Analysis of Speech Movements: Practical Considerations and Clinical Application

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The instrumental evaluation of speech movements is an important adjunct to the assessment and understanding of speech motor disorders. As the interface between the nervous system and aerodynamic modifications in the vocal tract, movement variables such as displacement, velocity, acceleration, and their time histories, can provide direct information on speech motor disorders that can only be inferred from acoustic or perceptual evaluation. Impairment in various aspects of neuromotor functioning is reflected in the motion of individual articulators and their coordination, and may reflect early signs of functional change due to disease or trauma. Within certain limits, movement analysis can be used as an objective method for categorizing speech motor disorders and monitoring change due to therapeutic intervention. Further, objective comparison of orofacial motor behavior during speech and nonspeech tasks may provide diagnostic insight into underlying pathophysiological processes. A perspective on the potential utility of speech movement analysis in the assessment, treatment, and understanding of speech motor disorders is the focus of the present chapter. The limitations of speech movement analysis and the need for clinically-relevant research will be presented.

INTRODUCTION

With the increased availability of measurement devices for transducing movements of the speech articulators, computer software for automated processing and analysis of data, and decreased cost of computer hardware, instrumental evaluation of human vocal tract movements is becoming more feasible for inclusion into the clinic. Analysis of upper and lower limb movements employing various instrumental tests have been used for the last 40 years to aid in the evaluation and diagnosis of various pathophysiological conditions and to determine the outcome of clinical trials (see Potvin & Tourtellotte, 1985 for review). For speech, movement analysis is a potentially important adjunct to more traditional acoustic and perceptual analyses used routinely in the clinic. In addition, analysis of speech and nonspeech (orofacial) movements can be used to evaluate the consequences of motor disorders that have not yet developed to the point of significantly affecting the communicative process. The purpose of the present chapter is to outline some of the ways in which analysis of movement parameters and movement patterns may be used clinically. Before proceeding, it may be helpful to reiterate a point made by Potvin and Tourtellotte (1985):

“To the extent that instrumented tests can be developed for measuring functions, their selective use can provide information that might not otherwise be available. However, investigators should be aware that the ability to measure small differences reliably can yield statistically significant differences that may not be of clinical importance.”

In the following, the focus will be on measurements that may have specific functional utility in terms of assessing speech production capabilities, detecting differences in neurologic function, and improving understanding of speech motor performance. Because of the current limitation in normative data and the wide range of inter- and intrasubject variability, both qualitative and quantitative methods will be presented.

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INTERPRETATION OF MOVEMENT

The evaluation of movement can be approached from a variety of perspectives. From a motor control perspective, speech production is observed to be a sequential production of different vocal tract configurations that are coordinated in space and time and overlap to various degrees. Visual inspection of speech movements allows for a qualitative impression of overall motor functioning. Compare, for example, the lip and jaw movement signals presented in the left half of Figure 1, obtained from a neurologically normal subject, with the movement signals in the right half of the figure, obtained from a subject with Parkinson's disease (PD). Each subject is repeating the same sentence and the scaling for the two sets of signals is the same. Without knowing what is being said, and disregarding the respective acoustic signals, it can be seen that there are marked differences in the two sets of movements. While there are some general similarities in the overall movement patterns, the extent of articulator motion of both the upper lip and lower lip/jaw movements for the PD subject is less than for the normal subject, consistent with the clinical manifestations of hypokinesia. Movement velocities, displayed above and below the respective UL and LLJ displacements, are severely reduced in magnitude for the PD subject as well. Further insight can be gained into the manifestations of the disorder by evaluating the acoustic signal simultaneously with the movement signals. The impoverished and slow movements from the Parkinson's subject are accompanied by a poorly differentiated acoustic signal consistent with the perceptual speech characteristics of imprecise consonant production.

