Evidence-Based Practice

It is the position of the American Speech-Language-Hearing Association that audiologists and speech-language pathologists incorporate the principles of evidence-based practice in clinical decision making to provide high quality clinical care. The term evidence-based practice refers to an approach in which current, high-quality research evidence is integrated with practitioner expertise and client preferences and values into the process of making clinical decisions.

Participants are encouraged to actively seek and critically evaluate the evidence basis for clinical procedures presented in this and other educational programs.

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The phrase evidence-based practice seems to be on everyone’s lips these days. Whether we are practicing speech-language pathologists or university researchers, we are now all being asked to carefully examine what we do (or teach our students to do) to be sure that there is rational evidence that it actually works. As appealing as it might be, the retort “I know that it works because I see changes happening” is simply not sufficient anymore. While it is true that change usually accompanies the work we do with our clients, can we really be certain that the change was due to the specific things that we did? Can we say that it wasn’t due to development or the normal recovery process or due to some other influence? Without evidence from controlled studies we can never be sure.

Do we have enough evidence yet to engage in truly evidence-based practice? The simple answer is no. There are a lot of things that we do clinically that are founded simply in our best guesses about what we think should work...but we don’t actually have any evidence that these things work. Fortunately, the situation is changing. As I hope you will see in this forum, there is a body of evidence emerging on several clinical fronts; the authors herein were approached because they are among the group of clinicians and researchers who have been asking the hard questions.

This forum covers a broad range of topics related to speech sound disorders. The topics themselves were chosen because they represent what clinicians do to greater and lesser extents. Although theories are discussed, the focus is on some common clinical practices and on the evidence that we have available to us about them.

The first two papers focus on long-standing areas of interest to most speech-language pathologists, but are topics that have also long been controversial. In his discussion of stimulability, Tom Powell reminds us of the ongoing controversy about what it represents and what we should be doing with the information we gain from it. His conclusion that we should probably focus on non-stimulable sounds may seem almost as controversial to some as the topic itself.

Speaking of controversy, Greg Lof pulls no punches in his discussion of using oral motor exercises to treat speech sound errors. Having heard Dr. Lof discuss this topic at ASHA Conventions and informally for the last few years, I felt certain he was the right person to tackle it here. His conclusion, that there is no valid justification for their use, is sure to raise many eyebrows. Like all the other papers in this forum, Dr. Lof sticks to the evidence, and it is difficult to argue with hard data.

The remaining four papers in this forum are likely less controversial, but are of interest because of their relevance and timeliness. Lynn Williams addresses a question that is always on the minds of clinicians: how one selects targets for intervention for children who present with multiple sound errors. She reminds us that we need to focus on the function of the sound in the child’s language system. She also notes that intervention is likely to be most successful if we select what she calls “non-proportional” contrasts. Finally, she introduces us to her “distance metric” and describes a rationale for selecting specific target words to use in treatment, in the process drawing on the literature from cognitive science.

Susan Rvachew’s paper on computer applications examines some of the available digital solutions to speech sound assessment and intervention. Of particular interest to some may be her brief discussion of the literature related to electro-palatography, a technology long available but still not widely applied. Her discussion of the effectiveness of all of these technological solutions will, I hope, motivate more speech-language pathologists to try them out.

No discussion of speech sound disorders today would be complete without dealing with phonological awareness. Heidi Harbers takes an interesting approach to this issue. We know that children with speech sound disorders are at increased risk for reading failure, and we know that phonological awareness skills can help us predict reading outcomes. But isn’t some of what we do in treating speech sound errors a form of phonological awareness training? Dr. Harbers asks the question: Does speech sound intervention indirectly improve phonological awareness? Put another way, she is asking: Is it necessary to teach phonological awareness to these children directly or not? Dr. Harbers addresses this question head on, but her paper will probably have its greatest appeal in the series of very specific suggestions she makes for assessment and intervention related to phonological awareness.

Finally, Barbara Bernhardt provides us with a glimpse into her research program on the application on nonlinear phonological theory to clinical speech sound issues. Although this theoretically rich topic requires the reader to pay very close attention to detail to reap the full benefit, the evidence Dr. Bernhardt presents for the effectiveness of using this approach is well worth the effort.

All of the authors in this forum have taken their task very seriously. They all demonstrate that there is much we do know about what does and doesn’t work in treating speech sound disorders. They also remind us of what is yet to be learned.
Stimulability and Treatment Outcomes

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Virtually every speech-language pathologist has assessed stimulability at one time or another. Procedures for stimulability testing are described routinely in textbooks on speech sound disorders in children, and stimulability has been the subject of scientific study for about 50 years (See Powell & Miccio, 1996 for a review). Given the long history and popularity of the procedure, it may be somewhat surprising that considerable controversy exists on how stimulability is to be defined, measured, interpreted, and applied in the clinical setting. This article attempts to synthesize key research findings regarding stimulability, with an emphasis on its relationship to treatment outcomes.

Defining Stimulability

Stimulability assessment seeks to determine whether production of an errored sound is enhanced when elicitation conditions are modified (i.e., simplified). Given auditory and visual models, if a child produces a target sound correctly when linguistic demands are minimal (as in isolation or in CV, VCV, or VC syllables), then the child is said to be stimulable for that sound. Thus, “stimulability” refers to improvements in performance under controlled imitative conditions vis-à-vis non-imitative conditions.

Over the years, the construct of stimulability has evolved. Most research published prior to 1970 operationally defined stimulability as the percentage of improvement averaged over all sounds in error (Sommers, 1983). It was viewed as a generalized ability, reflecting the fact that some children profit more from visual and auditory models than others.

Today, however, most speech-language pathologists view stimulability as a sound-specific construct (Powell & Miccio, 1996). This viewpoint acknowledges that a child may improve production of certain sounds differentially under imitative conditions (e.g., a child may be stimulable for target interdentals /θ/ and /ι/, but not for dorsals /k/ or /g/).

There has been much debate regarding the implications of stimulability in terms of motor, perceptual, and linguistic abilities. Most seem to agree that stimulability provides evidence of the structural and functional integrity of the speech production mechanism under certain (limited) conditions (Powell & Miccio, 1996). For this reason, stimulability data are deemed of greatest interest and utility when the client’s phonetic inventory is severely restricted. Accordingly, most of the more recent research in this area has studied the role of stimulability in treating speech disorders of preschool children. Older children typically have fewer sounds in error and are more likely to be stimulable (Lof, 1996).

The relationship between stimulability and perceptual skills has been a topic of considerable debate and research. It has been argued that stimulability entails a certain degree of perceptual integrity. To replicate a sound that is not part of one’s phonetic repertoire, one must perceive the signal (via the auditory or visual modality) and recognize it as unique (Powell & Miccio, 1996). This statement does not, however, imply that children with high scores on perceptual tests will necessarily do well on a stimulability task (or, indeed, the reverse). Instead, research to date indicates that performance on perceptual tasks and stimulability tasks are independent of one another (Lof, 1996; Rvachew, Rafaat, & Martin, 1999). Lof (1996) also provided evidence that highly visible sounds (e.g., /t/ or /t/) are more likely to be stimulable than sounds where the articulators are less visible (e.g., /k/). Some children with auditory perceptual problems may exploit visual cues to compensate for their auditory problems.

The linguistic implications of speech sound stimulability have also been a source of debate. Dinnsen and Elbert (1984) suggested that stimulability reflects some degree of linguistic knowledge. Implicit in the production of a novel sound is the recognition that the sound is independent and in contrast with the habitual (incorrect) form. A similar viewpoint was presented by Edwards, Fourakis, Beckman, and Fox (1999) who noted, “...if the child who ‘substitutes’ [t] for /s/ can be stimulated to produce the errored sound (i.e., if the child can make an imitative production of [s] in isolation that is perceived as [s] by the clinician), the child must at some level ‘know’ how to produce the feature [strident] that distinguishes these two fricatives” (p. 171). Lof (1996), however, reported that stimulability is unrelated to language skills. He argued that stimulability provides information about phonetic (but not phonemic) abilities and thus provides no information regarding the child’s underlying (phonemic) representation.

Measuring Stimulability

Stimulability data are most useful when they are collected for sounds that are missing from the child’s phonetic inventory—that is, sounds that were never produced by the child during the collection of spontaneous speech samples or standardized single-word articulation tests. In published reports, there has been diversity in the stimulus and response paradigms that were used to measure stimulability. Some of these variations will be reviewed here.

Stimuli. Stimulability assessment, by definition, involves imitation. Typically, the child is asked to look at the examiner’s mouth and to listen as the examiner produces the target sound in isolation and in syllables; thus, paired auditory and visual stimuli are provided. An adaptation of Carter and Buck’s (1958) nonsense syllable task has often been used to assess stimulability (Farquhar, 1961). This procedure elicits the target sound in isolation and in nine nonsense syllables. For example, stimulability of target /θ/ would be evaluated with the following items: /θu:/, /θi/, /θi/, /θu/, /θe/, /æθ/, /θæ/, /θæ/, /æθ/, /θæ/, /æθ/. This procedure is time efficient, typically taking less than one minute per phoneme to collect. Some examiners
augment this basic procedure by assessing production of the
target sound in words, phrases, and/or sentences.

By design, the basic stimulability paradigm involves presenta-
tion of a decontextualized stimulus; however, alternative
procedures have been described that employ stimuli that
are presented in the context of a storybook or play activity
(Hoffman & Norris, 2002; Tyler, 1996). These procedures
may be especially useful when assessing the stimulability
skills of toddlers or children with more generalized disorders
of language.

**Responses.** As noted above, multiple imitative responses
(typically 10) are elicited for each target sound. Credit is
given for responses that are consistent with the response
definition for that target sound, and a percentage of correct
productions can be computed. Some examiners allow two or
more attempts per target production, whereas others allow
only one.

**Interpretation of Stimulability Data**

Production of a sound during stimulability testing attests, to
some degree, to the child’s ability to perceive, to recognize
as different, and to produce the sound in question (Miccio,
2002). If the child is not stimulable for a sound, then one
might question the child’s motoric, perceptual, or linguistic
abilities. In addition, other conditions (such as poor attend-
sing skills or non-compliance) are likely to impact stimulability
scores negatively.

