Commercially Available Computer-Based Speech Feedback Systems

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Five commercially available computer-based speech feedback systems (Nasometer, Palatometer, Video Voice, SpeechViewer, and SpeechViewer II) were categorized according to the three-dimensional taxonomy of Watson and Kewley-Port (1989) and according to the speech attributes represented in the systems' displays. The goal of this paper was to provide a framework for the selection and use of computer-based systems for speakers who have speech difficulties secondary to hearing loss. There are limited treatment efficacy data available on these systems with these types of individuals.

The quantity and complexity of computer-based speech feedback systems increased substantially in the last decade (Bernstein, 1989; Kewley-Port, 1994). Some increases were due to expanded knowledge of speech production and speech training. However, most were the result of rapid advances in computing capabilities, especially in digital signal processing (Kewley-Port, 1994). In many applications the advances in digital signal processing have allowed for rapid signal capture, complex analyses, and feedback in real time. In addition, the costs of digital signal processing decreased in the last decade. A consequence of the advances in computing capabilities, as well as the reduced costs, was a noticeable increase in the number of commercially available systems. Various computer-based speech feedback systems were marketed with differing degrees of commercial success as indicated by their ability to remain in the market. The discussion that follows, however, is limited to only five systems: Nasometer (Kay Elemetrics), Palatometer (Kay Elemetrics), Video Voice (Micro Video), SpeechViewer (IBM), and SpeechViewer II (IBM). These systems were selected because of their commercial availability and stability, and because they operate on microcomputers (rather than mini- or mainframe computers) and are limited in their use of peripherals. As a consequence, clinicians are likely to use or consider them for purchase. Other computer-based speech feedback systems have been developed and described in the literature, but are not likely to be used by the average clinician because of hardware complexity or limited accessibility. Readers should see Bernstein, Goldstein, and Mahshie (1988) for a review of some of these systems.

In the following discussion, the feedback characteristics of the five systems will be described relative to the three-dimensional taxonomy of Watson and Kewley-Port (1989) and according to the speech attributes represented in the feedback displays. The taxonomy of Watson and Kewley-Port (1989) considers the nature of feedback in computer-based systems according to the physical source, type of standards or targets accessible, and level of detail. The level of detail is subdivided according to the evaluative and instructional nature of the feedback. As such, the taxonomy is a helpful first step in the analysis and comparison of speech feedback systems because it provides a basis for the appropriate selection of systems for particular clients and populations. It also provides a framework for how they should be employed clinically.

The coupling of clients to computer-based speech feedback systems is a substantive issue. Despite the rapid technological advances in system development, there are few data available to guide their appropriate use in the treatment of speech production. For example, there are only limited treatment efficacy data obtained with these systems when used with children who have speech problems secondary to hearing loss, although children with hearing loss are one of the populations targeted by the developers of these types of systems (IBM, 1988, 1992; Kay Elemetrics, 1992, 1993; Micro Video, 1991). Besides the paucity of efficacy data, it is largely unknown whether these types of systems provide any benefit beyond what clinicians already provide or whether they are cost effective. Viewing feedback systems according to a taxonomy provides a framework in situations in which limited or no treatment efficacy data are available.

DESCRIPTION OF SYSTEMS

The five systems under consideration were evaluated according to the taxonomy developed by Watson and Kewley-Port (1989). The types of inputs (electrophysiologic, articulatory, or acoustic) are listed in Table 1 for each module (distinct component) of each system. The category of electrophysiologic was used according to the Watson and Kewley-Port taxonomy, although none of the systems evaluated utilized this type of input. This category was retained for this discussion because future commercial systems may use this type of input, although at present such inputs (e.g., electromyographic, electroencephalographic) are not viable sources.

The potential types of standards employed by each module were determined with the categories being Sampled, Modeled, Clinician, and Other. Modules were classified as Sampled when productions or stored models obtained from a client were used as standards. If targets were based on an artificial modification of a client's previously sampled productions, or targets established from a simulation of a client's speech or articulatory characteristics, then the module was considered as having a Modeled standard. Modules were classified as having Clinician standards if a clinician's production or stored models could be used as a target. The category of Other referred to norms or stored models established independent of a client and clinician, targets or thresholds that were arbitrarily set by the module, or thresholds set manually by the clinician.