Figure 1. Upper lip (UL) and lower lip/jaw (LLJ) movement displacement and velocity from a neurologically normal subject and a subject with Parkinson's disease (PD). The subject's task was to repeat the utterance "Buy Bobby a poppy" at a comfortable rate and loudness with even stress. Shown below each set of movement signals is the respective acoustic speech signal.
Other qualitative observations can be made from movement signals that are important for a thorough understanding of the sensorimotor breakdown and functional deficits associated with particular speech disorders. Based on previous research it has been shown that multiple articulators engaged in the production of the same sound display spatial and temporal patterns that reflect their cooperative behavior (Gracco, 1988, 1990; Gracco & Løfquist, 1989). Individual speech movements generally display smooth continuous motion characterized by a unimodal velocity profile (Gracco & Abbs, 1986; Munhall, Ostry, & Parush, 1985; Nelson, 1983; Ostry, Cooke, & Munhall, 1987). Breakdown in the coordinative action of multiple articulators, a loss in the ability to smoothly sequence concatenated vocal tract gestures, or multiple peaks in the velocity profile associated with a single articulatory movement are observations that reflect qualitatively on the processes of speech motor control. From examination of discrete events associated with a single speech or nonspeech motor task, it is also possible to functionally evaluate the neuromotor system at the level that reflects on the net force applied to articulators to produce individual movements. In order to generate movement a certain pattern of excitation and inhibition is produced in the nervous system and directed to the lower motor neurons. The action potentials generated by the input signals result in two distinct peripheral events; electrical responses in the muscle membranes producing EMG’s, and the generation of forces originating from the contractile elements of the muscles. Movement reflects the summation of net active and passive forces with a certain time history filtered through the biomechanical properties of the structures being moved. If the structure is at least in part inertial, the initial acceleration of the load will be proportional to the initial contractile force. Similarly, the peak velocity of a movement is generally proportional to the force magnitude integrated over the movement time. Inspection of individual movement patterns can provide heuristic information regarding the neuromotor functioning of the patient and reflect on the mechanical characteristics of particular articulators.

BASIC KINEMATICS

In order to objectively and quantitatively evaluate speech movements a measurement framework is required. Any description of movement relies on the terminology of kinematics. A complete kinematic description of any movement, especially of the vocal tract, is geometrically complex. For most purposes, the motion of bodies can be reduced from irregular shaped masses to points, and the motion of such points can be described with kinematic variables. The description of point motion is analytically complex, requiring 15 data variables which change over time (Winter, 1979). For clinical purposes, the displacement (the distance from a starting to an ending position) and velocity (the directional speed) are the most useful for describing articulatory motion. In order to keep track of the changing kinematic variables and maximize their descriptive usefulness it is important to adopt a reference convention and a coordinate system. Motion can be described relative to some static articulatory position, such as lip movement relative to a rest position. An alternative that also provides spatial information is to reference the movements to an immobile anatomical structure. The most frequently used spatial coordinate system involves three perpendicular axes representing the sagittal, frontal, and transverse planes. Movements of articulators can then be described with respect to inferior-superior (y), anterior-posterior (x), and lateral-medial (z) directions, respectively, relative to some anatomical reference. The most important consideration for clinical use is that a convention be established, one that is consistent with respect to the purpose of the measurement and reproducible within and across subjects.

As mentioned, the displacement of a point on an articulator surface and the velocity at which the articulator moves are two important kinematic variables fundamental to the description and evaluation of motor disorders characterized by hypokinesia (reduction in movement extent), bradykinesia (slowness in movement; reduced velocity), and akinesia (slowness in movement initiation). Shown on the left in Figure 2 is a position time history of a single midsagittal point on the lower lip as it moves from opening for a vowel to oral closure for /p/. Under the displacement signal is the time history of the instantaneous velocity mathematically derived from the displacement signal. From the displayed signals, the maximum displacement, calculated as the distance between onset position and offset position associated with the movement, and the associated peak instantaneous velocity, are easily obtained. Additionally, the duration of the movement, defined as the time from onset to completion can also be obtained. As shown in the figure, the velocity profile can be further dissected to provide information on the accelerative and decelerative phases of the movement.
Ignoring gravity, the accelerative phase of a movement generally reflects the increase in net force applied to the load (articulator) due to the contraction of the muscles. In contrast, the decelerative phase of a movement generally reflects the decrease in net force acting on the load due to the relaxation of the contractile process and any antagonistic muscle actions. Displacement and velocity measures provide the means to describe and quantify movement and also allow some inference on the properties of the muscular actions that caused the motion. In addition to measuring the discrete components of a movement, the frequency and amplitude of repeated productions can also be calculated as illustrated on the right side of Figure 2.