To date, few prospective research studies have examined the
relationship between sound-specific stimulability and speech
sound learning in preschool children (Miccio, Elbert, & Forrest,
1999; Powell, Elbert, & Dinnnsen, 1991; Rvachew et al., 1999).
Despite variations in methodology, these studies collectively
suggest a strong, but imperfect, relationship between stimu-
lability and sound learning. If a child is stimulable for a sound,
then that sound is likely to be added to the child’s phonetic
inventory, even without direct treatment on that sound (Miccio
et al., 1999; Powell et al., 1991). In contrast, if a child is not
stimulable for a target sound, then the likelihood of short-term
gains is poor (Miccio et al., 1999; Powell et al., 1991; Rvachew
et al., 1999). The prognosis for short-term normalization of
sounds that are not stimulable appears much poorer than for
sounds that are stimulable.

**Application of Stimulability Data**

In the clinical setting, stimulability data have clear utility.
Stimulability appears to be a requisite, although not sufficient,
factor in the generalization of correct sound production. Many
treatment approaches encourage the speech-language
pathologist to focus treatment first on sounds for which the
child is stimulable. While gains in the production of stimulable
sounds are anticipated following the initiation of treatment, the
available research suggests that those gains will be limited in
nature and are unlikely to affect other aspects of the child’s
phonological system. Indeed, stimulable sounds are likely
(but not guaranteed) to improve regardless of what is taught
(Powell et al., 1991).

To maximize treatment effects, speech-language pathologists
should consider addressing sounds that are not stimulable
early in their treatment program (Powell & Miccio, 1996).
Sounds that are not stimulable are unlikely to change without
direct treatment, and the response evocation phase of treat-
ment is likely to be extended. One strategy that can be used
by speech-language pathologists is to encourage exploratory
sound productions and provide phonetic placement or other
types of cues to effect stimulability skills (Rvachew et al.,
1999). Once stimulability has been achieved, generalization
is more likely to be observed.

One argument against giving priority to treatment targets that
are not stimulable has been the presumed greater potential
for frustration on the part of the client (Bleile, 1994, 2002).
To minimize frustration, speech-language pathologists may
find less directive sound play activities to be an enjoyable
way to foster production of sounds that were not stimulable
(Miccio, 2002; Miccio & Elbert, 1996; Powell, 1996). The
speech-language pathologist can provide the nurturing and
the supportive environment necessary for the child to expand
his or her phonetic repertoire.

**Conclusion**

Despite methodological and theoretical differences, research
findings regarding the clinical utility of stimulability assess-
ment are quite consistent: sounds that are not stimulable have
a poorer short-term prognosis than those that are stimulable.
Consequently, treatment outcomes are likely to be enhanced
when speech-language pathologists use their skills to address
production of sounds that are not stimulable; the stimulable
sounds are likely to improve, even if they are not targeted
directly for treatment.

Although robust findings regarding stimulability and speech
sound learning are beginning to accrue, there remain many
unanswered questions. Stimulability assessment procedures
clearly need to be refined and standardized. Predictive validity
studies would be especially useful in this regard.

Systematic replications are needed to extend our knowledge of
interactions between stimulability and speech sound learn-
ing to include children of different ages, different diagnoses,
and different backgrounds. For example, the implications of
stimulability for childhood apraxia of speech (CAS) have not
been adequately investigated (Powell, 1996).

The utility of stimulability assessment with children speaking
languages other than English also deserves additional study
(Goldstein, 1996). The relationship between stimulability and
phonological differences across languages in bilingual and
polyglot speakers would be an especially interesting topic
for study.

Stimulability may also provide a useful metric for helping to
distinguish dialectal differences and speech production
disorders. For example, [l] may be excluded from the pho-
etic inventories of speakers of some non-standard dialects
of North American English (e.g., African American English
Vernacular, Cajun-influenced English). Stimulability for pro-
duction of /a/ (especially at at the phrase or sentence level)
might provide some evidence for the integrity of the motoric
systems. If a child were not stimulable for /a/, then one might
wish to evaluate motoric and perceptual factors in greater detail before attributing the sound’s absence to a dialectal difference. Clearly, there is a need for much additional research on this topic to help define best practice.

In a recent forum, approaches to the assessment of a preschool child with poor intelligibility were explored in a series of articles. Although the authors were chosen to represent a wide range of approaches, it is noteworthy that all included some type of stimulability task as a part of the assessment approach (Williams, 2002). Stimulability assessment has had widespread clinical implementation for many years and appears to provide a great deal of clinically relevant information for a modest investment of assessment time.

References


Oral Motor Exercises and Treatment Outcomes

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Some speech-language pathologists use oral motor exercises because they believe these exercises will facilitate speech sound acquisition in children who have articulation/phonological disorders and/or developmental apraxia of speech (DAS). They also use them to stimulate language development in those with late onset of speech. The use of these exercises has been the subject of considerable debate because of theoretical, empirical, and/or philosophical reasons. This paper will:

1. Describe the functioning of the oral structures during speech and nonspeech activities,
2. Examine the value of strengthening exercises for speech,
3. Evaluate whether non-speech tasks are relevant to improving speech, and
4. Review treatment studies that have used oral motor exercises for speech sound production improvements.

**Same Structures, Different Functions?**

One assumption made by those who advocate the use of oral motor exercises is that the same oral structures used for speech perform the same way for nonspeech gestures. There is considerable evidence, however, that the organization of these movements within the nervous system is not the same. Love (2000) stated that, “…speech movement control was mediated at a different level in the nervous system than was nonspeech movement control” (p. 142). A recent study by Watson and Montgomery (2002) supports this. These investigators examined neuronal activity within the subthalamic nucleus and found differences in activation for speech and nonspeech activity.

Differences in neural organization between speech and nonspeech activities are most easily illustrated by the many examples of “task specificity” in which the same structures are used for both nonspeech activities and for speech, but they function differently for each specific task. For example, it is well known that there are individuals with swallowing difficulties in the absence of speech problems; and, just as likely, there are those who have speech difficulties without swallowing problems. This suggests that the common structures function differently for each task (Martin, 1991). Providing therapy for the structures for swallowing probably will not bring about changes in speech functioning (Pauloski, Rademaker, Logemann, & Colangelo, 1998) because of the neuronal differences for nonspeech and speech tasks (Hardy, 1983; Love, Hagerman, & Tiami, 1980).

Additional evidence of task specificity comes from patients who have had some form of brain damage (e.g., CVA). It is not uncommon for some of these patients to have oral apraxia (a.k.a., nonverbal oral apraxia), but no problem with speech (i.e., no verbal apraxia). This can only happen if the different tasks were mediated at different locations in the brain (Duffy, 1995).

The literature on cleft palate also provides evidence of task specificity. Many studies (e.g., Calnan & Renfrew, 1961; Mc-Williams & Bradley, 1965; Powers & Starr, 1974) document that blowing exercises can aid in velopharyngeal closure during other blowing tasks, but that this closure is not maintained for speaking; these patients still produce nasalized speech. Again, the same structures are used (i.e., the velopharyngeal complex), but they function differently depending on the task.

One final example comes from the infant chewing literature. Moore and his colleagues (e.g., Moore & Ruark, 1996; Moore, Smith & Ringel, 1988) report that for babbling, the mandibular muscle activation patterns “…and the coordinative organization for speech and nonspeech behaviors is task-specific and distinct” (Moore & Ruark, 1996; p. 1045).

Due to task specificity, therapy targeting the oral structures with nonspeech activities would appear to be of questionable value. Although the identical structures are used, these structures function differently for speech and for non-speech activities, precluding the transfer of skills.

**Muscle Strengthening?**

Oral motor exercises are often justified because they purport to increase the strength of the articulators. But this leads to two questions: How much strength is necessary for speaking? Do these exercises actually increase strength?

It turns out that very little strength is needed for speech (Forrest, 2002; Love, 2000). For example, the lip muscle force for speaking is about 10-20% of the maximal lip force capabilities (Barlow & Abbs, 1983; Forrest, 2002). For the jaw, similar low force levels (i.e., 11%-15%) are used during speaking when compared to the maximum amount of force available (Forrest, 2002). It also appears to make little difference if the children have speech sound difficulties or not. For lingual pressure against the alveolar ridge, Robin, Somodi, and Luschei (1991) found there was no difference in the force generated by children with DAS and typically developing children without speech sound problems. Taken as a whole, strength is probably not all that important for speaking.

Even if strength were an issue for speaking, the question remains whether oral motor exercises will actually strengthen the articulators. A non-speaking example may help illustrate this point. Weight training to build muscles (e.g., the biceps) involves building strength and mass (Love, 2000). This entails multiple repetitions at maximum potential against the resistance that the weights offer until no more repetitions can be achieved (i.e., “lifting to failure”). After a few minutes of rest, the process is repeated. Relative to speech and oral motor exercises, it is doubtful if any of the exercises...
being used follows this muscle-strengthening standard. For example, are repetitions of “tongue wagging” ever done to failure? How many minutes of wagging are actually used in clinical practice? In reality, probably only a very few wags are actually performed. In addition, these waggings are usually not conducted against resistance (Duffy, 1995). Lacking resistance, the process becomes analogous to curling the arm toward the shoulder multiple times without anything in the hand. This simple repeated arm movement will not build up bicep strength, any more than tongue wagging will build up tongue strength.

Agility and range of movement are probably more important for speaking than is strength (Duffy, 1995). What speakers need is the ability to move the articulators in rapid and ballistic ways, movements that not only require little strength, but skills that are not gained through strengthening exercises. Duffy and others (e.g., Yorkston, Beukelman, & Bell, 1986) report that articulator strengthening may be possible, but is probably unhelpful even for individuals with dysarthria, the clients that one would assume would benefit the most from it. (For a comprehensive review of nonspeech oral exercises for dysarthria, see Hodge, 2002.) Recall also the previous example of velopharyngeal strengthening where a stronger, more compliant closure does not help with correcting nasalized speech because of lack of task specificity.

In sum, oral motor exercises probably do not actually increase the strength of the articulators. But if they do increase strength, they most likely will not help with speech production because of their lack of specificity for speaking.

