Motor Speech Treatment Hierarchy: a systems approach

Article *in* Clinics in communication disorders · October 1994

Source: PubMed

Deborah Hayden
The PROMPT Institute

Motor Speech Treatment Hierarchy: A Systems Approach

Deborah A. Hayden, MA

Children's Centre, Speech Foundation of Ontario, Toronto, Ontario

Paula A. Square, PhD

Graduate Department of Speech Pathology, Faculty of Medicine, University of Toronto, Toronto, Ontario

This article describes a conceptual model of hierarchical neuromotor speech control consisting of seven stages, or levels. The lowest levels sustain the driving force for speech, that is, physiological support including muscle tone of the trunk and neck and control of phonation. The next three levels describe control of specific articulators, that is, jaw, buccal-labial musculature, and lingual control. The control of these structures is considered in a three-dimensional framework that specifies planes of movement in the vertical, horizontal, and anterior to posterior dimensions. The next level describes coarticulation over multiple planes of movement for sequenced speech production. The final stage considers the refinement of prosody. This model is useful for the consideration of the development of speech motor control and for assessment and intervention for motor speech disorders.

Keywords: Motor speech control; treatment hierarchy

The Motor Speech Treatment Hierarchy (Hayden, 1986) was originally developed to help conceptualize the various levels of the motor system which must be controlled to produce normal speech. It was also designed to provide the practicing clinician with clearer insights into the relationships that must be maintained among systems for normal speech production. As such, the hierarchy serves as a guide for assessment and intervention procedures.

This article focuses on the Motor Speech Treatment Hierarchy and its application to the management of motor speech disorders in children. Although originally developed as a framework for PROMPT treatment (Hayden, 1984), Motor Speech Treatment Hierarchy, when applied as a bottom-up approach, has universal applications. That is, the hierarchy can be used to guide the progression of motor speech treatment regardless of the specific bottom-up therapy techniques utilized, for example, visual biofeedback, auditory-visual stimulation, phonetic placement, PROMPT, and so forth.

The PROMPT system, Prompts for Restructuring Oral Muscular Phonetic Targets (Hayden, 1984), uses tactile cues of pressure, place, and timing to promote and enhance effective neuromuscular innervation and coordination for the learning and integration of motor speech behaviors. This article discusses only the Motor Speech Treatment Hierarchy and the principles of motor speech treatment (Netsell, 1981; Abbs, 1988; Weismer, 1988). Only occasional brief references to PROMPT treatment are made. Specific information on the prompts themselves can be obtained from the original (Hayden, 1984) or subsequent articles (Square, Chumpelik, and Adams, 1985; Square, Chumpelik, Morningstar, and Adams, 1986; Square-Storer and Hayden, 1989). Owing to the limited scope of this article only brief outlines of the stages of the hierarchy are presented. For a more in-depth description see Hayden (1993).

Clin Comm Disord 1994; 4(3): 162–174

INTERVENTION HIERARCHY

Seven stages of intervention comprise the Motor Speech Treatment Hierarchy. These are illustrated in Figure 1. Proceeding from the most fundamental to the most advanced, they are (1) general body tone, (2) phonation, (3) vertical plane movements (jaw), (4) horizontal plane movements (lip retraction and rounding), (5) anterior-posterior, superior-inferior trajectories (tongue), (6) temporal coordination of multiple planes, and (7) normalized prosody.

The stages are interdependent; that is, each stage interacts with the stages above and below it. In this discussion, each stage is considered within the context of the entire system. The importance of acquiring voluntary motor control of each subsystem is once again stressed. The clinician must have thoroughly assessed the child's level of motor speech control at each stage. This ensures that intervention will begin at the correct level. All levels of the system are interrelated, and a goal of treatment is to integrate actions learned at one level with previously learned action routines. Figure 2 illustrates the integration process. First, the clinician facilitates production at the "weakest" link and then attempts to establish the required speech actions at that level. The establishment of the new speech actions is represented by the top box in Figure 2. Next, the newly acquired speech actions are integrated with those actions learned earlier in therapy or that are already in the client's repertoire. This means that for different clients treatment begins at different levels. Regardless of the level at which treatment begins, new speech actions (movements of the articulators across one or more planes of movement that produce a phoneme equivalent, e.g., /a/) are integrated with previously established action routines (speech motor

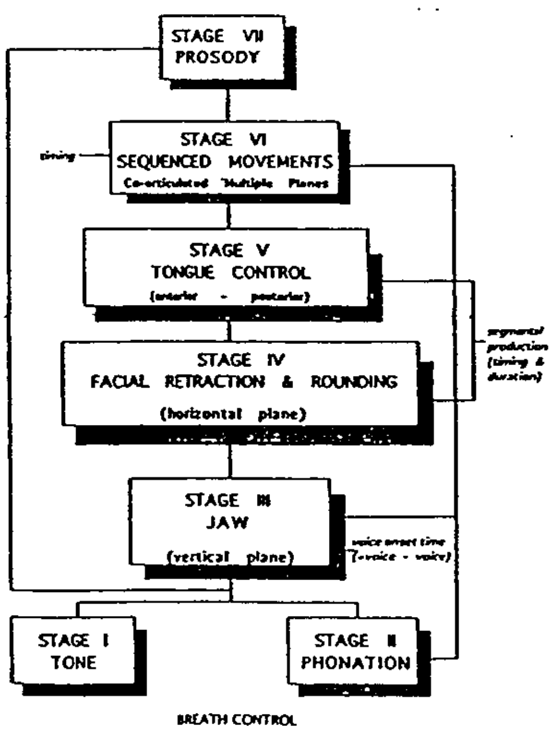

Figure 1. The Motor Speech Treatment Hierarchy developed for PROMPT treatment.