The Level of Detail referred to how much information was present in the feedback (High or Low) and the degree to which a module evaluated the correctness of a client's productions (Representative or Evaluative). Displays were classified as High only if they could represent more than two speech attributes simultaneously, or if the evaluative nature of the modules were represented in more than one manner. Modules were classified as Representative if they simply depicted attributes of speech production without providing evaluative feedback, such as with spectrograms and fundamental frequency contours. Representative modules were further noted if their displays allowed a client to make direct comparisons to a standard. The category of Evaluative was applied if a module provided information about correctness whether it be binary (correct/incorrect) or a goodness-of-fit metric.

Besides the Watson and Kewley-Port taxonomy, the types of speech attributes displayed by each module were also categorized. As indicated in Table 2, the categories of Intensity, Frequency, Duration, Voicing, Vowel Production, and Consonant Production were used. The categories of Vowel Production and Consonant Production were used when vowel or consonant productions were judged or displayed as complex units. The categorizing of modules according to speech attributes was done without regard to the primary focus of the module because many of the modules represent more than a single attribute and can therefore be used to treat various types of speech problems. Discussion of the five units follows.

Nasometer

The Nasometer was designed to assess and treat nasality. The feedback is based on the calculation of a nasalance score, which is the ratio of acoustic energy emanating from the oral versus the nasal cavities. The acoustic input to the

Table 1

Categorization of the Five Speech Feedback Systems With the Watson and Kewley-Port (1989) Taxonomy

		Physical Source			Standard				Level of detail			
					Self		Normative		High		Low	
System	Module	Electro-Phys.	Articulatory	Acoustic	Sampled	Modeled	Clinician	Other	Rep.	Eval.	Rep.	Eval.
Nasometer	Analyze			×				×			×[a]	
	Bar graph			×				×			×[a]	
Palatometer	Palatometer		×	×	×	×	×	×	×[a]			
Video Voice	Formant displays											
	Gobbles model			×	×		×	×	×[a]	×		
	Practice model			×	×		×	×	×[a]	×		
	Drill			×	×		×	×	×[a]	×		
	Free form practice\Gobble			×	×		×		×[a]	×		
	Temporal display			×	×		×		×[a]			
	Pitch-amplitude-rhythm displays											
	Practice			×	×		×	×	×[a]	×		
	Free form			×	×		×		×[a]	×		
	Games			×	×		×	×	×[a]	×		
	Fun 'n games modules											
	Pitch painting			×				×	×			
	Kaleidoscope			×	×			×	×			
	Magic box			×				×	×[a]			
	Driving home			×				×		×		
	Hickory dickory clock			×				×	×	×		

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Table 1 *continued from page 92*

System	Module	Physical Source			Standard				Level of detail			
					Self		Normative		High		Low	
		Electro-Phys.	Articulatory	Acoustic	Sampled	Modeled	Clinician	Other	Rep.	Eval.	Rep.	Eval.
	On the air			×				×	×			
	Jumping jack			×				×				×
	Laser blaster			×		×		×		×		
	Bombs away			×				×				×
	Falling star			×	×		×					×
	Speech ball			×				×				×
	Treasure hunt			×	×		×			×		
	Up, up, and away			×		×		×		×		
	Voice-a-sketch			×	×		×	×				×
SpeechViewer	Sound awareness			×				×			×	
	Loudness awareness			×				×			×	
	Pitch awareness			×				×			×	
	Voicing onset awareness			×				×				×
	Loudness and voicing awareness			×				×	×	×		
	Pitch skill building			×		×		×		×		
	Voicing skill building			×		×		×				×
	Vowel accuracy skill building			×	×		×	×		×		
	Vowel contrasting skill building			×	×		×	×		×		
	Pitch and loudness patterning			×	×		×		×[a]			
	Waveform patterning			×	×		×		×[a]			
	Spectra patterning			×	×		×				×[a]	

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Table 1 *continued from page 93*