**Relevance to Speech?**

The use of nonspeech activities to improve speech also raises the question of their relevance. Data on neural control show that relevant behaviors must be used in order for change to occur (Forrest, 2002). The context of the activity is crucial. For sensory motor stimulation to improve articulation, the stimulation must be done with relevant behaviors (Forrest, 1998), with the goal clearly in mind.

Oral motor exercises lack relevance to speaking, because they are typically “disintegrated” from the goal of talking; talking is a highly integrated task. To understand how disintegration of an integrated task is not appropriate and how the final goal must be clearly established, let’s examine another exercise analogy, this time shooting a free throw in basketball (Weismer, 1996). In preparation to shoot, the player’s knees bend, her shoulders drops slightly, and she rocks slowly onto her toes. She then springs upwards from her toes, using her knees like springs. As her jump progresses upward using her legs, her arms that were against her chest, now fluidly move above her head, with one arm pushing the ball forward. These are just a small number of the steps that are actually used to effectively propel the ball toward the basket. To help learn to shoot, no coach would ever segment this myriad of muscle movements and train just one movement separate from the other movements. There would be no “exercises” that disintegrated the leg movements, so that there is isolated practice on just the heel elevation, or just the knee bends, or just the slow rocking onto the toes. The many leg motions are not separated from the shoulder or arm motions. Shooting the basketball involves an integration of many fluid motions that must be taught as a whole, not separated into bizarre subparts. For training to be effective, there cannot be disintegration of the muscle movements that need to occur in smooth concert with each other (Forrest, 2002).

Unlike the coach training the basketball player, when oral motor exercises are used, there is an immediate disintegration of the highly integrated task of speaking, breaking it into smaller sequences that are not relevant to the end goal of speaking. It is doubtful that multiple repetitions of lip puckering will help children produce the lip rounding that accompanies the /l/ vowel any more than practicing the wrist movement for the forward thrust will aid in better free throw shooting. All highly integrated tasks must be taught as a whole, not as isolated parts.

One other basketball example deals with the goal of practice (Weismer, 1996). A coach would never ask players to practice flapping their empty hands to simulate dribbling a basketball. Using an imaginary ball would not be effective in teaching how to actually bounce a real ball. Likewise, practicing biting the lower lip is unlikely to be effective in producing an /f/ sound. The lip-biting movement is not related to the end goal of speaking. And there is no relevance to the end product of speaking by using an exercise of tongue wagging, because there are no speech sounds that require tongue wagging.

Typical articulation therapy involves a focus on production of individual speech sounds; although some researchers go beyond the training of individual speech sounds and advocate training even larger end products during the initial stages of therapy. Ingram and Ingram (2001) offer an innovative perspective on how whole words should be taught, with the individual sounds never separated from the word. They believe that there should be emphasis on training the whole, not the parts, because the word is the end goal that is relevant to communication. The concept of the lack of relevancy created by training parts of the whole is best summarized by Forrest (2002) who stated, “...part training is not a cost effective or time-effective means of enhancing the development of speech” (p. 19).

**The Clinical Evidence?**

Theoretical and philosophical objections aside, the question remains as to whether or not such exercises work in practice. Unfortunately, limited efficacy research exists on the use of oral motor exercises to bring about speech sound change. However, a review of the few available studies overwhelmingly demonstrates that such exercises do not have an impact on improving speech sound production (Lof, 2002).

One of the earliest studies of oral motor exercise (for /l/ misproduction and tongue thrusting) was conducted by Christensen and Hanson (1981) who treated 10 children aged 5:8 to 6:9. For 14 weeks, half of the children received only articulation therapy while the other half received articulation treatment along with therapy that used neuromuscular facilitation techniques. They found that both groups made equal speech improvements. This means that these exercises did
not provide children with any therapeutic advantage leading to better speech sound production. Interestingly the exercises were effective in remediating tongue-thrusting behaviors during swallowing (probably due to task specificity).

Colone and Forrest (2000; Forrest & Peabody, 2003) conducted a well-controlled single subject treatment study using two 8;11 year old monozygotic twin boys with similar phonetic inventories. They provided oral motor exercise treatment to one child and a phonological treatment to the other child for seven sessions. They report that oral motor exercises were not useful in improving speech sound production skills, but a phonological approach was effective for positive changes in the treated sound and for generalization to untreated words and word positions. Similar learning patterns then occurred when using the same phonological approach for the child who had previously been administered the oral motor approach.

Occhino and McCann (2001) used an alternating treatment single-subject research design to evaluate the effectiveness of oral motor training on speech production for a 5-year-old boy. The treatment systematically alternated between oral motor exercises (e.g., blowing, brushing, sticky food chewing, etc.) and an articulation approach to sound correction. They found that the exercises were not helpful for the child to produce more intelligible speech and they even were not beneficial in changing any of the child’s oral motor skills.

Abrahamsen and Flack (2002) also implemented a single subject multiple baseline design for a 4-year-old child with suspected DAS. They provided 10 hours of individual treatment using blowing, licking, and oral stimulation techniques. There was no evidence of effectiveness of these oral motor treatments for changing speech sound production.

Only one study (Fields & Polmanteer, 2002) has shown that oral motor exercises were effective in improving speech sound production skills in children. Eight 3- to 6-year-old children were randomly assigned to one of two groups: four children received 10 minutes of oral motor treatment and 10 minutes of speech therapy, and four children received 20 minutes of only speech therapy. Fewer errors at the end of 6 weeks of treatment were reported for the children who received the combination of treatments. However, because of many methodological and statistical issues, the merit of this study must be questioned. In particular, the severity and gender distribution of the two groups did not appear to be equal; the group who received speech therapy only appeared to be more severely involved. As well, the treated sounds and the equivalency of the sounds being treated between groups were not reported.

**Conclusion**

The above discussion clearly indicates that there is little, if any, theoretical, philosophical, or clinical justification for using oral motor exercises to improve speech sound production skills. It is puzzling why clinicians continue to use these exercises. It is especially puzzling why they would use them with the population that is often mentioned with these exercises, children with DAS. By definition, children with DAS have adequate oral structure movements for nonspeech activities, but not for volitional speech (Caruso & Strand, 1999). These points were emphasized by Davis and Velleman (2000) who stated, “…there is presently no research available to support the efficacy of oral-motor therapy for improvement of speech production skills. Thus, it is appropriate to work with children with DAS on nonspeech oral-motor skills themselves, but improvement in speech should not be expected as a result” (p. 187).

Oral motor exercises are currently widely used in clinical practice (Pannbacker & Lass, 2002). Lacking evidence for the effectiveness of these exercises, however, clinicians often resort to “because it works” observations (Kamhi, 1999). This is what happened when speech-language pathologists wrongfully embraced facilitated communication as a treatment approach. Many clinicians observed what they thought were treatment effects, but when put to scientific scrutiny, these effects had nothing to do with treatment (Shane, 1994).

Gierut (1998) presents an excellent review of phonological/articulation treatment efficacy. She reports on effective treatment approaches for children with speech sound disorders, but none of these approaches include the use of oral motor exercises. Until treatment outcome data demonstrate the validity of nonspeech oral motor exercises, clinicians should be very cautious in their application and especially cautious about making claims about treatment efficacy [Ed.: See also articles by Williams, Rvachew, and Bernhardt in this manual].

**References**

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Target Selection and Treatment Outcomes

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Recent research has demonstrated that target selection is an important link between phonological assessment and intervention. It is a significant variable in treatment efficacy because, as suggested by Camarata and Nelson (1992), acquisition efficiency is at least predicated on the selection of targets that are addressed in intervention.

Typically, speech-language pathologists have relied on phonetic factors that were based on developmental norms and/or stimulability. Specifically, those who adhered to a traditional approach to target selection chose sounds that were stimulable and early developing. This traditional approach to target selection was based on the assumption that earlier, stimulable sounds were easier to produce and followed a developmental sequence of acquisition.

New Perspectives on Old Procedures: Phonological Complexity

Currently, new methods of target selection examine the role that phonological complexity has on treatment outcomes. These recent methods confront clinicians with new perspectives on old procedures that lead to the following questions in selecting treatment targets:

- Earlier or later developing sounds?
- Stimulable or non-stimulable sounds?
- Are sounds consistently or inconsistently absent?
- One target or more than one target sound?
- Targets from the same or different classes?
- Clusters or singletons?

In a “non-traditional” approach to target selection, it is recommended that speech-language pathologists choose sounds that are non-stimulable, later-developing, phonetically more complex, linguistically marked, and represent least phonological knowledge. Several studies (Gierut, Elbert, & Dinsen, 1987; Gierut, Morrisette, Hughes, & Rowland, 1996; Miccio, Elbert, & Forrest, 1999; Powell, Elbert, & Dinsen, 1991; Tyler & Figurski, 1994) have reported that teaching more complex sounds results in greater overall change in the child's phonological system. It should be noted, however, that some of the findings related to greater phonological complexity have not been supported in other studies. See Rvachew and Nowak (2001) and Rvachew, Rafaat, and Martin (1999) for alternative findings.

A closer examination of the rationales underlying the traditional and non-traditional approaches to target selection is provided in Table 1.

Notice that the rationale provided for the target selection factors within the non-traditional approach reflects the shift in treatment outcomes from the learnability of the sound to the phonological restructuring of the system. The focus of treatment outcomes within the newer methods of target selection is on system-wide change, rather than sound learning. Consequently, the rationales provided under the traditional approach involving phonologically less complex targets are still valid when ease of learning an individual sound is considered. This change in treatment outcomes from sounds to system is a central difference between the traditional and non-traditional approaches to target selection.