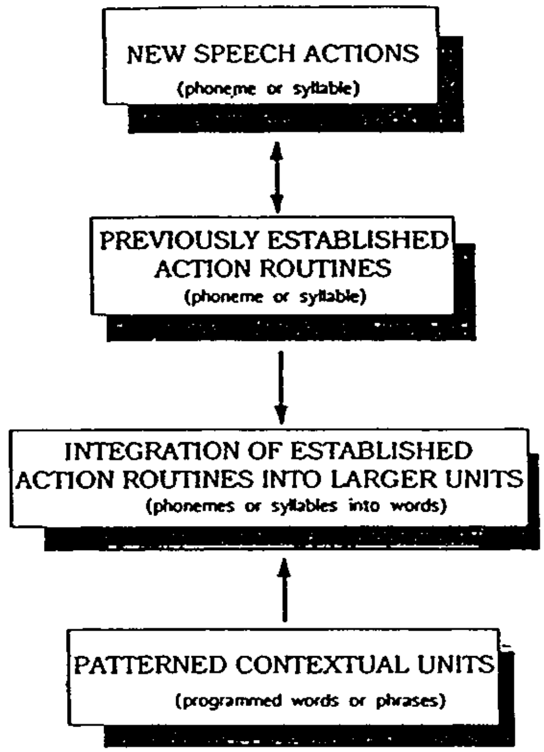

Figure 2. Integration of newly learned speech actions (top box) with previously established action routines (second box from top) and previously taught contextual units of language (bottom box) to achieve voluntary motor control over novel, self-generated units of speech (third box).

actions that are habitual and produce a phoneme equivalent, e.g., /i/) until "voluntary" control of the integrated actions is achieved (e.g., /ai/). In addition, patterned functional contextual units such as "I want a ______"—using both the new and established action routines—should be taught. These patterns are programmed in or hard-wired as whole units and serve as a contextual framework for the action routines. They also prepare the way for the use of functional and larger language units in the natural environment. These are represented in the bottom box in Figure 2. The goal of the treatment—the establishment of voluntary generation of novel utterances that are motorically controlled—is represented in the third box. This ability stems from the ability to integrate new action routines into patterned contextual units, or from synthesizing established action routines to produce completely novel utterances.

The sections that follow discuss the establishment of motor control at each level of the hierarchy (see Figure 1). It must be stressed that although each section emphasizes the importance of voluntary control, the clinician *must always* strive to create activities that are developmentally appropriate and that promote functional communication (also see Strand, 1992). As well, the clinician might be working at several levels simultaneously, for example, stages III and V (maintaining jaw stability and range while working on tongue-tip control). In this case, although the goal would be voluntary control at stage III, it is important that the clinician integrate and expand the action routines into higher stages that are not yet under voluntary control.

STAGE I. GENERAL BODY TONE

The ability of the body to support itself against gravity and perform movements with other muscle groups smoothly and in a coordinated fashion is dependent at the most basic level on muscle tone. Either too much tone (hypertonicity) or too little tone (hypotonicity) will cause difficulties in voluntary control of the speech valves. Thus, both general tone and the tone of individual speech valves must be assessed.

In children with dysarthria, muscle tone disturbances will be observed. These tone disturbances, however, may be specific to certain orofacial muscle groups. It has not been widely acknowledged that the tone disturbance might be specific to the speech musculature or even to select muscle groups within the speech system. Nonetheless, results of recent neurophysiological studies of the cortical control of orofacial movements indicate that individual muscles or sets of muscles could indeed be impaired (Fowler, Rubin, Remez, and Turvey, 1980; Abbs and Welt, 1985; Gracco, 1990; Square and Martin, 1993). The hypothesis put forward here is that, for many children with severe speech disturbance, "regional" tone abnormalities occur within the speech system. The cause of these abnormalities could be direct damage to the neurological system, or they could result from a compensatory relationship between muscle groups. For example, in an attempt to stabilize jaw position, a child may increase tone in the oral-facial muscles. In most cases, these compensations occur unconsciously. These same children may or may not have gross body muscle tone abnormalities. We classify all children with tone disturbance, either "regional" or generalized, as "developmentally dysarthric." In a child with "pure" developmental apraxia of speech (DAS) or a "pure" phonological disorder, tone disturbances *should not* be present. Nevertheless, it has been our clinical experience that in many children *traditionally* labeled as "apraxic" there is a regional tone disturbance of the speech system. Therefore, examination for tone abnormalities should include not only observation of the entire body but also regional examination of the trunk, neck (which is comprised of many of the extrinsic laryngeal muscles), face (including not only lips but also facial muscles responsible for retraction and rounding), and tongue musculature.