		Physical Source			Standard				Level of detail			
					Self		Normative		High		Low	
System	Module	Electro-Phys.	Articulatory	Acoustic	Sampled	Modeled	Clinician	Other	Rep.	Eval.	Rep.	Eval.
SpeechViewer II	Sound awareness			×				×			×	×
	Loudness awareness			×	×		×				×[a]	
	Pitch awareness			×				×			×[a]	
	Voicing onset awareness			×				×				×
	Voicing awareness			×				×	×	×		
	Pitch skill building			×		×		×		×		
	Voicing skill building			×		×		×				×
	Phoneme accuracy skill building			×	×		×	×		×		
	Phoneme chaining skill building			×	×		×	×		×		
	Two phoneme skill building			×	×		×	×		×		
	Four phoneme skill building			×	×		×	×		×		
	Speech segment accuracy and contrasting			×	×		×	×		×		
	Pitch and loudness patterning			×	×		×		×[a]			
	Waveform and spectrogram patterning			×	×		×		×[a]			
	Spectra patterning			×	×		×				×	

[a]These modules allow direct visual comparison to a target although no evaluation of correctness is made by the software.

Table 2

Speech Attributes Displayed in the Modules of Five Commercially Available Speech Feedback Systems

System	Module	Attributes displayed						
		Intensity	Frequency	Duration	Voicing[a]	Vowel Production	Consonant Production	Lingual Placement
Nasometer	Analyze	×[b]		×				
	Bar graph	×[b]		×				
Palatometer	Palatometer			×		×	×	×
Video Voice	Formant displays							
	Gobbles model	×	×	×	×	×	×	
	Practice model	×	×	×	×	×	×	
	Drill	×	×	×	×	×	×	
	Free form practice\gobble	×	×	×	×	×	×	
	Temporal display	×	×	×	×	×	×	
	Pitch-amplitude-rhythm displays							
	Practice	×	×	×				
	Free form	×	×	×				
	Games	×	×	×				
	Fun and games modules							
	Pitch painting	×	×	×	×			
	Kaleidoscope	×	×	×	×			
	Magic box	×	×	×	×			
	Driving home	×		×	×			
	Hickory dickory clock		×	×	×			

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Table 2 *continued from page 95*

System Placement	Module	Attributes displayed						
		Intensity	Frequency	Duration	Voicing[a]	Vowel Production	Consonant Production	Lingual
	On the air	×	×	×	×	×	×	
	Jumping jack	×		×	×			
	Laser blaster	×	×	×	×			
	Bombs away				×			
	Falling star				×	×	×	
	Speech ball			×	×			
	Treasure hunt					×	×	
	Up, up, and away	×		×	×			
	Voice-a-sketch			×	×	×	×	
SpeechViewer	Sound awareness			×				
	Loudness awareness	×		×				
	Pitch awareness		×	×				
	Voicing onset awareness				×			
	Loudness and voicing awareness	×		×	×			
	Pitch skill building		×	×				
	Voicing skill building			×	×			
	Vowel accuracy skill building					×		
	Vowel contrasting skill building					×		
	Pitch and loudness patterning	×	×	×	×			
	Waveform patterning	×	×	×	×			
	Spectra patterning	×	×	×	×	×		

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Table 2 *continued from page 96*

System	Module	Attributes displayed						
		Intensity	Frequency	Duration	Voicing[a]	Vowel Production	Consonant Production	Lingual Placement
SpeechViewer II	Sound awareness	×		×				
	Loudness awareness	×		×				
	Pitch awareness		×	×				
	Voicing onset awareness				×			
	Voicing awareness	×		×	×			
	Pitch skill building		×	×				
	Voicing skill building			×	×			
	Phoneme accuracy skill building					×	×	
	Phoneme chaining skill building					×	×	
	Two phoneme skill building					×	×	
	Four phoneme skill building					×	×	
	Speech segment accuracy and contrasting					×	×	
	Pitch and loudness patterning	×	×	×	×			
	Waveform and spectrogram patterning	×	×	×	×	×	×	
	Spectra patterning		×	×		×		

[a]The category of Voicing includes feedback on voice onset and offset.
[b]Nasalance as a relative measure of oral versus nasal energy.