<table>
<thead>
<tr>
<th>Selection Factor</th>
<th>Traditional Approach</th>
<th>Non-Traditional Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulability</td>
<td>Select sounds that are stimulable. Rationale: Sounds that are stimulable are easier to learn (Hodson &amp; Paden, 1991; Winitz, 1975)</td>
<td>Select sounds that are not stimulable. Rationale: Stimulable sounds will emerge without direct intervention (Miccio et al., 1999)</td>
</tr>
<tr>
<td>Developmental Norms</td>
<td>Select early developing sounds. Rationale: Early developing sounds are acquired first (Khan &amp; Lewis, 1990; Shriber &amp; Kwiatkowski, 1982)</td>
<td>Select later developing sounds. Rationale: Training later developing sounds will result in greater system-wide change (Gierut et al., 1996)</td>
</tr>
<tr>
<td>Consistency</td>
<td>Select sounds that are inconsistently produced in error. Rationale: Variability may be an important indicator of flexibility, change, and potential growth (Forrest et al., 1994; Tyler &amp; Saxman, 1991)</td>
<td>Select sounds that are consistent in their error productions. Rationale: Consistent errors represent stable underlying representations, which will result in across-the-board change (Forrest et al., 2000)</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Select sounds for which the child has most knowledge. Rationale: Sounds for which the child has some knowledge will be easier to learn.</td>
<td>Select sounds for which child has least knowledge. Rationale: Training least knowledge results in greater system-wide change (Gierut et al., 1987)</td>
</tr>
</tbody>
</table>
**Additional Factors in Target Selection**

In addition to phonological complexity, there are other factors that can be considered in selecting treatment targets. Although these factors can be considered jointly or separately, they represent opposite ends of a spectrum: One factor involves linguistic principles that are universal to all human languages; the other factor is specific to the phonological organization of each child’s sound system. Each of these factors are discussed below.

**Markedness/Implicational Relationships**

Markedness represents implicational relationships among classes of sounds within natural languages of the world. Specifically, a marked property of a language refers to the presence of a particular feature in a given language in which another feature is necessarily implied by the occurrence of the marked feature. For example, there are languages that have both stops and fricatives, and there are languages that have stops without fricatives, but there are no languages that have fricatives without stops. Therefore, fricatives are a marked class of sounds in which the presence of fricatives necessarily implies the presence of stops in a given language. Other marked classes of sounds include the following:

- Voiced implies voiceless consonants
- Affricates imply fricatives
- Clusters imply singletons

The Target Selection Principle is: Treat marked properties in order to facilitate the acquisition of unmarked aspects.

**Systemic Factors**

Williams (2000a, 2000b) recently described a systemic approach to target sound selection as part of the multiple oppositions intervention approach. The systemic approach is based on the function of the sound in the child’s rule set and its potential for having the greatest impact on phonological restructuring. The function of a sound is a concept that assumes that the importance of target sounds is broader than the characteristics of the sound itself. Sounds can be characterized as early or later developing, stimulable or non-stimulable, most or least knowledge. However, the function of a sound is dependent on the role it plays in a particular child’s unique phonological system and; therefore, it will vary from child to child. A sound might function broadly as an obstruent, continuant, anterior non-continuant, voiceless fricative, and so forth, depending on the child’s unique phonological organization that was constructed to compensate for a limited sound system relative to the larger ambient system. Thus, the function of a particular sound is independent of the characteristics of a sound.

This approach to target selection is based on three premises:

1. Knowledge of the child’s unique phonologic organization relative to the adult sound system;
2. Selection of targets that will focus the new information for maximal restructuring of the child’s original organization; and
3. Selection of specific targets that are based on a distance metric (maximal distinction and maximal classification).

Maximal distinction is the selection of target sounds that are maximally distinct from the child’s error in terms of place, voice, and manner. Maximal classification involves selection of sound members from different manner classes, different places of production, and different voicing. The goal is to achieve maximum phonological reorganization with the least amount of intervention. Selection of targets that are more distinct from the child’s error (maximal distinction) makes them more salient and, therefore, presumably more learnable. Further, selection of targets that are representative of the sound classes collapsed across a phoneme collapse (maximal classification) provides focused training across a rule set. Together, these two components of the distance metric provide the critical “corner pieces” of a "puzzle" using salient, focused input that will facilitate the child’s phonologic learning and reorganization.

As indicated above, guidelines for target selection using this approach include selecting sounds that represent the extremes of the child’s phonologic organization. For example, a child collapsed voiceless non-labial obstruents and clusters to [t] word-initially, which resulted in a 1:7 extensive collapse, as diagrammed below:

```
  k
 / \ 
|   |
| t |
 \ / 
 s
```

Based on the guidelines described above, the target sounds selected using a systemic approach might include [t] ~ [k, tʃ, s, tr]. The sounds are maximally classified and maximally distinct from [t] in terms of place (alveolar ~ velar and palatal); manner (stop ~ affricate and fricative); and linguistic unit (singleton ~ cluster). Notice that selection of these targets addresses the function of the sounds by expanding the child’s repertoire of voiceless non-labial obstruents from the single phoneme of /t/. Thus, the target sounds functioned as voiceless non-labial obstruents in this child’s system, yet the characteristics of the target sounds themselves might include properties that could be dichotomized according to early and later developing sounds, stimulable and non-stimulable, most or least knowledge.

In sum, the systemic approach to target selection suggests that the importance of target sounds is broader than the nature of the sound itself, but encompasses the function that a given sound has within the child’s system in its potential to impact phonologic learning.

The Target Selection Principle is: Select targets on the ba-
sis of the function of the sound within the child’s unique organization of his/her sound system using a distance metric.

**Other Factors: Non-Proportional Contrasts and Lexical Properties**

In addition to the selection of treatment targets, other variables have recently been identified as important factors in treatment outcomes. These include the selection of contrastive sounds in constructing non-proportional minimal pair treatment sets and selection of treatment words to be used as stimuli. Each of these factors is described below.

**Non-proportional Contrastive Pairs**

Two intervention models (maximal oppositions, cf., Gierut, 1990; and treatment of the empty set, cf., Gierut, 1992) specify the selection of non-proportional contrasts in constructing treatment sets. The construct of proportionality refers to the redundancy and saliency of particular contrasts. For example, \( t \sim s \) is a proportional contrast because it is a frequent and non-salient contrast (\( t \sim s \) only differs in terms of manner and the contrast does not involve a major class feature distinction). Whereas, \( m \sim s \) is a non-proportional contrast because the contrast is not frequent, but it is salient (\( m \sim s \) differs in place, voice, and manner and it involves a major class feature distinction, i.e., sonorant \( \sim \) obstruent).

**The Selection of Contrastive Sound(s)**

The Selection of Contrastive Sound(s) Principle is: Select non-proportional contrasts to facilitate system-wide change.

**Lexical Properties**

Recently, several investigations have examined the lexical properties of treatment words on treatment outcomes in phonological intervention (cf., Gierut & Morrisette, 1998; Gierut, Morrisette, & Champion, 1999; Gierut & Storkel, 2001; Morrisette, 1999; Morrisette & Gierut, 2002; Storkel & Rogers, 2000). Two aspects of the lexical properties of treatment words have been identified to impact phonologic learning: frequency and density. Frequency refers to the number of occurrences of a given word in a language. High frequency words are recognized faster than low frequency words. Neighborhood density refers to the number of phonological neighbors a word has.

### Table 2. Comparison of Target Selection Factors

<table>
<thead>
<tr>
<th>Non-proportional Contrastive Pairs</th>
<th>Treatment Variables</th>
<th>Examples of Intervention Approaches</th>
<th>Examples of Treatment Targets (target sound is underlined)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Selection: Traditional</td>
<td>Minimal Pairs</td>
<td></td>
<td>( t \sim f / # )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• early developing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• stimulable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• most knowledge</td>
</tr>
<tr>
<td>Target Selection: Non-traditional</td>
<td>Minimal Pairs (MP); Maximal Oppositions (MO) Empty Set (ES) Multiple Oppositions (Mult Opp)</td>
<td>( t \sim t / # ) (MP) ( w \sim s / # ) (MO) ( t \sim z / # ) (ES)</td>
<td></td>
</tr>
<tr>
<td>Target Selection: Markedness</td>
<td>Minimal Pairs; Maximal Oppositions Multiple Oppositions</td>
<td>( \emptyset \sim z / # ) (MP; MO)</td>
<td>• fricatives imply stops</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• fricatives imply stops</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• voiced implies voiceless</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• affricates imply stops and fricatives</td>
</tr>
<tr>
<td>Target Selection: Systemic Approach</td>
<td>Multiple Oppositions</td>
<td></td>
<td>( g \sim f / # )</td>
</tr>
<tr>
<td>Selection of Contrastive Sounds (non-proportional contrasts)</td>
<td>Maximal Oppositions; Empty Set</td>
<td>( m \sim s / # ) (MO)</td>
<td>• maximally distinct</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• non-proportional contrast</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• one target sound</td>
</tr>
<tr>
<td>Selection of Treatment Words (lexical properties)</td>
<td>Any treatment approach</td>
<td>( t \sim u / # ) tech ~ check (low density/hi frequency)</td>
<td></td>
</tr>
</tbody>
</table>

**Examples of Intervention Approaches**

- **Minimal Pairs**: \( t \sim f / \# \)
  - early developing
  - stimulable
  - most knowledge

- **Maximal Oppositions**: \( t \sim t / \# \)
- **Empty Set**: \( t \sim z / \# \)

- **Multiple Oppositions**: \( g \sim f / \# \)
  - distance metric (maximally distinct and maximally classified)

- **Markedness**: \( \emptyset \sim z / \# \)
  - fricatives imply stops

- **Systemic Approach**: \( m \sim s / \# \)
  - maximally distinct
  - non-proportional contrast
  - one target sound

- **Selection of Contrastive Sounds**: \( r \sim s / \# \)
  - maximally distinct
  - non-proportional contrast
  - two target sounds
which a fricative, /z/, was selected to contrast with null word-maximal oppositions, and multiple oppositions approaches in intervention approach. Another example of the systemic approach to target selection variables that were presented in this article (traditional, non-traditional, markedness, systemic approach, non-proportional contrasts, and lexical properties).