Trunk

Incorrect breathing patterns and inability to achieve breath support for sequenced speech valving must be corrected before proceeding to subsequent stages. In cases of tone abnormalities of the trunk, the speech-language pathologist should work with a physiotherapist or occupational therapist to establish good trunk control for the improvement of breath support, balance, and sitting. In less severe cases, PROMPT can provide cues to aid the child in establishing breath control for speech by simultaneously applying manual pressure on both the anterior and posterior portions of the thoracic cavity.

Hemiparesis

Hemi*facial* tone disturbance often, but not always, coexists with general hemiparesis. Facial hemiparesis will cause unequal muscle contraction to the midline of the face. Often, other facial muscles are used to compensate for the tone imbalance. The clinician must analyze abnormal muscle movements and recognize where "overmovement" of uninvolved or "undermovement" of involved and uninvolved muscle groups will result in disordered speech, especially sequenced speech valving.

Facies or Specific Facial Muscle Groups

Hypertonicity in the facial area makes transition and accurate timing for retraction and protrusion of facial muscles impossible. Facial muscle hypertonus may result in retracted lips or increased tension in the corners of the obicularis oris. Facial muscle hypotonus will result in poor labial valving and sometimes an open jaw posture. The speech clinician must learn techniques for reducing regional hypertonicity from the physiotherapist, through short-courses such as Neuro-Developmental Therapy (NDT) (Langley and Lombardino, 1991), or as described in oral-motor therapy techniques (Marshalla, 1985, 1992).

The Tongue

The tongue must be able to function separately from the jaw in order to perform the quick, isolated movements necessary for rapid speech. When aberration of tone exists, the tongue is likely to be slow in movement and valving imprecise. Normal tongue/jaw separation in children should occur by three to five years of age. Dependent on hyper- or hypotonic conditions in the whole body, trunk, or specific orofacial muscle groups, the tongue needs to be considered differentially. Treatment will need to focus on (1) capitalizing on muscle groups within the tongue that have adequate control, (2) decreasing or increasing strength/tone in muscle groups that are functioning poorly, and (3) increasing independent movement of the tongue from the jaw.

STAGE II. SUPPORTIVE SPEECH FUNCTIONS: PHONATION AND BREATHING

To sustain speech, a child must be able to maintain breath support and develop control for speech breathing. As explained in the previous section, tone difficulties will greatly influence muscular support for breath control, that in turn will lead to difficulties controlling subglottic pressure or oral pressures (Netsell, 1983). Phonation and breathing control difficulties are not, in our opinion, consistent with our conceptualizations of DAS. A child with difficulties in these areas would be diagnosed as having developmental dysarthria by our group.

It has been our observation that a child can produce an adequate breath support for speech if there is evidence of (1) a combination of abdominal and thoracic chest expansion, (2) the ability to inhale rapidly and exhale slowly, (3) and the ability to produce an open vowel with consistent start/stop control (a-a-a-a). The ability to start and stop a controlled phonation on the same exhalation is fundamental. This control is the basis for coarticulated speech production. In addition, there should be *no* evidence of clavicular breathing or shallow abdominal breathing. Until control of phonation is established, treatment directed at more advanced stages should not be undertaken. On/off production need not be more than two seconds in duration but *must* be under control. The treatment hierarchy we use to establish phonatory control is discussed later in the article.

STAGE III. SINGLE MOVEMENT TO COMBINED MOVEMENT ON A SINGLE PLANE

The first oral articulator to be used to manipulate human sound is the jaw. At around six months of age, the jaw performs movements in a vertical plane and accomplishes four actions. (1) It allows the oral aperture to be open, providing little resistance for vowel production; (2) it closes the oral aperture completely so that the air stream is directed back and superiorly for nasal productions; (3) it enables the lips to approximate each other for early bilabial productions; and (4) it lifts the front of the tongue when closed, and back of the tongue when open, to aid in the early phoneme approximations and productions of both front tongue (/t/, /d/, /n/) and back tongue dorsum (/k/, /g/, /ŋ/) movements. Independent functions of lip and tongue control in speech play appear later.

Difficulties with control of jaw movement in one plane is, in our opinion, indicative of a developmental dysarthria rather than DAS. At stage III of the treatment hierarchy, the focus is on establishing jaw control and integrating it with control of breath support and glottic valving. To maintain a base for all other phoneme features, the child must be able to produce voiced–voiceless contrasts at various degrees of jaw aperture.

Jaw + Voice

The first goal of this stage is to integrate vertical jaw movement and voicing. It is important to focus on the maintenance of voicing only during vertical plane movements, before expecting maintenance of voicing on multiple planes of movement. Typically, bilabial + low back vowels are worked upon so that the jaw must rise completely to assist with bilabial closure and then open to its "speech" maximum (e.g., m-a; b-a). Movements should not be exaggerated.