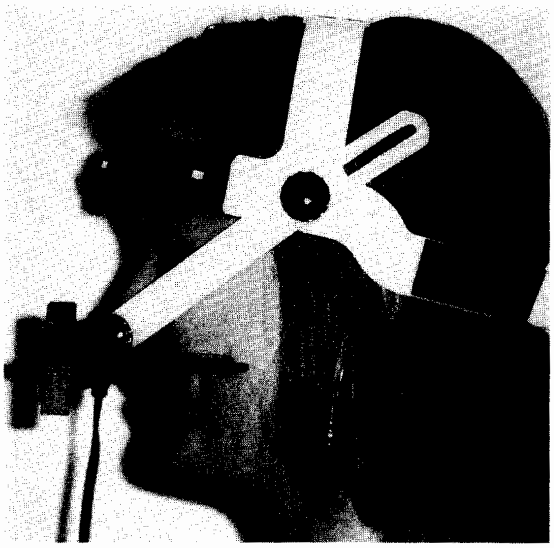

Figure 1. Headset for the Nasometer.

Nasometer comes from two directional microphones separated by a metal plate. This separation plate is placed on the upper lip between the nose and mouth and is held in place with a headset (see Figure 1). The microphones feed into an external interface that connects to a circuit board housed within a computer.

The Nasometer has two distinct displays or modules. The Analyze Module is useful in the assessment of nasality but can be used in treatment because it provides a visual trace of nasalance over time. The Bar Graph display was specifically designed by the developers of the system for treatment and represents fluctuations of nasalance in real time; the bar rises toward the top of the display as the percentage of nasalance increases and lowers as the percentage of nasalance decreases. As indicated in Table 1, the level of detail for both types of displays is low, with neither providing direct information about the correctness of productions. A target can be set externally by the clinician relative to previous performance by the client or normative samples, but correctness is decided by the clinician or the client.

Drawbacks of this system are that the menu and headset are awkward. The menu is layered, without the use of windowing or function keys, which adds steps when maneuvering through it. The headset is problematic because the separation plate is bulky and the pressure it applies to the upper lip can be uncomfortable if used over an extended period of time. These drawbacks are likely to be overlooked, however, because Nasometer is one of few systems commercially available that can be used to treat problems with nasality.

Palatometer

Together with acoustic input from a microphone, the Palatometer accepts articulatory input from a thin plastic, custom pseudopalate in which approximately 96 electrodes are embedded (see Figure 2). The microphone and pseudopalate are connected to a peripheral interface which in turn is connected to an internal circuit board. The pseudopalate is placed over the upper dentition and palate and held in place by the surface tension form by the saliva on these structures. Each pseudopalate is custom built and comes with a calibration file that translates the electrode arrangement in the pseudopalate to the software and ultimately a visual display. Via the visual representation (palatogram) of the electrode configuration, the Palatometer displays information about circuits in the pseudopalate that are completed due to lingual-palatal contact (see Figure 3). The design of the feedback display is flexible. Clients can view electrode displays with or without target displays for comparison and the target displays can be inputted or constructed. The system has the potential of providing feedback relative to hits, misses, false positives, and false negatives through size and color coding, with the complexity of the code set by the clinician. Two-channel displays can be used in which the clinician is connected to a separate channel. In addition, a number of post-hoc feedback and analysis schemes are available, and the option exists by

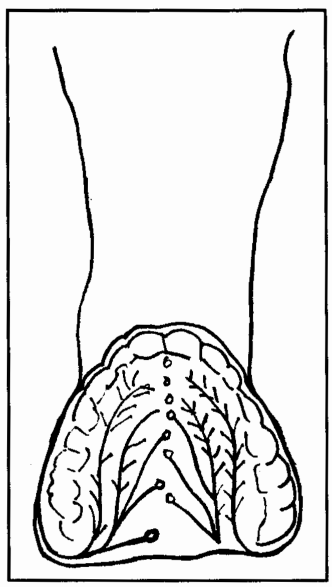

Figure 2. Pseudopalate for the Palatometer.

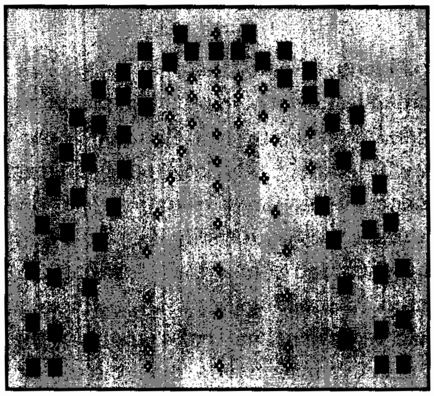

Figure 3. Palatogram for a /t/ production. (The squares represent locations on the pseudopalate where lingual-palatal contact was made.)

which the data can be exported to the Computer Speech Laboratory (Kay Elemetrics) software for more extensive offline analysis.