**Figure 2.** Representation of the displacement and velocity of a point on the lower lip associated with a single oral closing movement for /p/ (left hand portion of the figure). Shown are some of the variables to be measured (see text for further details). The displacement and velocity of the same point on the lower lip during repetitive opening and closing movements associated with repetition of /paei/. From repetitive syllables, the frequency of production can be derived as shown.
INSTRUMENTATION

Prior to presenting a protocol that we have been using to instrumentally evaluate speech and non-speech movements, a brief discussion of the movement transduction devices and general operating principles follows. Monitoring upper articulator movement can be accomplished using a variety of transduction techniques. In general, these techniques convert mechanical energy, represented as movement of an articulator or group of articulators, to electrical energy, represented as an analog voltage. Many methods are available to convert a physiological event to an electrical signal and generally involve direct or indirect variation in electrical quantities such as resistance, capacitance, inductance, or the magnetic linkage between coils. The four basic techniques currently available in different forms for use in the speech clinic involve strain gauge transduction, optical transduction (optoelectronic sensing devices), imaging (ultrasound), and electromagnetic transduction. The following will briefly review the techniques and commercially available devices with respect to their basic principles of operation, clinical utility, and practical limitations. A more detailed analysis can be obtained from various sources such as Abbs and Watkin (1976), Baken (1987), and Geddes and Baker (1968).

Strain gauge transduction

Strain gauges are resistive elements that are mounted on a flexible, lightweight strip of metal anchored at one end and attached to a moving surface on the other end. The voltage output from a gauge is proportional to the movement at the end of the mobile attachment. Strain gauge transducers are used for monitoring external articulatory movements such as the lips and jaw. Initially, the technique was used in the transduction of jaw and lip movements by Sussman and Smith (1970a, b). Refinements of the method of attachment have been reported by Abbs and Gilbert (1973) and Müller and Abbs (1979). A significant clinical development was reported by Barlow, Cole, and Abbs (1983) in which strain gauge transducers were attached to a lightweight aluminum frame which could be mounted to a subject's head. This refinement allowed the monitoring of lip and jaw movement without requiring stabilization of the subject's head; for many neurological patients, head stabilization is an unacceptable condition. The cantilever beams can be instrumented to sense motion in one or two (orthogonal) dimensions, although the two dimensional units and their attachments add significantly to the overall weight and can decrease stability. The cantilever beams are commonly attached to a point on the midsagittal plane (midpoint of the lips and chin) providing inferior-superior and anterior-posterior motion sensing. Strain gauge transducers provide a continuous analog output that can faithfully reproduce the fastest lip and jaw movements. A bridge amplifier is required for each direction of movement to supply an excitation voltage to the resistive elements and to amplify the signal prior to storage or analog-to-digital (A/D) conversion.

Optical transduction

The most notable optical technique for tracking human movement involves a position sensing device and pulsed light-emitting diodes to track points in a two or three dimensional coordinate system (Watsmart, Northern Digital, Inc., of Waterloo, Ontario, Canada; Selspot, Selective Electronics, Inc., of Sweden). Devices that rely on the sensing of LED's are limited in a similar manner to the strain gauge devices in that they can only be used to monitor the external articulators such as the lips and jaw. There are some photoelectric devices that rely on the sensing of light reflection which can be used to monitor tongue movement (Chuang & Wang, 1978; Fletcher, 1982). However, such optical scanning systems for tongue motion require small LED light sources and photosensitive detectors arranged in an artificial palate worn by the patient. In addition to this practical limitation and the lack of commercial availability, a distance dependent error has been reported requiring a refinement in calibration procedures (McCUTCHEON, LAKSHMINARAYANAN, & FLETCHER, 1990). A final device, using charge coupled device (CCD) sensors eliminating reflection errors, is currently being marketed (Optotrak, Northern Digital, Inc.). Similar to the optoelectric devices, the CCD device provides three dimensional information on the movement of visible sensors with 0.1 mm accuracy over a one cubic meter volume. These commercial devices can also be purchased with customized software for analog-to-digital conversion, signal processing and automated analysis. The most significant drawback to these systems is the cost which may be as high as $50,000 to $60,000 for a complete three dimensional acquisition and analysis system.

Imaging

The most common imaging device having potential clinical application is ultrasound (see Sonies, 1982 for review). An ultrasound signal is
passed into the body and the differential tissue properties associated with different structural layers provide different reflections to the generated sound. The ultrasound reflections are a series of echoes that can then be detected by the transducer. The longer the echoes take to be reflected, the further the tissue is away from the source. Through a knowledge of the anatomy and the different transmission times, the structures within the path of the ultrasound can be reconstructed. For the human vocal tract, ultrasound can be used to visualize and track motion of soft tissue structures such as the tongue and vocal folds. A number of research studies have employed ultrasound to evaluate the shape and motion of the tongue (Sonies, Shawker, Hall, & Gerber, 1981; Stone, Morish, Sonies, & Shawker, 1987; Stone, Shawker, Talbot, & Rich, 1988), the movement of the tongue dorsum during speech (Keller & Ostry, 1983), movement of the vocal folds during devoicing (Munhall & Ostry, 1985) and tongue motion during swallowing (Stone & Shawker, 1986). While ultrasound devices are commercially available they are costly and are often not optimized for vocal tract use.