Voiced–Voiceless Contrast Control

Subhierarchies of treatment are often used by our group. An example subhierarchy for working on easier to harder speech actions to train voice-voiceless contrasts is presented in Figure 3. If the child has significant hypertonicity, the pressure seal for /p/ may be easier to achieve than that for /b/. For other children, devoicing may be difficult, so /b/ is easier than /p/. If the child has acquired /b-a/, he/she must be taught to control devoicing, as in /p-a/ (same vertical plane). If voiceless /p/ cannot be achieved, the concept of voicelessness can be achieved with /h/. The /h-a/ sequence involves no movement of the jaw but teaches a voiceless–voiced sequence. Once the /h-a/ sequence is attained, the /p-a/ sequence should be easier to establish. Conceptualization of the amount of control required for /b-a/-/p-a/-/m-a/ is depicted in Figure 3. The least control is required for nasals of long duration such as /m/. Quick movements, such as those required for production of the bilabial /p/, require the most control. Movements that correspond to the voiced bilabial /b/ require timing control that falls between /p/ and /m/.

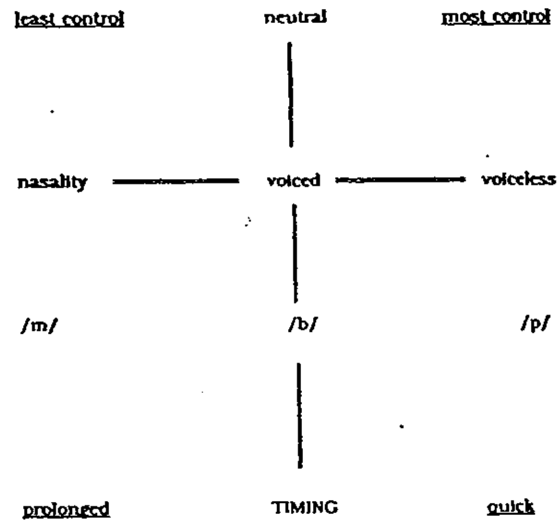

Figure 3. An example of a subroutine for training voice–voiceless contrasts integrated with jaw movements.

STAGE IV. ADDING A HORIZONTAL PLANE OF MOVEMENT

Planes of movement are almost always overlooked in traditional speech treatments because speech is typically conceptualized as a string of phonemes rather than as a sequence of movement trajectories that are superimposed upon a valved air stream. PROMPT is a motor treatment based upon the mastery of movement trajectories which are temporally integrated with valving actions of the larynx, velopharynx, and lips. Thus, the next stage in the sequence is the mastery of the ability to use smooth and well-controlled facial contractions for horizontal movements, as, for example, /i/ (retracted) and /u/ (rounded). Lip/buccal retraction and rounding also affect the placement of muscular contraction in the tongue; that is, retraction and rounding appear to aid the tongue in early speech production by influencing both the points of anterior-posterior valving and the degree of rising for development of early-occurring vowels (i.e., /i/, /ʌ/, /o/, /u/), and later, for consonants (i.e., /s/, /ʃ/, /r/, etc.).

The retracted labial action is usually acquired before rounding, although there is individual variation. In treatment, the important point is that, in adding a plane of movement, all lower levels of control are maintained. Once well-controlled movements can be produced, CV, VC, and CVC sequences are possible. It has been our experience that children between three and four years of age with "pure" phonological disorders usually demonstrate very good ability at this level. Children with DAS may have acquired all preceding levels but begin to break down here; that is, transition between and the integration of two planes of movement, coordinated with phonatory and respiratory valving, cannot be achieved.

Jaw + Voice + Facial Retraction

Intervention begins by pairing the actions required for the retracted vowel /i/ with the vertical jaw actions required for the bilabials /m, b, p/. A typical sequence might be bilabials with different manner and voicing paired with the retracted vowel /i/; for example, /m-i/, /b-i/, and /p-i/. For children with increased muscle tone of the retractors, these combinations should be relatively easy. Difficulties are more likely seen when transitions between the *two planes* of movement are introduced, as in the actions required for /a/ and /i/ coupled with bilabials (e.g., (1) /m-a/-/m-i/, (2) /b-a/-/b-i/, (3) /p-a/-/p-i/). If these series are mastered, then the action sequences correlative to these vowels and consonants can be reordered for various combinations that require the ability to maintain control between postures (coarticulation). All combinations should be attempted and accuracy achieved before proceeding with other sequences (e.g., /i/-/a/, /m/-/a/, /a/-/b/, /i/-/p/, /a/-/m/, /m/-/i/).

Voice + Jaw + Facial Retraction/Rounding

If lip rounding resulting from contraction of the obicularis oris and accompanying facial muscles can be easily produced, programming can continue using the movements that correlate with the following vocalic sequences: (1) /a/-/a/, /a/-/u/, /a/-/o/; and (2) /o/-/u/, /u/-/i/, /o/-/i/, /i/-/u/, /i/-/o/. In this sequence it is important to remember that because /o/ requires more tension and contraction across the upper lip than does /u/, and the jaw position is lower for /o/ than for /u/, transitions involving /o/ will generally be more difficult.

These vowel combinations, once established, should then be incorporated into the consonant sequences already established. *Voicing control* must be maintained. The child should now be able to produce the movement sequences required for three or more vowels (/a/, /i/, /o/, and /u/) and combine them with the movements that correlate with the bilabial consonants (/m/, /b/, and /p/). Possible combinations could now include such functional words as *mom*, *pop*, *bam*, *mop*, and *bee*.