The feedback of the Palatometer is largely representative, with correspondence to a target being the typical therapeutic format. The level of information displayed is substantial and can require a large amount of cognitive processing by a client and clinician. The Palatometer is the only one of the five systems that uses articulatory and acoustic, rather than just acoustic, input. The use of articulatory input should be an advantage with speakers who are hearing impaired because the feedback does not require a functioning auditory system and is more directly linked with the activities targeted for modification. As a result, the Palatometer comes closer than other systems to informing speakers what changes are needed rather than just feedback on accuracy or correspondence. One limitation, nonetheless, is that the feedback is limited to sounds requiring lingual-palatal contact and many speakers with hearing loss have speech differences that extend beyond problems with lingual-palatal contact.

Two additional drawbacks exist for use with children. The first is the need for the construction of a custom pseudopalate, which can be a lengthy and expensive process. It requires a dental impression so that a stone cast of the upper palate and dentition can be made. A preliminary pseudopalate (without electrodes) is constructed from the stone cast and if it fits adequately a pseudopalate with electrodes is constructed. The cost of this process is in addition to the cost of the basic system and can introduce a delay between identification and treatment. It is also a process that may have to be repeated due to oral changes (e.g., dentition and growth) or inadequate fit. The second drawback is the cognitive demand of the feedback (as suggested above) as well as the cognitive demand for appropriate care of the instrumentation. As a consequence, Kay Elemetrics (1993) recommends not using the Palatometer with children below 5 years of age.

Video Voice

The Video Voice system is a complex multi-modular speech feedback system that uses acoustic input. The speech is directed from a microphone to a peripheral interface and then to a board housed within a computer. Many of the modules are inter-related and are grouped according to three families of modules: Formant Displays, Pitch-Amplitude-Rhythm Displays, and Fun and Games. The Formant Displays consist of a quadrant that represents the F1/F2 vowel formant relationship with inputted speech represented as a series of dots that correspond to the formant frequencies. With time and changes in production, a multiple dot trace is produced on the display. An overlay of the English vowel space can be imposed on the quadrant. Consonant, fundamental frequency, and intensity are also roughly represented in the quadrant. The display can be used with or without a standard, and it can be used in game-like formats. When comparisons are made to a predetermined model or standard, a goodness-of-fit metric can be displayed for all of the modules except the Temporal Display. Mobiles (moving cartoon figures) are also included in the Formant Displays. These mobiles are activated when a speaker reaches a preset threshold for the goodness-of-fit metric, but they can also be controlled independently by the clinician.

The display of dots in the Formant Displays is a relatively simple type of visual image, although it carries substantial information. The inclusion of the goodness-of-fit metric and the mobile further increases the level of detail. The Formant Displays provide clients with information about relative correspondence and some additional information about the degree of accuracy. However, like many of the modules in the various systems, they suggest little in the way of how to direct change. The actual tasks vary with the different modules and standards, and are largely at the discretion of the clinician.

The Pitch-Amplitude-Rhythm Displays consist of three modules that can be used to display either the overall intensity or frequency of speech productions as a function of time. The displays are activated by voicing, and the voicing onsets and offsets are used by the modules to assess rhythm. Amplitude is represented as the positive portion of a waveform envelope and frequency is depicted as a contour. The Pitch-Amplitude-Rhythm Displays can be used with or without a standard. When a predefined model is used for comparison, the displays include two goodness metrics; one for rhythm and one for either frequency or intensity. As with the Formant Displays, mobile reinforcers and game-like formats are also included.

The Fun and Games Modules are a set of 14 videogame-like displays that vary in difficulty, treatment focus, and level of detail. For example, some displays provide simple color representations of pitch and intensity whereas others can provide feedback about the correctness of words and phrases. The games can range from acoustic activation of a kaleidoscope to a person jumping a hurdle in response to a voice onset, or a maze that is negotiated with correct word productions. Most of the displays are highly flexible and allow the clinician to adapt the display to fit the needs of individual speakers. Tables 1 and 2 illustrate the diversity of this group of modules.