In the first row of this table, an example of a traditional target selected for a minimal pair contrastive approach would be t ~ f /# ___ (word-initially) in which /t/ was selected as the target because it is an early developing sound; we will assume that the child is stimulable for /t/ and further that /t/ represents “most knowledge” in the child's sound system. In contrast, the next row provides examples for several different intervention approaches under a non-traditional approach to target selection. Following the previous example with the error substitution of [t], a minimal pair approach would select /tʃ/ as the target because it is a later developing, presumably non-stimulable sound of which the child has least knowledge. A maximal oppositions approach would utilize a non-proportional contrast that would pair a sound that is independent of the child's error, that is, [w], with a target sound that is maximally different, later developing, non-stimulable, and represents least knowledge. The empty set approach would also utilize non-proportional contrasts by pairing two unknown sounds (i.e., two target sounds) that are maximally different, later developing, non-stimulable, and represent least knowledge. A further example of non-proportional contrasts is shown in the fifth row with examples of treatment targets for the maximal opposition and empty set intervention approaches. Finally, the multiple oppositions approach would select several target sounds to contrast with the child's error substitution, [t], utilizing a distance metric. Based on the distance metric, the targets could be either early or later developing, stimulable or non-stimulable, and represent most or least knowledge. Another example of the systemic approach to target selection is shown in the fourth row with the multiple oppositions intervention approach.

Markedness is represented in the third row for minimal pairs, maximal oppositions, and multiple oppositions approaches in which a fricative, /z/, was selected to contrast with null word-finally because the presence of fricatives implies stops. Thus, training fricatives word-finally should result in the inclusion of not only the trained class of fricatives, but also the untrained class of stops word-finally. The markedness construct is further utilized in the multiple oppositions approach by selecting a voiced fricative (voiced implies voiceless consonants) and an affricate (affricates imply stops and fricatives).

The final row represents the influence of lexical properties on the selection of treatment words to be used in intervention. Lexical properties can be used in selecting treatment words that will be used within any treatment approach. An example of word pairs for the contrast t ~ /ʃ/ # ___ would be “tech” ~ “check” in which the target sound /ʃ/ is trained in a high frequency word that has a low neighborhood density.

Conclusion

In conclusion, it is clear that selection of treatment targets is the critical link between assessment and treatment in obtaining effective and efficient treatment outcomes. In this article, differences between traditional and non-traditional methods of target selection were discussed as they differ in terms of phonological complexity, as well as in their perspective of phonologic learning, (i.e., sound learning versus system-wide change). Although several studies were cited that provide evidence that teaching more complex sounds results in greater overall change in a child's sound system, recent studies have challenged some of these findings. Additional factors were described for selection of treatment targets, including markedness and the systemic function of sounds within a given sound system. Finally, construction of non-proportional contrastive sound pairs and lexical properties of the treatment words were discussed as additional variables that influence treatment outcomes. Clearly, additional research is needed to further examine the comparative efficacy of different target selection criteria on treatment outcomes. Further, the possibility of additive relationships between the different variables of the treatment input on treatment outcomes needs to be examined.

References


Computer Applications and Treatment Outcomes

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Treatment of developmental speech sound disorders requires that the speech-language pathologist identify the source of the problem and then design an effective treatment program. Computer software can help with this process, but one must ask whether there is research evidence that the tools chosen are effective and/or that they can be effectively and efficiently applied with a given client in a particular clinical setting. This article will examine some of the available software with these questions in mind.

The applications chosen were consistent with the theoretical perspective articulated by Rvachew and Jamieson (1995). We proposed that all speech sound errors have the same proximal causes, either (a) a mismatch between the standard underlying representation (UR) for a given phoneme contrast and the learner’s UR for that same phoneme contrast, and/or (b) a mismatch between the learner’s UR and the learner’s surface form.

Assessment

A detailed description of the child’s underlying phonology is a critical first step to the success of any intervention. The Computerized Articulation and Phonology Evaluation System (CAPES; Masterson & Bernhardt, 2002) provides such a description quickly and easily. CAPES elicits a speech sample by presenting the child with digitized still photographs for labeling. The child’s responses can be recorded and a transcription of the responses entered quickly with a user-friendly interface. The software generates an initial description of the resulting data in the form of the traditional chart showing the child’s omission, substitution, and distortion errors for each consonant and consonant sequence in the initial, medial, and final positions of words. Analyses that describe the child’s productions in terms of word length, syllable stress, word shape, place, manner, and voice features, and phonological processes can also be generated. Presumably, these detailed analyses would lead to the implementation of a linguistic intervention approach. Experimental studies have demonstrated the effectiveness of phonological process (Almost & Rosenbaum, 1998) and minimal pair approaches (Weiner, 1981), and many case studies are appearing that suggest that approaches based on nonlinear phonology (Bernhardt & Gilbert, 1992; Ed: see also Bernhardt, this issue) and optimality theory (Barlow, 2001) may also be effective. I am not aware of any studies that show that access to detailed linguistic analyses leads to more effective treatment, but this gap could easily be filled now that this tool is available for clinical use.

CAPES provides a detailed description of the child’s error patterns and points to reasonable hypotheses about the nature of the child’s URs. Perceptual analyses (i.e., transcription) are often not definitive in this regard however. For example, Tyler, Edwards, and Saxman (1990) conducted acoustic analyses of children’s efforts to produce /t/ and /k/. Some children whose productions of these targets were consistently perceived to be [t] articulated target /t/ and target /k/ with consistent but subperceptual acoustic differences, indicating that a contrast between coronal and dorsal place was represented underlyingly. Baum and McNutt (1990) and Forrest, Weismer, Hodge, Dinnisen, and Elbert (1990) reported similar findings for stop and fricative place contrasts. The existence of such “covert contrasts” has important implications for the choice of treatment approach and for the child’s rate of progress in speech therapy (specifically, progress in speech therapy is superior for children with adult-like URs). Covert contrasts can be identified using speech analysis software or electropalatography, tools that will be discussed in more detail below in the context of treatment procedures.

Information about the child’s ability to perceive phonemic contrasts may also reveal a primary problem with the nature of the child’s URs (Lof, 1996). The Speech Assessment and Interactive Learning System (SAILS, 1997) is a tool for assessing young children’s perceptual phonological knowledge using a computer game format. Rvachew, Rafaat, and Martin (1999) found that phonological process therapy was more effective when the child had good perceptual phonological knowledge of their target phonemes prior to treatment, relative to progress for target sounds that were associated with poor pretreatment perceptual phonological knowledge. This result parallels the finding of Tyler and colleagues (1990) with respect to the impact of the child’s underlying knowledge on treatment success. SAILS will be discussed in more detail as a treatment tool below.

A systematic oral-peripheral examination can provide evidence that the child’s speech errors are based at the articulatory level, rather than (or in addition to) the phonological level. One element of the oral examination that is frequently and regretfully omitted is the precise measurement of the child’s alternate motion and diadochokinetic rates. Williams and Stackhouse (2000) found that even 3-year-olds can imitate multisyllabic real words and nonwords at a rate of 3 syllables per second without any consonant omission errors. Although these tasks are not difficult for preschool age children, accurate measurement of repetition rates can be tricky for the speech-language pathologist using the tally-and-stopwatch method (Rvachew, Ohberg, & Savage, 2006). Very precise measurement of repetition rates can be easily accomplished using any software that provides a waveform display such as those discussed below under treatment: articulation. Software to facilitate the recording of syllable repetitions from young children has recently been made freely available (Hodge & Daniels, 2004; for a tutorial on the use of the TOCS™ MPT Recorder® ver. 1, see Rvachew, Hodge, & Ohberg, 2005).
**Treatment: Underlying Representations**

Many children with speech sound errors have poor perceptual knowledge of the acoustic cues that define the misarticulated phoneme in contrast to the child’s substitution for that phoneme (see Rvachew & Jamieson, 1995 for a review). SAILS was designed to directly address these difficulties by teaching the child to identify well-produced and misarticulated versions of the targeted phoneme. The program consists of two different word modules for each of the following consonants: /k, l, r, s, ŋ/. Each module is comprised of natural speech tokens of a single word. All misarticulated words were authentically produced by a child with a phonological delay (i.e., the test does not involve simulated speech sound errors). The basic procedure is common to several well-known phonological interventions (e.g., sensory-perceptual training—traditional approach, Van Riper & Emerick, 1984; auditory bombardment—cycles approach, Hodson & Paden, 1983; developing awareness of the properties of phonemes—metaphon approach, Dean & Howell, 1986). However the stimuli themselves are unique to the computer program and could not be implemented without such technology—specifically, the program allows the clinician to provide the child with exposure to multiple talkers and to stimuli that range in quality from marginal to prototypical exemplars of the targeted sound category. The results of a randomized-control study suggest that these particular aspects of the program may be critical to its success (Rvachew, 1994). In this study, 4-year-old children were randomly assigned to three treatment conditions, each of which included 6 weeks of traditional articulation therapy targeting /ʃ/, as well as concurrent experience with the SAILS computer game. Each of the three treatment groups listened to different stimuli, however: (a) multiple correct and incorrect recordings of the word shoe; or (b) a single correct version of the word shoe contrasted with moo; or (c) a single version of the word cat contrasted with Pete. The results indicated superior gains in articulation accuracy for the group that received the standard SAILS shoe module. The children who listened to “shoe” and “moo” also made better progress than the control group, but their gains were not as great as those of the experimental group. Subsequent to this initial treatment efficacy study, it has been demonstrated that the use of this program enhances the effectiveness of the cycles approach to treatment (Rvachew et al., 1999). Clinical effectiveness of the program has also been demonstrated in a study in which undergraduate students provided either SAILS or a literacy-focused intervention to children who continued to receive speech therapy from their speech-language pathologists (Rvachew, Nowak, & Cloutier, 2004). In contrast to previous studies, the clinicians were free to provide the type and amount of speech therapy that they judged to be appropriate and the SAILS program was not coordinated with each child’s specific therapy goals. Statistically significant differences in post-treatment articulation ability were observed during picture naming and narrative tasks for the group whose speech therapy program was supplemented with the SAILS intervention. This series of studies establishes the efficacy of linguistic approaches to speech therapy in general, and of the SAILS program in particular.

**Treatment: Articulation**

Articulatory learning requires that the child repeatedly practice the achievement of specific targets with feedback and knowledge of results (Ruscello, 1993). Computer technology can assist with all of these aspects of motor skill learning. Repeated practice is facilitated by products such as LocuTour Articulation (Scarry & Scarry-Larkin, 1997). Achievement of a specified target is facilitated if the child has an adult-like UR, a requirement addressed by SAILS as discussed above. The natural auditory, tactile, and kinesthetic feedback that occurs during speech production can be supplemented with feedback from electropalatography, ultrasound, or speech analysis software. Knowledge of results is typically provided in the form of clinician- or child-judgments about the accuracy of the child’s speech sound production. However, IBM’s Speech Viewer III (2001) contains several modules that attempt to provide information about the child’s success in achieving a given target.