Communication activities in which these movement units are practiced as *words* that manipulate the child's environment should always be an early goal. Thus, treatment activities should focus on language interchanges in which these movement units can be used functionally.

STAGE V. SEQUENTIAL CONTROL OF FACIAL AND ORAL MOVEMENT: JAW + VOICE + FACIAL RETRACTION/ROUNDING + TONGUE CONTROL

Control of the laryngeal and respiratory valves has now been integrated with jaw movement in the vertical plane and with lip retraction/rounding in the horizontal plane. It is important that control of phonation, range of jaw movement, and facial muscle contraction for both retraction and rounding be established and under good voluntary control before progressing further.

It is at this point that the tongue is brought into play as an independent and flexible articulator. That is, the tongue now begins to perform actions independent of jaw actions. The tongue, being comprised of extrinsic and intrinsic muscles, is capable of achieving numerous postures. Two distinct stages of control occur: separation of tongue from jaw movement, followed by achievement of multiple flexible postures. This is a slow process. In normally developing children, tongue–jaw separation begins around nine months but is not usually completed until after age four (Kent, 1988).

Intervention generally proceeds from tongue tip control to dorsal control (Oller, 1978). Nonetheless, there are always exceptions. In children with motor speech disorders, intervention at this stage requires that the clinician carefully evaluate the child to determine whether or not some aspects of tongue control already exist. For example, some children may be able to release the tongue blade area but not the tip, or release the tip but not the dorsum. Others may have some use of the blade and tip but limited use of the mid to dorsal sections. In some children, back tongue movements may be more accessible if there is an increased facial tone and the tongue is generally in a retracted position. Thorough assessment will guide intervention and provide information about how to facilitate the integration of various muscle groups.

With the above exceptions, the following introduction of phonemes is usually acceptable to achieve control of the appropriate integrated actions: /t/, /d/, and /n/, the labial dental /f/, mid palatals /ʃ/ and /r/, velars /k/ and /g/, independent tongue-tip control movements /l/, /s/, /z/, /ŋ/, /θ/, /ʃ/, /dʒ/, and /ʒ/. It should be noted that using a tactile-kinesthetic approach such as the PROMPT system enables one to teach fricatives, affricatives, glides, and semivowels earlier than might be possible with other intervention programs. Concurrently, mid-vowels which require lingual posturing are considered (e.g., /ʌ/, /ɪ/, /ɛ/), as well as diphthongs (e.g., /oi/, /ai/, /iɛ/, /ei/) which require vertical and horizontal plane changes.

Traditionally, clinicians begin treatment that focuses on lingual postures. It should be obvious now why we consider this to be an error. Every new motor variable added to the system creates additional requirements. The clinician must understand that control for phonation, jaw, and labial rounding and retraction must occur first. The effects of action routines, and their interactions must be remembered.

Finally, it should be noted that tongue tension is critical for production of all consonants and vowels. It can be enhanced using mylohyoid prompts which increase contraction of selected lingual muscle groups. The child should not be expected to *maintain* appropriate muscle postures at the beginning. As the child's system is stimulated, and control at lower levels is more firmly established, lingual muscle tone for the appropriate sets of muscles will normalize. The speech system will do more of the work and the clinician less. That is, use of mylohyoid prompts, or tension cues, will decrease as the child gains better control.

STAGE VI. SEQUENCED MOVEMENT ON MULTIPLE PLANES, VOICE + JAW + FACIAL CONTRACTION AND ROUNDING + TONGUE CONTROL + TIMING

At this stage, a new goal of treatment is to deliver prompts or cues that signal relative durations of segments as well as transitions between them. Aspects of timing have already been of great importance at preceding levels. The child has practiced both voice onset timing and control of duration of continuants. We presume that control of voice onset time sets the stage for voluntary control of segment duration, and voluntary control of segment duration sets the stage for the control of durations of transitions. A review of Figure 3 (our conceptualization of the amount of control needed to maintain temporally controlled changes for different valving characteristics of the phonemes /m/, /b/, and /p/) would be helpful at this point as one example. Quick movements, such as those required for the voiceless bilabial /p/, require the most control. The least control is required for nasals of longer duration such as /m/. The voiced bilabial /b/ requires timing control that falls between /p/ and /m/.

Voice Onset Time/Voicing Errors

In dysarthria, resonance deviancies often occur because of tone or strength aberrations. In hypotonicity, there is weakness and limited movement of the oral structures; thus, velopharyngeal closure may be inadequate. Increased upper body tone will produce some improvement. With hypertonicity, the velum will be limited in its range of movement. This condition is extremely difficult to correct and needs to be considered within the framework of the entire body, especially the chest and head area. With apraxia, resonance deviancies may occur because the speech system cannot control all levels of movement when increasingly complex movements, that must be temporally sequenced, are required. The system often reverts to the simplest level of movement.

In children with motor speech disorders, the ability to control multiple muscle contractions will determine how much difficulty the system will have with flexible coordinated movements that affect the timing of velopharyngeal control. In children with mild developmental dysarthria this may be a problem. It is our impression that in DAS, nasality, if observed, occurs only at the level of words or phrases where sequential and timing variables interact with air stream management. At the level of phoneme production, usually only one plane of movement is required. Therefore, valving can be more easily coordinated with the articulatory movement required.