Video Voice is a highly flexible system with a substantial number of modules and a wide range of options. The feedback characteristics of most of the modules can be modified substantially by a clinician. In addition to the more easily represented attributes of intensity, frequency, duration, and voicing, Video Voice provides information about the correctness of consonants and vowels in several of its modules.

SpeechViewer

SpeechViewer is an earlier version of SpeechViewer II which will be described subsequently. Although an earlier version, SpeechViewer was included in this discussion because it was purchased by and is currently being used in many facilities where speech services are provided. It was designed for acoustic input although other transducers such as accelerometers have been used (Horii et al., 1990; Rainier & Pratt, 1994). The transducers and an output speaker plug directly into an internally housed digitizing board. Like Video Voice, SpeechViewer is a multi-modular system. It is divided into three types of feedback modules: the Awareness Modules, Skill Building Modules, and Patterning Modules.

The Awareness Modules provide simple cartoon-like visual representations of selected attributes of speech without models for comparison and without any evaluation by the software. For example, the Pitch Awareness Module represents changes in fundamental frequency with the raising and lowering of mercury in a thermometer. It does not tell the speaker whether his/her fundamental frequency matched a previous sample nor does it indicate whether the production was correct.

The Skill Building Modules provide evaluative feedback and are more game-like than the Awareness or Patterning Modules. A high level of detail is used in these displays, thus young children may have difficulty using all of the information provided (Pratt, Heintzelman, & Deming, 1993). These modules are flexible in that the level of difficulty and type of standards used are largely dictated by the clinician. Included in the Skill Building section is a module dedicated to the construction of vowel models. This module is a positive aspect of the system because it allows for the construction of vowel models from various sized sets, and represents (in the resulting matrices) the variability of the samples. Therefore, thresholds can be set by the clinician independently of the naturally occurring variability.

In contrast, the Patterning Modules provide traditional graphic representations of acoustic signals such as waveforms, fundamental frequency contours, intensity envelopes, and spectra. Most of the displays include a substantial amount of detail but provide little in the way of evaluation of speech productions. Comparisons can be made to models but the clinician and client must decide the adequacy of the fit. These modules tend to be used more with older children and adults than younger children because of the level of detail and the need for external evaluation.

SpeechViewer II

As indicated previously, the SpeechViewer II is an update of the original SpeechViewer. The nature and organization of the system are similar to the original version. Like its predecessor, SpeechViewer II is multi-modular and designed for acoustic inputs. Various types of standards can be used depending on the module, and much of the feedback relates to multiple acoustic dimensions. Nonetheless, there are some notable differences. The Awareness Modules allow for more comparison to targets, whereas several of the SpeechViewer Awareness Modules simply depicted attributes of the speech productions. In the Patterning Modules, a spectrogram was added to the Waveform Module making the feedback more complex. The Accuracy Modules were also expanded to include consonants and a chaining task. The chaining task consists of producing three sounds correctly in a set sequence. Feedback is given for each sound and an audiovisual reinforcer is activated when the entire task is completed correctly. Another change was the inclusion of a Two Phoneme Comparison Module in which a client maneuvers an actor through an obstacle course by producing two different sounds correctly. To move an actor left, the client must say one of the sounds correctly; to move it right, the other sound must be produced correctly, all while the actor moves forward. This module is similar to the Falling Star Module in Video Voice.

One of the most substantive changes is the addition of an accuracy module called Speech Segment Accuracy and Contrasting Module. It allows for comparisons to previously sampled utterances, including words, phrases, or short sentences. With this module, a speaker attempts to produce the target and the module provides binary feedback (accurate/inaccurate) on the entire utterance, not just single phoneme categories. The feedback is reflected in a single action by the module, such as a bumble bee flying to the center of a flower. The feedback is neither dynamic nor immediate. However, given the amount of processing required, the time delay is not unreasonable.

The quality of the feedback was also changed. The graphics and animation were improved and more mobiles were added to each module. The inclusion of more mobiles is helpful when systematic and long-term treatment occurs with a given module. The hardware was upgraded and the reliability of the vowel accuracy feedback appears to have improved. An additional feature is the incorporation of a data tracking system that can be used with all of the modules.