Electropalatography (EPG) provides a computer display of the position and timing of tongue contacts with a custom-made artificial palate into which is embedded rows of electrodes (Scobbie, Wood, and Wrench, 2004). Descriptive EPG studies of children with speech delay have yielded three general findings:

1. Children who produce the same error type (e.g., lateral distortion of fricatives) can demonstrate widely varying articulatory patterns when producing perceptually similar speech sound errors;
2. Some children produce “undifferentiated lingual gestures” in which large parts of the palate are contacted by the tongue during the articulation of sounds that would normally be associated with discrete areas of contact; and
3. Some children demonstrate covert contrasts, that is, varying patterns of articulation for different target sounds that result in perceptually similar phones.

See Gibbon, Stewart, Hardcastle, and Crampin, 1999, for a review. Many case studies (e.g., Carter & Edwards, 2004; Dagenais, Critz-Crosby, & Adams, 1994; Dent, Gibbon, & Hardcastle, 1995; Howard, 1998) have described a positive response by children who have failed to respond to conventional forms of speech therapy, and, thus, the results are very encouraging, even in the absence of randomized-control trials. However, a great deal more study is required in order to establish the limits of normal variability in articulatory patterns, to identify those children who are most likely to benefit from this approach, and to evaluate clinical effectiveness and cost efficiency.

EPG can provide visual feedback only about the articulation of sounds that involve lingual-palatal contact. Ultrasound has recently been adapted for the purpose of providing visual feedback about tongue shape and movement (Stone, 2005). Ultrasound can be used to visualize vowel and liquid articulation as well as some aspects of obstruct articulation, such as the grooving of the tongue for the production of coronal sibilants. Some case studies in which ultrasound was used to improve speech articulation in hearing and hearing-im-
paired adolescents have been published (Bernhardt, Gick, Bacsfalvi, & Adler-Bock, M., 2005; Bernhardt, Gick, Bacsfalvi, & Ashdown, 2003).

A more readily accessible tool for providing feedback is spectrographic analysis, a technology that provides a visual display depicting formant frequencies over time. Formant frequencies reflect the shape of the vocal tract, and changes in formant frequencies over time reflect changes in vocal tract shapes as speech is articulated. ProTrain 2000 (2000) was developed specifically for clinical applications and can be implemented on almost any computer that has a sound card (to which a microphone can usually be connected). ProTrain 2000 displays two spectrograms at once, the clinician’s model of a correct production and the child’s attempt to match the clinician model. The two productions can then be directly compared, both in terms of the sound of the two productions and the formant frequency patterns that are shown in the spectrograms. The child’s task during therapy is to match the relative positions of certain formants and the way in which they change with time. For example, in the case of /i/, the child is usually required to lower the frequency of the third formant frequency. Case studies, single-subject experiments, and larger sample descriptive studies have reported positive results (e.g., Becker, 1998; Ertem & Maki, 2000; Masterson & Rvachew, 1999; Shuster, Ruscello, & Toth, 1995) with the use of such visual feedback. There are two primary advantages to this approach:

1. The child is free to discover his or her own articulatory solution to the challenge of producing the desired formant changes; and

2. The child is rewarded for producing gradual articulatory changes that are in the right direction even before they result in a perceptually correct speech sound.

Speech Viewer III (2001) was developed to address the need for knowledge of results when attempting to achieve a given target. For example, the vowel module presents a visual display that shows a monkey advancing up a tree toward a coconut. The distance between the coconut and the monkey is intended to represent the closeness of the match between the acoustic properties of the child’s production and an acoustic template for the target vowel. Modules that target certain sustained consonants and games that encourage the child to contrast two phonemes are also available. Unfortunately, the feedback provided by the software is often inaccurate or inconsistent. Two studies with subjects who have hearing impairment have suggested that this software does not offer any advantages in comparison with traditional interventions (Pratt, Heintzelman, & Deming, 1993; Ryalls, Michallet, & Le-Dorze, 1994).

**Summary**

This brief article shows that there are computer-based tools available for all phases of phonological intervention. The tools discussed here are firmly grounded in current knowledge and theory about the nature of speech sound disorders. The SAILS approach has been subjected to randomized control trials and has proven to be effective in the remediation of concomitant speech perception and speech production difficulties. The use of EPG, ultrasound, and spectrographic displays to provide feedback about articulation has been examined in descriptive studies with encouraging results. Thus far, clinicians are better able than machines to provide accurate information about the success of the child’s efforts to produce specific speech sounds. All of the technologies described here require further testing for efficiency and feasibility of application in a variety of clinical settings, but the results to date are very promising indeed.

**References**


Phonological Awareness and Treatment Outcomes
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Phonological awareness refers to the ability to attend to sound units of the language to the exclusion of meaning. Phonological awareness includes awareness of words, syllables, intrasyllabic units (i.e., onsets and rimes), and individual sounds in syllables and words. This final level of awareness, termed phonemic awareness, is the most complex and important to attain in order to learn to read and spell. Because of the hierarchical nature of phonological awareness, children come to phonemic awareness after they attend to larger units of sound (e.g., syllables, rimes).

There are strong indicators suggesting that the period between ages 2 and 4 years is a very active time in the development of phonological awareness (Chaney, 1992). Although emerging early, these skills develop gradually over time (Chaney, 1992; Smith & Tager-Flusberg, 1982) in conjunction with the development of spoken language skills. Phonological awareness skills develop from implicit understanding to a more explicit level (Ball, 1993; Stackhouse, 1997). For children to understand the alphabetic principle in reading instruction, an explicit understanding of phonemes is needed in order for them to link speech to print.

Early delays in phonology may impede the development of underlying phonological representations, thereby setting the stage for later phonological awareness deficiencies (Fowler, 1991; Studdert-Kennedy, 1987). Significant differences in phonological awareness skills have been found when comparing children with phonological impairments with children who are considered to be phonologically normal (Bird, Bishop, & Freeman, 1995; Webster & Plante, 1992). In addition, the severity of phonological impairment was found to be a predictor of phonological awareness and literacy skills in both preschoolers and school-aged children with phonological impairments (Bird et al., 1995; Catts, 1993; Larrivee & Catts, 1999; Webster & Plante, 1992). Children with phonological impairments may have difficulty reaching the phonemic level of awareness. Bird and Bishop (1992) suggested that children with expressive phonological impairments may operate at the level of the syllable and are not able to identify smaller segments (sounds) at all, thus preventing them from identifying the phonological units represented by graphemes.

Although Bird and colleagues (1995) found that children with persisting phonological impairments (not resolved by 5½ years) appear to be more at-risk for literacy problems, two retrospective studies raise questions as to how well conventional phonological intervention (i.e., without explicit work on phonological awareness) develops phonological awareness skills in children with expressive phonological impairments. Clarke-Klein and Hodson (1995) found that children who had histories of severe speech production disorders, but who had attained an adult sound system through intervention, evidenced significantly poorer phonological awareness skills and displayed poorer spelling strategies in third grade when compared to children with no histories of speech production disorders. Lewis and Freebairn (1992) also found that remnants of a preschool phonology disorder were detectable past grade school age and into adulthood, affecting the areas of phonological awareness and production, as well as spelling and reading.

How well phonological intervention assists in the development of phonological awareness skills in children with expressive phonological impairment has been directly examined in only three published studies. Howell and Dean (1991) examined patterns of phonological change and their association with metalinguistic change in 13 preschool children (mean age 4;1; range 3;7-4.7). Using their Metaphon approach to intervention, which specifically addresses phonological awareness when addressing intelligibility, each child attended one individual 30-minute intervention session per week (mean length of intervention was 22.5 weeks; range 11-34 weeks). Phonological production and metalinguistic skills (sentence and word segmentation, repair strategy use, and syntactic awareness) were measured before and after intervention. Comparison of pre- and post-intervention scores indicated a significant difference in phonological production scores and in the metalinguistic tasks that required phonological awareness skills (i.e., repair strategy use, and phoneme/sentence segmentation). Harbers, Paden, and Halle (1999) examined changes in awareness of sound class features and syllable shapes along with production in four preschool children who participated in an intervention program that combined components of the Metaphon (Howell & Dean, 1991) and the cycles approach (Hodson & Paden, 1991). For all participants, production of most of the five phonological patterns improved in conversation by an average of 50% (range 15% to 96%) after only 6 to 9 months of intervention. Although improvement was noted in feature awareness for all phonological patterns, the effects of intervention on awareness were not as immediate as production gains or similar across the four children. Using older children (5;6-7;6; mean age 6;1), Gillon (2000) compared the effects of phonological awareness instruction specifically on reading outcomes in children with spoken language impairment. One group of children received phonological awareness intervention (emphasizing development of skills at the phonemic level and letter-sound knowledge training), while another group of children received traditional intervention that focused on placement and sound production. Two additional groups served as experimental controls. After receiving 20 hours of intervention (in 1-hour individual sessions), the children receiving phonological awareness instruction made significantly more improvement in their phonological awareness, word decoding, and reading comprehension skills than did the children who received traditional intervention. Additionally, children who received phonological intervention showed more improvement in speech production when compared to the improvements made by the children in the other groups. Although traditional intervention was effective in improving the children’s speech production, it had little effect on developing...
phonemic awareness or reading skills.

Children with underlying phonological disorders are more vulnerable to reading and spelling difficulties than children with articulation problems because of the linguistic involvement associated with a phonological disorder (Stackhouse, 1985). Without measurement to determine otherwise, phonemic awareness skills may be insufficiently developed in the intervention process. For children with phonological impairments, the use of traditional methods focusing on the articulatory aspect of sound production may ignore the underlying representation and organization of a child’s sound system. Without explicit focus on improving awareness of phonemes, children may not be able to access the needed sound information for literacy tasks (Gillon, 2000). Unless clinicians thoroughly understand the concept of phonological awareness and its role in phonological intervention and literacy, they may easily teach it in ways that produce little benefit to children.