The following treatment subhierarchy is generally applied for establishment of timing variables associated with voicing. Control at most levels has already been achieved at very early stages. Nonetheless, the entire subhierarchy of activities is presented here to demonstrate the complexity of coordination of glottic valving with supraglottal articulation over several planes of movement.

Voice On/Off

The child should have achieved control of the following as evidence of appropriate control of voicing for speech: (1) production of an open vowel on command, (2) production of a stop and an open vowel with a one-second inter-phoneme interval, (3) production of a stop and two open vowels of a set duration, (4) ability to vary the duration of two open vowels, (5) production of one stop and three vowels of a set duration, (6) production of a stop and four vowels of a set duration, and (7) production of a sequence of four vowels of different durations.

Deviancies in jaw control affect the child's ability to control the duration of open vowels. Thus, the following aspects of jaw control must be considered while working within on phonatory control. These levels of mandibular control are also generally achieved early in the treatment hierarchy, that is, stage III. First, the jaw should be in midline position. Second, the jaw should move vertically in line with the maxilla and should not slide anteriorly, posteriorly, or laterally. Third, the jaw should move smoothly; and fourth, the jaw should not show reduced or overextended excursion at a full open position. PROMPT tactile cues may be used to help ameliorate any of the above deviancies.

Voice + No Voice + Jaw Control

The following hierarchy is provided to help the clinician break down the steps that should be considered when establishing the control of timing of voicing supraglottal movements over various planes: production of a voiced CV of a set duration, e.g., /ba/; production of a consonant, e.g., /p/, and a vowel, e.g., /a/, of a set duration without attempting to coarticulate; production of two voiced CVs or VCs of a set duration; production of a sequence of two CVs, e.g., C-V-C-V, where C is an unvoiced plosive; production of one CV or VC, e.g., /pa/ /ap/, with controlled blending; production of two CVs or VCs with controlled blending; production of a VC voiced nonplosive, e.g., /ab/, and a CV unvoiced (plosive), e.g., /pa/; production of a sequence of four bilabials CV or VC syllables of voiced-voiceless contrast, e.g., /ba pa ba pa/, /pa ba pa ba/, etc.; and variations of the durations of the vowels in the preceding step. Once the child has mastered timing of on/off voice production + jaw movement, the actions for lip contraction, /i/, lip rounding, /o/ /u/, and lingual movements can be added.

Once good control of voicing at the voice on/off level is achieved, the clinician should proceed to the sections below. Breakdowns at subsequent levels will require the clinician to go back and assess mastery of previous levels.

In general, the more planes of movement (vertical to horizontal, anterior to posterior) and timing variabilities that the child must control, the more difficult the production will be. This concept is clarified in Figures 4, 5, and 6. Movements that correspond to phonemes and the short words they produce are plotted in a three-dimensional framework that denotes jaw height (vertical plane), lip movement (horizontal plane), anterior to posterior placement of the tongue, relative durations of movements, and movement trajectories.

Figure 4 is a three-dimensional representation of production of the syllable /mu/. The sequenced movements required involve a relatively low level of control. First, the jaw position does not change. Point of contact/constriction is from anterior (bilabial) to posterior (tongue dorsum). The durations of the segments are approximately equal. Finally, the movement trajectory is from anterior to posterior only.

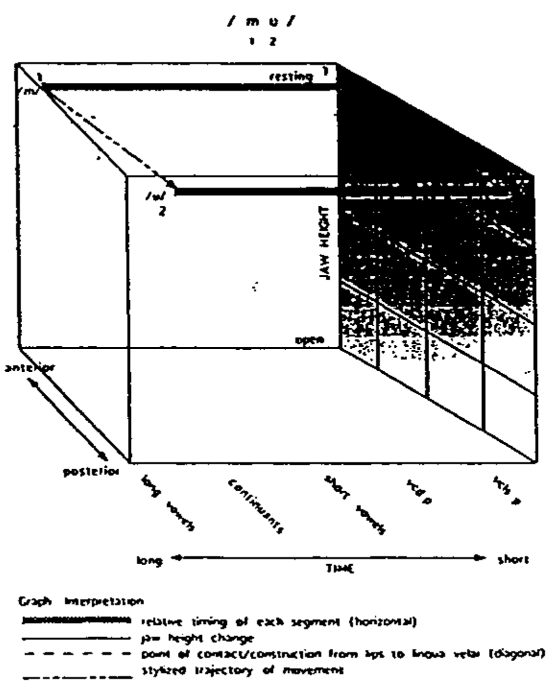

Figure 4. Speech actions required at stages III (jaw), V (tongue), and VI (sequencing and timing) of the Motor Speech Treatment Hierarchy for production of the syllable /mu/.