**Electromagnetic transduction**

Using alternating magnetic fields it is possible to track point movement of small transducers placed on the tongue, lips, velum, and jaw in the midsagittal plane. The basic device employs a sinusoidal signal driving a transmitter coil which produces lines of magnetic flux. Small receiver coils, or transducers, moving through the magnetic field are induced with a signal that is proportional to the effective cross-sectional area of the receiver coil and the flux density. If the transmitter and receiver axes are parallel, the magnitude of the induced signal is a measure of the distance between the transmitter and receiver. Recently, a commercially available electromagnetic system for tracking movements of the upper articulators has been developed and marketed under the name of the Articulograph AG100 (Carstens Medizinelektronik, Göttingen, West Germany). This system allows the tracking of up to five small receiver coils placed on various supraglottal articulatory structures in the midsagittal plane. The transmitter assembly is placed on the subjects head and secured in a manner similar to the head mounted movement system developed by Barlow et al. (1983). Although the system is commercially available, development and refinement is continuing (see Tuller, Shao, and Kelso, 1990 for initial evaluation of system performance). The system requires a microcomputer to calculate the x-y positions of each transducer in real time and stores the data on the computer disk. Software routines are provided for data display and analysis. Cost of the system, including a microcomputer, is approximately $42,000. Other magnetic devices are commercially available to record positions and movements of the mandible and the interested reader is referred to an article by Michler, Bakke, and Møller (1987) for further information.

There are a variety of commercial devices for the transduction of speech movements, each with certain strengths and weaknesses. The optoelectric devices are capable of three dimensional motion tracking and provide sophisticated software for analysis; the major limitation is the cost. The headmounted movement system is a low cost alternative that can be used with children and adults. The system can be configured to allow transduction in two dimensions although some problems may arise due to the extra weight of the transducer unit. Ultrasound and the Articulograph are the only devices available that allow transduction of tongue movements. Similar to the optoelectric devices, the cost of the respective equipment is high. For all devices, a certain amount of technical sophistication and a basic understanding of the operating principles is required. A final consideration is the transduction of lower lip and jaw movement. The movement transduced at the lower lip is actually a combination of lower lip and jaw movement. In order to evaluate the separate lower lip and jaw actions during speech or nonspeech movements, both the jaw and lower lip and jaw movements are acquired. The jaw signal is then subtracted from the lower lip/jaw signal yielding net lower lip movement. Using the magnetic device, a transducer coil placed on the midpoint between the lower central incisors, can be used as a reflection of “true” jaw motion. For the optical devices, a custom fitted jaw splint can be used with an additional light emitting diode used to track jaw motion. While it is possible to obtain jaw movement from a sensing device placed on the chin, such placement may result in skin movement artifact (see Kuehn, Reich, & Jordan, 1980). For most clinical applications, the combined movement of the lower lip and jaw may suffice, eliminating the need to factor out the contributions of the two articulators.

**Other considerations**

Once obtained, the data must be stored in some form for analysis. The storage device may be an
Most movement disorders result in a reduction in movement extent (hypokinesia), speed (bradykinesia), a slowness in initiation (akinesia), or become generally dyscoordinated. Each of these clinical signs can be evaluated kinematically and subsequently quantified for intrasubject comparisons. We have recently been using a limited speech and oral motor inventory with subjects having various movement disorders focusing on movements of the lips and jaw. Subjects are requested to produce syllables and nonspeech gestures at two rates; a comfortable (preferred) and maximal rate. Words and sentences are also repeated at a comfortable rate and are used for both qualitative and quantitative examination. Nonspeech movements are used to evaluate the orofacial motor system to determine the extent of neuromuscular involvement. It is felt that this protocol provides the minimal amount of information necessary to understand the functional and structural changes accompanying many motor disorders. In the following, movement data for a portion of the protocol will be presented from two subjects, both with PD, who have different degrees of speech motor impairment. Subject one (S1) has minimal speech motor involvement while subject two (S2) has a moderately severe dysarthria characterized by imprecise consonants. Motion of the upper lip and lower lip/jaw were transduced using a head mounted movement system (Barlow et al., 1983) instrumented with strain gauges aligned for two dimensional sensing. The head mounted frame was oriented such that inferior-superior and anterior-posterior movements were referenced to the Frankfort plane.

