a transducer below the chin. An attractive feature likely to promote its clinical application for children with speech disorders is that ultrasound, like EPG, has a facility to provide visual feedback of tongue shape and movement. Ultrasound can display dynamic images of the tongue that are not only relatively intuitive and therefore easy to interpret but are also in real time. These features mean that the technique can be used for visual feedback of tongue shape and position with children and adults with speech disorders (Bernhardt et al., 2010).

Ultrasound images of the tongue are relatively easy for children to interpret, making the technique attractive for providing biofeedback (Bernhardt et al., 2010). Bernhardt, Gick, Bacsfalvi and Adler-Bock (2005) developed ultrasound treatment guidelines for English vowels, as well as stops, sibilants, and liquids based on a series of studies with adolescents and adults with hearing impairment or residual speech impairments. Bacsfalvi, Bernhardt and Gick (2007) reported the results of a speech therapy programme for adolescents with hearing loss, which involved the use of ultrasound as biofeedback for vowel production. All participants showed some improvements in tense-lax vowel contrast for high vowels. Although a promising new approach, there is a need for adequately controlled studies to determine whether it is beneficial for children with speech disorders.

Developing clinicians' confidence with vowels

One way to encourage further clinical research into vowel errors is to develop transcribers' confidence and skills in identifying vowel errors. Our experience suggests that vowel analysis is an aspect of phonetics that clinicians and students find difficult. This is probably due to a combination of factors, including the fact that we accept a wide range of accent-related variations in vowels as "normal", as Pollock and Keiser (1990) point out. In addition, vowels seem to be intrinsically more difficult to analyse in any categorical manner, because of the free variation between duration, anterior-posterior and close-open dimensions of tongue position and lip position. A further compounding factor may be the lack of attention to vowels on phonetics curricula. A survey of curricular content of phonetics courses within Speech and Language Therapy education programmes in the United Kingdom (NetPHON, 1995) suggested that analysis of vowels was not given high priority on some courses. Many students are given practice only in broad transcription of Received Pronunciation (RP) or of a limited set of accent types. The increasing awareness of the importance of vowel disorders, which is evidenced by this book, highlights the need for phonetics teaching to develop high level skills in vowel analysis. Clinicians need to develop confidence in their ability to analyse vowels in a way that integrates perceptual quality with articulatory parameters, taking into account factors such as duration and vowel movement. A firm grasp of the acoustic properties of different vowels will build confidence in using computer-based visual feedback techniques for vowel errors (cf. Howard, this volume). Curricula could develop skills in vowel mapping (using a system such as the cardinal vowel system, Jones, 1917), familiarity with a wide range of normal and disordered vowel systems and confidence in using appropriate diacritics to modify vowel symbols of the International Phonetic Alphabet.

Conclusion

The therapy approaches described in this chapter reveal a wide range of possibilities, from which clinicians can select and adapt in order to meet children's needs. Speech clinicians will be familiar with many of the approaches described in this chapter because they are already used routinely in clinical contexts for resolving consonant errors. New technologies offer new opportunities when used as a component of a therapy programme for vowel errors. Furthermore, commercially available computer games designed to develop phonological awareness skills, such as Earobics (Earobics, Cognitive Concepts, 2000), Phoneme Factory (Wren and Roulstone, 2006) and LiPS (Lindamood and Lindamood, 1998) can be attractive and motivating for children as part of a therapy programmes for vowels. Despite these positive recent developments, we agree with Hall et al. (1993) when they stated over a decade ago that "much has yet to be learned about strategies and techniques for vowel remediation" (p. 160).

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