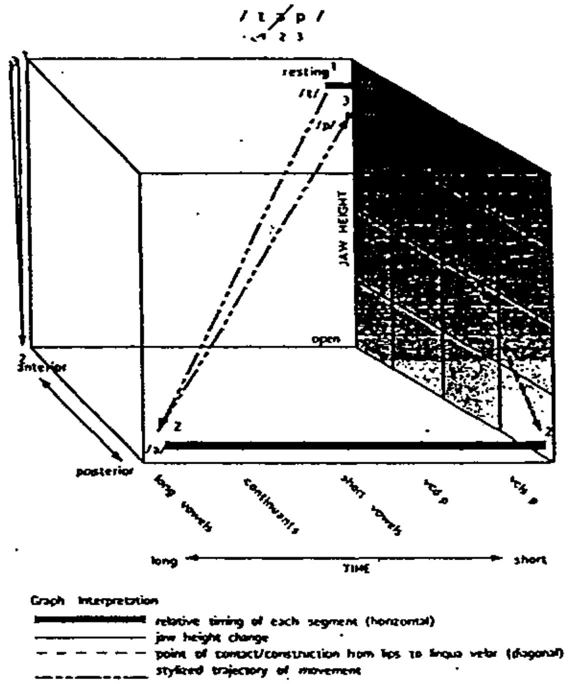

Figure 5. Speech actions required at stages III (jaw), V (tongue), and VI (sequencing and timing) of the Motor Speech Treatment Hierarchy for the production of the syllable /tap/.

Figure 5 illustrates the increased complexity of control required to produce the movements requisite for the word /tap/. Jaw excursion is from closed to fully opened to closed. Durations of postures vary greatly, and movement trajectories from anterior to posterior to anterior must be integrated.

Figure 6 illustrates the movements required to produce the word /boit/. Although /boit/ is a CVC in which all Cs are plosives, like /top/, it should be immediately clear how much more complex the movements are for this production.

There are two guiding principles concerning the complexity of motor movements for speech production: (1) The more constant the vowel and consonant the more stable the voicing component and the easier the production, e.g., *dad*, *no*; and (2) the more deviant (extreme) the production, the more difficulty the child will have in maintaining smooth transitions without sacrificing a variable such as voicing or duration, e.g., *net* or *kod*. When the clinician translates these principles into therapy intervention it is important that he/she choose

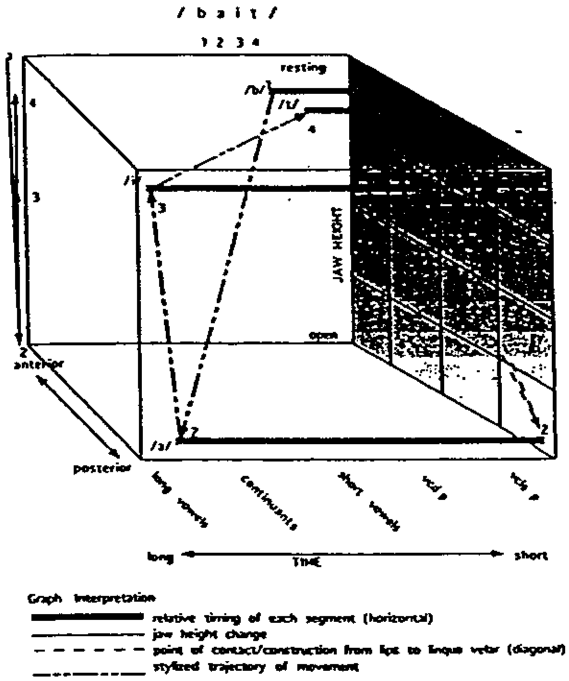

Figure 6. Speech actions required at stages III (jaw), V (tongue), and VI (sequencing and timing) of the Motor Speech Treatment Hierarchy for the production of the syllable /bait/.

initial word lexicons that maintain central or long vowels and consistent consonants, e.g., *dad, man,* before progressing to more variable durations, e.g., *pet, take,* or combinations thereof, e.g., *red, pair.* Often clinicians will experience a child sacrificing one variable/feature for another in a more complex set, e.g., *kod* = *dod, dog* = *gog*. When the motor demands are too great for the system to maintain, the process of consonant deletion, postvocalic devoicing, assimilation, stopping, or cluster reduction often occurs. For example, /ʃu/ becomes /u/, and /lait/ becomes /la/ or /jai/.

Coarticulation Processes (Multiple Planes)

By now the child should have general control of timing aspects related to voicing and segmental duration. For children with severe impairment, production of phrases of more than two or three words will be unintelligible. Thus, at this word/phrase level the focus is on overall timing as it relates to (1) intelligibility; (2) smooth, well-coordinated transitions; and (3) stress markers that determine appropriate syllabication and mark meaning.

In the PROMPT system, the clinician uses the sequenced prompts to control timing of steady-states and transitions, as well as to provide extra emphasis for stress markers. Timing between words is controlled by providing input on initial start or stop sequences. Prompts may or may not be given for every word, depending on the client's needs.

STAGE VII. PROSODY/SUPRASEGMENTALS

This stage is a culmination of all stages before it, and can be described by the basic physical qualities of amplitude, duration, and fundamental frequency of the voice. Although controlled through motor speech functions, prosodic features convey more than words in that they function to decode the communicative intent of word use. Prosody begins to develop very early in communication attempts. The development of prosody in speech is paradoxical in that it is both the most fundamental and also the most complex system in communication. Prosody provides the underlying melody line for speech that infants first respond to and imitate. It is also one of the last systems to embody the combined motor speech processes and to carry these processes into complex communications.