An initial step in the analysis involves examination of some of the data in two dimensional space. Shown in Figure 3 is the path of the jaw in x-y space, with anterior-posterior movements represented on the x axis and inferior-superior movements represented on the y axis, for a series of speech and nonspeech opening and closing movements. The subject produced repetitive opening and closing movements of the lip/jaw and repeated the syllable /sa/ for approximately 5 seconds the two rates; a comfortable (preferred) and fast (maximal) rate. A number of observations can be made from the x-y representation. First, the increase in speed required for the fast rates results in a general reduction in the movement extent for each task. Second, the extent of movement for /sa/ repetitions is less than that for opening and closing the mouth and the /sa/ repetitions are produced in the middle two thirds of the space occupied by the opening and closing nonspeech movements. Finally, the path taken by the jaw in both tasks and conditions is essentially straight and smooth. These observations from an individual with Parkinson's disease are qualitatively similar to those made for normal subjects. Figure 4, in contrast, displays similar data obtained from S2. As mentioned, this subjects' speech motor skills are more severely affected than the previous subject. From the x-y representations of the speech and nonspeech movements it can be seen that the lip/jaw movements are reduced in extent, less smooth, and more variable than was observed in the previous figure (note the different scales for the two figures).
Figure 3. Two dimensional movement of the lower lip/jaw for repetitive productions of oral opening/closing (nonspeech) and /sae/ for S1 (see text). Movement directions as indicated.

Figure 4. Two dimensional movement of the lower lip/jaw for repetitive productions of oral opening/closing (nonspeech) and /sae/ for S2 (see text). Movement directions as indicated.
In order to evaluate such data quantitatively the time histories of the movements must be displayed. Presented in Figure 5 are examples from the two subjects of continuous opening and closing inferior-superior movements (nonspeech) of the LLJ. The well defined peaks and valleys in the displacement trace provides a way of automatically identifying the different movement phases (opening-closing) and calculating the displacement and frequency of repetition. Below each trace is the summary of a software routine which identifies the peaks and valleys in the displacement trace and calculates the frequency of repetition (F0), and the average displacement (mm) of the sequential movements.

Shown in Figure 6 are the upper lip and lower lip/jaw movements in the x and y dimensions associated with repeated production of the syllable /pa/. It can be seen that the upper and lower lips move in both a superior-inferior and anterior-posterior direction. The movements are generally smooth and regular, and the upper lip moves less in extent than the lower lip. Shown in the next figure (Figure 7) are examples from the two subjects illustrating the results of the automated analysis routine applied to the displacement traces. Average movement displacement and the frequency of production at each rate was calculated from the inferior-superior movement of the lower lip/jaw. Subjects repeated the syllables at a comfortable or preferred rate and as fast as possible for approximately six seconds. The peaks and valleys in the displacement signals are indicated by the vertical ticks above the traces and the summary measures were calculated as shown under each trace. From these results it can be seen that the lower lip/jaw movement for the more severe subject (S2) displays a smaller movement displacement compared to the less impaired subject (S1) although the preferred rate of repetition is approximately equivalent (2.9 vs. 2.8 Hz). At the fast rate the less severe subject (S1) is able to increase the frequency of production (2.8 to 5.4 Hz; 93% increase) with a concomitant reduction in the movement displacement (8.0 to 5.6 mm). In contrast, S2 is unable to increase the frequency of syllable repetitions to the same degree (2.9 to 3.5 Hz; 20% increase). In addition to measuring the movement displacement and frequency, similar measures can be made on the derived velocity time histories.

**OPENING/CLOSING--PREFERRED RATE**

**Figure 5. Opening and closing lower lip/jaw movements in the inferior-superior direction for S1 and S2. Peak centered information is displayed under each trace.**
Figure 6. Upper lip and lower lip/jaw movement in the anterior-posterior (x) and inferior-superior (y) directions for repetition of the syllable /pae/. As shown, UL and LLJ movement for the opening and closing involve movement in both x and y directions.