**Implications for Clinical Applications**

Because spoken language provides the foundation for the development of reading and writing skills, current roles and responsibilities with respect to reading and writing for speech-language pathologists as outlined by the Ad Hoc Committee on Reading and Written Language Disorders (ASHA, 2001) include prevention, early identification, assessment, intervention, collaboration and advocacy. Clinicians need to be both informed and proactive if they are to identify and promote the underlying skills that contribute to literacy.

**Assessment**

Assessing both awareness and production skills at the time of diagnosis is important to learn more about the extent of the sound system disorder. Harbers and colleagues (1999) suggested that assessing both awareness and production may indicate when each component should be emphasized during intervention. Gathering information about literacy socialization from caregivers would be especially valuable and may help to direct efforts in involving the family in the intervention process. (See Jenkins & Bowen, 1994, for an example of a checklist.) If the child is 4 years of age or older, it is reasonable to directly assess phonological awareness skills, along with production, at the initial evaluation when determining the existence of a phonological disorder to gain baseline data.

By monitoring phonological awareness development throughout the course of intervention, clinicians will be able to identify the presence or absence of early literacy achievement. Conducting informal probes during the intervention process is also helpful in determining whether or not an increase in intelligibility is accompanied by gains in awareness. The information gained from these probes may assist in directing the focus of intervention. Phonological awareness skills of blending and segmenting sentences, syllables, and onsets/rimes are developmentally appropriate for preschool children and are necessary steps in reaching the phonemic level of awareness. For older preschool children and those in kindergarten or first grade, examining spelling skills would be extremely valuable in determining whether a conscious awareness of sounds is present and how that awareness is represented by print. The Test of Invented Spelling (Mann, Tobin, & Wilson, 1987) and the phonemic awareness subtest of the Early Reading Screening Instrument (Morris, 1992) are useful invented spelling screening tools.

Clinicians need to verify that phonemic awareness skills have also developed in the course of intervention and are sufficient to support the child when learning how to read and spell. For a child who is being considered for discharge, it is imperative to consider his/her phonological processing skills (i.e., phonological awareness, memory, multisyllable word production, and rapid automatic naming) with post-intervention production skills. The Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999) is a useful tool for this purpose and can be administered to children as young as 5 years of age. The Phonological Awareness Test (Robertson & Salter, 1997) is a comprehensive assessment tool that focuses on phonological awareness (syllable, rhyme, and phoneme levels) and includes sections that examine print knowledge. Several nonstandardized measures are available that assess varying levels of awareness. (See Justice, Invernizzi, & Meier, 2002; and Torgesen & Mathes, 2000 for a review.)

A decision tree outlined by Justice and colleagues (2002) provides questions that are aimed at guiding practitioners to select those candidates who would benefit from early literacy screening. Interestingly, the suggested outcomes are either to conduct a screening or informally monitor early literacy knowledge, both roles that can be implemented by speech-language pathologists.

**Intervention**

When discussing the preparation of preschoolers with specific language impairment for school, Fey, Catts, and Larrye (1995) stated that “...it is reasonable, if not advisable, to include structured phonological awareness activities in a comprehensive intervention package for preschoolers with language impairments” (p. 17). Programs promoting phonological awareness in preschool children at risk for literacy problems may help to prevent the full impact of a phonological impairment on later literacy development (Stackhouse, 1997).

Hodson (1994) contends that, for children with unintelligible speech, intervention should aim at increasing intelligibility and improving emergent literacy skills. To increase intelligibility, cognitive reorganization should be emphasized rather than simply articulatory retraining (Grunwell, 1982). For reorganization to take place, children require information that will encourage them to make their own changes (Howell & Dean, 1991). Gains in intelligibility, however, do not automatically affect phonological awareness skills. Richgels (2001) asserts that phonemic awareness is not needed in spoken language, but is required in order to link speech and print. He stated that the ability to combine and contrast phonemes in speech is unconscious perception of phonemes rather than awareness. Because of this, we need to make our interventions assist children to reach the phonemic level of awareness. Gillon (2000) emphasized that the ability to consciously access information about sounds needs to be made explicit for children with phonological impairment, so that they will be...
Activities to promote children’s explicit awareness will be successful only when adults are explicit with their own awareness. Making knowledge explicit tends to be easier for large segments (syllables, onsets/rimes) than for small segments, such as sounds (Goswami, 2001). Jenkins and Bowen (1994) provide suggestions for using the phonological awareness hierarchy (words, syllables, onsets/rimes, and sounds) as a framework for phonological intervention. Syllable awareness can be promoted by clapping out the number of syllables in multisyllable words. When targeting final consonant singletons or sequences, rhyme families can be utilized. Younger children can be encouraged to produce real and nonsense word rhymes to promote sound play. Alliteration (i.e., maintaining the onset of a word) can become a common sound play clinicians utilize in intervention when prevocalic consonants are targeted. Listening to stories that contain rhymes or alliterations is also a worthwhile activity. Not only do children need to recognize these phonological units, they must also be able to make comparisons with them.

In the Metaphon approach, Howell and Dean (1991) present two ways to increase children’s awareness about the information they need to effect change in their phonological systems: conceptualizing the features of the target pattern and providing feature awareness feedback. Conceptualization of the features of the target pattern increases the saliency of information needed for a revised pattern to be formed. Examples of this technique include using a giraffe to emphasize velar sounds, long items to focus on continuancy, and a caboose to focus on a closed syllable shape. (See Harbers et al., 1999, or Howell & Dean, 1991, for more examples.) For patterns that appear to be more difficult for a preschool child to produce (e.g., velars and liquids), an emphasis on awareness of the features of patterns through conceptual activities may be needed in the early stages of intervention (rather than a focus on production) to support the child’s reorganization of feature knowledge (Harbers et al.). Providing feature awareness feedback is a means to reinforce the salient information, as well as to promote self-monitoring. This type of feedback focuses the child’s attention on the key information needed to assist them in improving production and awareness. Awareness feedback draws attention to the information in an explicit way. Because it also promotes self-monitoring, awareness feedback integrated into production activities is an easy technique to scaffold awareness while supporting production.

In addition to the Metaphon techniques, other techniques can promote awareness of target patterns. Using clarification requests facilitates reflection on the form of the word. These requests can begin by being direct (e.g., Did you say that word with two sounds?) and move to become more general (e.g., What did you say?). To promote awareness, these requests need to be made after correct, as well as incorrect, attempts at production. Young children learn to respond to the adult’s intonation, rather than to think about how a word was produced. Print should also be used to support awareness and production and exposes the preschooler to future links between speech and print. Changing the letter “l” into an ar-row pointing upward reminds the child of tongue placement and tracing the letters representing fricatives in a continuous flow to emphasize continuancy are examples of this.

Speech-language pathologists must also support and extend the information teachers and parents have about the link between speech and print. Catts (1991) discussed the unique position speech-language pathologists have in literacy instruction because of their training. Information about sound production (i.e., place, manner, and voicing) can greatly enhance teacher instruction in sound-letter association. If teachers have a better understanding of the relation between spoken and written language impairments, they become better able to assist children with phonological impairments during reading instruction. By supporting and extending the information base of parents, speech-language pathologists can assist them in advocating for their child. When well informed, families can be of great assistance in prevention activities by participating with their child in sound play, joint book reading, and phonological awareness activities.

**Conclusion**

This article has focused attention on the important role of phonological awareness for intelligibility and literacy. Facilitating the emergence of phonemic awareness, along with speech intelligibility, in children with phonological impairments is important to support their success in literacy skills. The information gained from assessing children’s phonological awareness skills before, during, and after intervention will assist speech-language pathologists in identifying their role in supporting the early literacy skills of the children with unintelligible speech. Intervention studies are needed to explore this important connection for young children with phonological impairments.

**References**


Phonological theories are constructed to account for speech sound inventories and alternation patterns within and across languages. In the clinical realm, such theories have provided useful frameworks for analysis of children’s speech patterns and selection of goals for treatment (e.g., Barlow & Gierut, 1999; Bernhardt & Stemberger, 1998, 2000; Edwards & Shriberg, 1983; Gierut, 1998; Grunwell, 1985; Hodson & Paden, 1991; Ingram, 1981). Phonological theories have sometimes suggested specific therapeutic approaches, such as the cycles approach (Hodson & Paden, 1991), paired contrasts (Elbert & Gierut, 1986), metaphonological awareness (Dean & Howell, 1986), syllable structure interventions (Bernhardt, 1994). Advances in phonological theories provide new clinical opportunities for phonological intervention. In the 1990s, studies were conducted that applied nonlinear phonological theories to intervention (Bernhardt, 1990, 1992; Bernhardt & Stemberger, 1998, 2000; Edwards, 1995; Major & Bernhardt, 1998; Von Bremen, 1990). Detailed descriptions of clinical applications of nonlinear phonology are available elsewhere (e.g., Bernhardt, 1992; Bernhardt & Gilbert, 1992; Bernhardt & Holdgrafer, 2001a, 2001b; Bernhardt & Stemberger, 1998, 2000; Bernhardt & Stoel-Gammon, 1994). The first section of this article includes an overview of major concepts and applications of those concepts in the intervention studies. The second section describes the studies briefly and presents highlights of the results.

Application 1: Phonological Hierarchy

Nonlinear phonological theory acknowledges sequential (or linear) phonological patterns (e.g., that nasal consonants in English have the same place of articulation as the following stops: ruMBa, baND, taNGo), but emphasizes the hierarchical (nonlinear) nature of phonological form and the effects of that hierarchy on phonological patterns. The major division in the hierarchy is between phrase and word structure, and segments (speech sounds) and features (see Figure 1).

In the studies applying nonlinear theories to intervention, the concept of hierarchy was paramount. Both structural targets and segmental and feature targets were included for each child, in accordance with the major division within the hierarchy.

Application 2: Syllable and Word Structure

The highest level of the structural division of the hierarchy is the phrase, a grouping of words with different levels of phrasal stress. Words are composed of feet, which are composed of syllable groupings reflecting relative stress. Syllables are subdivided into onsets (consonants occurring before the vowel) and rhymes (the stress-bearing units, or moras, and any additional consonants). In the intervention studies, each child had two types of structural goals. One type was new structural form: new word shapes (e.g., CVC, CCV, CVCCV), stress patterns, or word lengths. The other type involved strengthening of existing word positions that were minimally developed in terms of features and segments present in the inventory. For example, a child may have used fricatives word finally only, even though there were other initial consonants. The goal was to strengthen word-initial position by introducing fricatives.