The scope of this article is the tenets upon which the Motor Speech Treatment Hierarchy is based, so the areas covered in stage VII will be only briefly described. Mentioned in the following sections are intonation, stress, juncture, and speech rate, and what the clinician may need to consider when facilitating these parameters in treatment.

Intonation

Intonation can be described as the vocal pitch contour of an utterance, or the way in which fundamental frequency changes from syllable to syllable, or even from segment to segment (Newman, Craighead, and Secord, 1885). Intonation is affected by several factors including syllabic stress and tongue position. In DAS, the intonation pattern or melody line is usually intact and is usually easier for the child than is marking stress, or coordination of valving and movement trajectories. In children with dysarthria, transition time between oral valving movements will negatively affect intonation, stress, and voicing.

Stress and Juncture

Stress refers to the degree of prominence or importance given to some part of an utterance and is usually discussed with respect to syllables (Rabiner, Levitt, and Rosenberg, 1969). Acoustically, stress is carried primarily by the vowel segment within a syllable, although emphasis or stress can also be placed on initial or final consonants. In the PROMPT system, the clinician increases duration for vowels and pressure for consonants to increase the stress of a segment or syllable.

In DAS, stress can be programmed at a word level and, if there is no dysarthric component, spontaneously generalized into phrases. In children with a dysarthric component, stress patterns are not necessarily generalized, and they may need to be programmed at the whole-phrase level to be maintained. In other words, the entire phrase with all of its motoric and valving demands will be taught with the needed stress markers. Timing and transition difficulties inherent to dysarthric speech make stress a variable feature on a spontaneous level.

Juncture or *pausing* makes special distinctions in speech of certain grammatical divisions. It also can be used to make distinctions between similar articulations such as "common" and "come on." The PROMPT system can be used to help control for timing and rate variables that influence juncture. It appears that juncture is often difficult for children with DAS. Juncture must be taught along with stress, mainly because grammatical forms and semantic understanding have usually not been completely developed. Gross and fine motor activities using body parts paired with music (e.g., instruments, peg boards, buzzer boards) can be used to visually and acoustically represent juncture.

Speech Rate

Speech rate is affected by the range of articulatory movement. As the speed of speech movements (articulation) increases, transition time, movement range, and segment durations decrease. In order to speak faster and maintain intelligibility, a speaker must maintain valving control while reducing range of movement. Hypertonicity affects movement transitions primarily because muscles do not have "freedom of movement." Instead, they become fixed in a position while they "struggle" to move into another. Transition time slows while movement range among some articulators increases, most notably jaw excursion. In lips and tongue muscles, range may decrease but transition time continues to be arduous. Overall, speaking rate is slow.

Hypotonia may also result in decreased range of movement and poor valving control. The clinician's goal is to *increase* range of movements and the force of valving. In some clients this may mean that only two or three words are intelligible per breath. Always the goal should be increased intelligibility with control. Using the PROMPT system the clinician may stimulate pressure variables for each phoneme. This will aid the child to increase bilabial and lingual valving force. This, in turn, will lengthen duration, thereby increasing range of movement and slowing rate of production.

Studies on acquired apraxia indicate that the primary bases for apractic speech errors are the temporal and spatial incoordination of elemental movements in connected speech. Therefore, increased or decreased speech rate in apraxia may be because of the patient's unconscious efforts to sequence appropriately all subcomponents of an action. In children with "pure" DAS, rate will not be influenced by deviant muscle tone. Thus, transition and sequencing control should be a primary emphasis of treatment. In summary, rate of speech production in disordered speakers is related to tone, breath support, voicing, and transition time. Each of these must be evaluated if the clinician is to understand how to help a child speak with control and intelligibility.

SUMMARY

The Motor Speech Treatment Hierarchy used to guide PROMPT intervention represents a theoretical framework for the application of all bottom-up motor speech treatments. In addition, the hierarchy can be used prior to motor speech treatment to evaluate what aspects of the child's neuromotor system are intact and which elements are operating ineffectively or partially. When consideration is given to the development of the speech motor system and the interaction among the various valves and/or articulators, it becomes apparent that treatment must focus on the integration of all these aspects in order to be successful.

The goal of intervention must be the voluntary control of all speech actions. But voluntary control of all speech actions is not possible for all children, and the clinician must realize that compensatory actions, although beneficial in the short term, will limit more complex interactions later. It is for these reasons that more attention should be given to mastery of control at the lower stages of the hierarchy. The clinician should not assume that all actions are intact based upon the perceived quality of speech. For the child with "pure" DAS, intervention usually begins at stage V or VI, whereas for children with developmental dysarthria, intervention begins at lower levels of the hierarchy. The responsibility, as always, lies with the clinician to determine the most appropriate level at which intervention should begin and the steps needed to achieve the best speech production. The clinician's knowledge provides the foundation for changing deviant motor speech patterns and for providing for our clients voluntary control of motor speech function. It has been the aim of this article to provide for clinicians a framework for treatment that will enhance their clinical effectiveness.

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