SUMMARY OF SYSTEMS

The Palatometer and Nasometer are special purpose systems that provide very specific types of feedback, largely information about correspondence to a target. The Palatometer provides the most direct feedback of all of the systems and is highly flexible in its use of standards and feedback arrangements. Video Voice, SpeechViewer, and SpeechViewer II are more multipurpose, acoustic-based systems. The Video Voice has the broadest range of options and the most modules of these three multipurpose systems. SpeechViewer II's more limited range is offset by being highly evaluative and more sophisticated concerning graphics, animation, and signal processing. Many of the systems' displays provide a high level of detail, although most of them can be simplified. High levels of detail can be troublesome when treating young children, as suggested previously with the Palatometer. Clinicians need to be cognizant that more information does not necessarily mean better feedback (Levitt, 1989). For example, the bar graph produced by the Nasometer is simple and easily interpreted by most speakers. In contrast, the Formant Display in Video Voice is more complex with determination of correctness less transparent. The feedback provided in the Patterning Modules in SpeechViewer and SpeechViewer II are also very complex and require knowledge of speech acoustics to easily ascertain acceptability.

An additional comment is that all of the systems have some type of data management capabilities. SpeechViewer II and Video Voice allow for online data acquisition in the background. Video Voice also has a mechanism for individual education plan construction. All of the systems include in their manuals therapeutic suggestions and warnings about inappropriate use.

TREATMENT EFFICACY

As indicated earlier, treatment efficacy data on these systems are lacking, particularly as applied to individuals with hearing impairment. Data do exist in the literature from treatment studies that were conducted with prototypes of, or systems similar to the Palatometer and Nasometer (Fletcher, Dagenais, & Critz-Crosby, 1991; Fletcher & Hasegawa, 1983; Fletcher & Higgins, 1980). It seems reasonable that those data can be applied to the commercially available systems. However, a weakness of most of the studies is that pre-test/post-test designs were used without adequate controls. For example, Fletcher and Higgins (1980) did not use a control group when assessing the treatment efficacy of the TONAR II for improving nasal resonance in children with a profound hearing loss. Fletcher and Hasegawa (1983) treated a young child who had a profound hearing loss with palatometry and glossometry simultaneously. They concluded that the child's productions of the vowels /i/ and /ɑ/ and the consonant /t/ improved with treatment. However, they did not document stable pre-treatment baselines and their design was insufficient to establish that their system was the sole source of any progress made. Fletcher et al. (1991) also did not use a control group when treating consonant production with palatometry. They treated a group of 5 children having profound hearing loss and observed positive changes from the pre-test to the post-test. Nonetheless, normal variability and development were not taken into account, nor was the fact that these children were also being treated for vowel production via glossometry. Because controls were not imposed (such as a control group or the use of a single-subject design), other sources of change could not be eliminated. In contrast, Dagenais, Critz-Crosby, Fletcher, and McCutcheon (1994) recently compared traditional aural-oral treatment of consonants with treatment via palatometry. A pre-test/post-test design was used but a control group was included. In addition, group membership was randomly assigned. They found that palatometry was at least as effective (possibly more effective) as the traditional aural-oral approach in treating consonant production in children with profound hearing impairment.

There have been no published studies using the Video Voice or SpeechViewer II. A number of treatment studies using SpeechViewer were funded by IBM and the American Speech-Language-Hearing Foundation but few of those studies were published in peer-reviewed forums and only two of the studies pertained to subjects with hearing impairment (Mahaffey, 1991). Pratt et al. (1993) found that the Vowel Accuracy Module was effective in the treatment of vowels in young children with hearing impairment, although their results were vowel and child dependent. Rainier and Pratt (1994) used a single-subject design and found that the Loudness Awareness Module with accelerometric input was effective in treating nasal resonance in a school-age child with a profound hearing loss. They also observed significant generalization.

There are multiple reasons why published treatment efficacy data are scarce. One reason is that collecting treatment data is labor intensive and time consuming, and therefore expensive. Applied treatment research in the area of communication disorders also tends to have a lower priority for funding as compared to basic and clinically-related research (McNeil, 1994). In addition, treatment data collected with computer-based feedback systems have the potential of becoming obsolete by the time the studies are completed because the systems can be updated so readily. The obsolescence of the systems and data does not mean that treatment efficacy studies should not be conducted on these systems. If computer-based feedback systems are judiciously viewed according to their feedback characteristics, such as with the Watson and Kewley-Port (1989) taxonomy, then data resulting from their use can be extended to other systems having similar characteristics.

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