For structural targets in the intervention studies, treatment strategies were developed that focused on either onsets and rhymes, or moras (Bernhardt, 1994; Bernhardt & Stemberger, 2000).

Application 3: Feature Hierarchy

The segmental portion of the hierarchy includes segments and features. The features are also considered to have hierarchical organization (see Bernhardt & Stemberger, 1998, 2000). Manner features are typically viewed as “higher” than place features. Within each category, there is also hierarchical organization. For example, /p/, /b/, /m/, /w/, /f/, /v/ are all [labial], but /f/ and /v/ have an additional dental component. This [labiodental] feature is a sub-category of [labial]. Such details of pronunciation are at the lowest level of the phonological hierarchy. In the segmental/feature condition of the
Features and segments show other relationships of dominance. A particular feature or feature value may be considered the default because it is more frequent, less complex, or more unmarked in comparison with the contrasting nondefault. In English, there are more [-labiodental] labials (/pl/, /bl/, /lm/, /w/) than [+labiodental] labials (/fl/ and /v/). Thus, [-labiodental] is the default, and [+labiodental] the nondefault. Segments have different combinations of features. The fewer the number of nondefault features, the less complex the segment. Across languages, /t/ is considered to be an unmarked, or default, consonant (Bernhardt & Stemberger, 1998, 2000). Stops are the most frequent manner category for consonants across languages; default manner features, therefore, include [-nasal], [-continuant], [-sonorant], and [-lateral]. Alveolar features [coronal] and [+anterior]) are highly frequent consonant features across languages, and, thus, those features are place defaults. In terms of laryngeal features, /t/ is [-voiced]. Among non-sonorant consonants, [-voiced] consonants are more common than [+voiced] consonants across languages; therefore, [-voiced] is the default. The consonant /v/ has several nondefault features: [+continuant] (fricative), [labial], [+labiodental], [+voiced], and thus /v/ is more complex than /t/.

In early development, phonological systems have more default features than nondefault features. Thus, throughout the intervention studies, nondefaults were the usual feature targets of intervention. In the later studies, the rate of acquisition for new individual (nondefault) features and new feature combinations with nondefaults was compared. (Note that a child’s default values may be different from those of the adult language. For example, the child may use velar rather than alveolar as a default. In this case, the adult default feature would be the treatment target.)

Application 4: Interaction of Structural and Feature Constraints

Phonological patterns occur because of constraints on phonological form at the various levels. Assume a child’s consonant inventory shows absence of word-final [-/t/ and /v/]. Whether /t/ and /v/ are deleted or replaced by other consonants depends on other aspects of the phonological system. For example, if syllable-final consonants (codas) are generally impossible, then word-final /t/ and /v/ will not be produced, even if they are present word initially. Negative constraints on syllable structure override feature requirements. If positive structural constraints require production of codas, but a child cannot articulate fricatives in that position, then word-final fricatives will be replaced by other consonants. Positive constraints on structure override segmental accuracy (top-down effects in the phonological hierarchy). If accurate pronunciation of target segments is more important than preservation of syllable and word structure, /t/ and /v/ may be deleted in coda, even if the child produces other word-final consonants. In this case, faithfulness to segmental content overrides structural integrity of the syllable (a kind of bottom-up effect in the phonological hierarchy).

In summary, there are constraints requiring production of segmental content (positive, or faithfulness constraints) and some preventing production of phonetic content (negative or markedness constraints), both in terms of higher structural levels of phonological form and in terms of the lower feature levels. Describing a child’s phonological system entails determination of both the positive constraints (the strengths) and the negative or inhibitory constraints (the developmental needs). In setting up treatment goals and strategies in the intervention studies, strengths of the system were used to address the needs. For example, new features were generally targeted in existing word structures; new word structures were generally targeted using existing features and segments.

General Methodology of the Nonlinear Intervention Studies

The intervention studies were conducted with preschool children with moderate to severe phonological disorders who spoke Canadian English. Taking production of the highly frequent English monosyllable CVC as a marker for severity, about half of a pool of 60 subjects showed less than 50% accuracy on production of CVC (with deletion of one or both Cs) or a severe impairment. Some of the children also had delays in language production, but language comprehension and hearing were within normal limits. No major physical impairments were observable.

Studies differed slightly in number of weeks (16-18) and sessions per week (two versus three), but each child had at least two blocks of treatment lasting 6-8 weeks each. Children received individual treatment except in one group study. For most studies, each child had both word structure and feature target conditions within each 6-8 week treatment block, with two sets of each target type within each condition, and three to four sessions per individual target. If a child mastered any targets of the first treatment block, new targets for that condition were introduced in block 2. Where possible, order of goals and conditions were counterbalanced across subjects.

There were both small n studies, conducted by university researchers (e.g., Bernhardt, 1990; Edwards, 1995; Von Bremen, 1990) and larger group studies conducted by speech-language pathologists in community health settings and overseen by university researchers (Major & Bernhardt, 1998; Bernhardt, Major, & Brooke, 2003). For all studies, the author was ultimately responsible for clinician training, goal selection, and program planning, although in the later community-based studies, Major and S. Edwards contributed to clinician training, and clinicians did the analyses and worked out a tentative intervention plan.

Clinicians, in consultation with university researchers, developed intervention activities. Awareness activities were included for all targets in all treatment sessions. For syllable and word structure, activities also focused on either onsets and rhymes or moras within syllables, using imitation and awareness. Segmental and feature targets were addressed with either awareness only or awareness plus oral-motor facilitation and imitation. Activities were play-based, but included opportunities for drill. Children were given tangible rewards.
for participation and the use of their “new way of talking” in everyday conversation. Parents or caregivers received a training session, participated in all sessions with the clinician and child, and conducted home activities.

Speech samples were audio-taped before each treatment condition and at the end of the project using a Marantz OMD-430 audiotape recorder and PMZ microphone. The main probe samples were based on spontaneous single word elicitations from a 164-word list (Bernhardt, 1990), or, in the later studies, the Photo Articulation Test (Pendergast, Dickey, Selmar, & Soder, 1984). In addition, connected speech samples were used to confirm or amplify patterns observed in the single word samples. Samples were transcribed by master’s level students in speech-language pathology in the university laboratory. The author or project staff performed reliability checks on the transcriptions. Where differences in transcriptions were observed, consensus transcriptions were developed. Phonological analyses were done with the support of computer software developed during the project (Bernhardt, Cam, & Major, 1994).

**Highlights of the Results**

**Applications 1 and 4: Phonological Hierarchy, and Interactive Constraints**

Results showed different rates of learning for the various hierarchy-based conditions across participants. This differential rate supports the concept of levels and suggests that the various levels of the hierarchy have individual developmental paths. One of the unexpected outcomes of variable learning rates for the levels was the positive impact on the mood of the participants. By examining all levels of the hierarchy, it was possible to demonstrate a child’s strengths in addition to his or her needs to the families. This launched the programs on a positive note. The fact that children tended to improve on at least one target in the first treatment block helped maintain momentum and enthusiasm.

**Application 2 and 4: Syllable and Word Structure, and Interactive Constraints**

Across the studies, most children showed significantly faster rates of change for word and syllable structure targets than for segmental and feature targets. In Bernhardt’s (1990) study with six participants, a greater proportional gain in accuracy was noted for word structure targets compared with segmental targets, especially in the first block of treatment (Wilcoxon Mann-Whitney test \( W = 108, p = .015 \)). In a group study with 19 children (see Major & Bernhardt, 1998), there was an average gain of 24% in word shape accuracy, compared with a 13% gain in consonant accuracy (excluding deletions), after 12 weeks of intervention (t-test \( t = -2.11038, p = .0418 \)). In Von Bremen’s (1990) study with identical twins, the twin assigned to the word structure condition mastered both his targets and those of his brother (assigned to the segmental condition), who took longer to achieve both types of targets.

The difference between outcomes for conditions may reflect the dominant status of the word structure levels in the hierarchy. Structure involves larger units, and is more general than precise articulation of segments. The fact that new word structures were targeted using existing segments (Application 4) may have facilitated the accelerated change. The word structure changes were beneficial in several ways: (a) additional word shapes and frameworks became available for the new feature and segment targets, (b) intelligibility was enhanced at the end of the first treatment block because of reduction of deletions in particular, and (c) motivation was enhanced early in the project.

**Application 3: Feature Hierarchy**

Establishment of new features and segments generally required two blocks of treatment. Detailed discussion of feature outcomes is beyond the scope of this paper. However, in Bernhardt (1990) and Von Bremen (1990) higher level features showed faster gains than lower level features for seven out of eight subjects. Manner and laryngeal features showed faster gains than place features, as might be predicted from their relative positions in the hierarchy. Because it was difficult to determine relative height within the hierarchy for some targets, in subsequent studies, individual (nondefault) feature development was contrasted with development of new feature combinations with existing nondefaults. Preliminary analysis does not appear to confirm a strong difference between the two types of targets, with individual difference, but further analysis is necessary.

The concept of default was useful in describing the phonological patterns observed and setting up goals for intervention. The concept of “favorite sounds” or “sound preferences” has been around since the 1970s (Edwards & Shriberg, 1983). The notion of default is a theoretically based construct from adult phonology that accounts for the appearance of favorite sounds. Introducing various types of features at different levels in the feature hierarchy also was useful in addressing the breadth of the target phonological system and enhancing opportunities for generalization (evident in the children’s productions). New pronunciations are challenging, and giving the child several different targets to attempt within a given time period (as with a cycles approach) provides more than one opportunity for change.

**Conclusions**

Application of linguistic theories is challenging, because it takes time to learn the theories and to design and test potential applications. The application of nonlinear phonological theory to phonological intervention benefited individuals in the studies and other children indirectly. Clinicians who participated in the projects have reported continued application of the principles and practices within their clinics. As theories advance, clinical practice can keep pace, in order to maximize opportunities for success in intervention.
References