/pae-pae-pae.../

Figure 7. Output from an automated analysis routine that picks peaks and valleys in the displacement signal (indicated by the vertical ticks above and below the respective signals) and calculates the number of peaks (valleys), the frequency of production (F0 in Hz), mean cycle duration (period), and the mean cycle size (mm). Shown are data from two subjects with different degrees of speech motor impairment secondary to PD. Subjects repeated the syllables at a preferred rate and as fast as possible.
A comparison of speech and nonspeech movement tasks is presented in the next two figures (Figures 8 and 9). These data were obtained from the same two subjects presented in the previous figure. In each case the subject's task was to purse and retract the lips and to repeat the vowel sequence "uu"-"ee," at comfortable and fast rates. Because these movements are predominantly produced with anterior-posterior movements of the lips, only the anterior-posterior movements were measured. For S1 (Figure 8), both lips appear to be moving together (in phase) for all tasks. The consistency of the timing relations can be easily calculated using cross correlation. The nonspeech task (purse-retract) is not constrained by phonetic requirements and allows a more detailed evaluation of orofacial mobility. For this subject the nonspeech task is accomplished by equivalent contributions of the upper and lower lips. In contrast, "uu/ee" repetitions predominantly involve lower lip action. The frequency of both the speech and nonspeech tasks increase in the fast rate condition, although the nonspeech tasks demonstrates a greater degree of change. Results from the more severely involved subject (S2) are presented in Figure 9. For this subject, the rate changes are much less noticeable with the nonspeech task demonstrating a greater degree of impairment than was noted in the speech task. In addition, the nonspeech task was apparently difficult for S2 who demonstrates slow and labored protrusion and retraction of the lips. There is also some indication of a dyscoordination of the upper and lower lip movements at the faster rate during the speech task.

![Graphical representation of speech and nonspeech movement tasks](image-url)

*Figure 8. Two different repetitive tasks involving predominantly anterior-posterior (x) motion of the UL and LLJ for S1. Shown are the position time histories for alternating and continuous pursing and retracting and alternating vowel production "uu-ee" at preferred and maximally fast rates. Below each panel is the average frequency of production.*
Other applications

There are additional applications in which movement transduction and analysis can be used in the clinical evaluation of movement disorders. Instrumental tests can be used to provide information on the reaction time, speed, and visuomotor integrative abilities of the patient. In simple reaction time, the delay from the presentation of an auditory or visual stimulus to the onset of some response is measured. If the response involves movement to a target, such as closing the lips, the movement time can also be measured. Reaction time and movement time can be differentially affected in certain disorders such as Parkinsonism (Evarts, Teräväinen, & Calne, 1981) and provide a means to objectively assess akinesia and bradykinesia, respectively during a nonspeech task. Tracking tests require the subject to follow a moving target with the output of a transducer attached to one of the articulators (see McClean, Beukelman, & Yorkston, 1987 for application to components of the speech motor system). Clinical applications usually involve scoring techniques which reflect the magnitude of the error between the target and the patients output. Such tests have been useful in evaluating ataxia or characterizing the impairment in producing smooth continuous motion of an effector. While not directly applicable to the perceptual deficits associated with speech motor disorders, these nonspeech results may prove useful in understanding the neurological condition, aspects of which may be masked by compensatory behavior of the patient. These novel techniques have been used in evaluating limb impairments associated with a variety of neurological disorders. The reader is referred to Potvin and Tourtellotte (1985) for an extensive compilation of measures and references.

RESEARCH NEEDS

In attempting to provide a quantitative basis for the evaluation of speech movements, two needs are obvious; the need for standardization and
normative data bases. All measures that have been described or implicated can be used to objectively monitor subject performance and evaluate disease progression or improvement due to therapeutic intervention. However, diagnostically, such measures have limited utility due to: 1) the lack of norms currently available, 2) solid correlational studies which attempt to relate kinematic characteristics with disease states or severity of involvement, and 3) technical standardization to allow valid intersubject comparisons. However, it may be the case that norms, while useful, may prove to be relatively uninformative or even misleading due to the range of variability in the normal population. This is not to suggest that normative data are not necessary. Rather, it may be more important to realize that speech movement data should not be evaluated in isolation without considering concomitant acoustic and perceptual characteristics of the disordered speech as well as overall motor and sensory performance levels. Only through a synthesis of observations can we hope to understand the communicative breakdown that is often interleaved with a more general sensorimotor deficit due to damage to the nervous system or modifications in nervous system operation.

CONCLUSIONS

Movement analysis is an objective and quantitative method of describing the behavior of the orofacial system during speech and nonspeech tasks. Evaluation of speech movement characteristics verify, refine, and extend, inferences and observations based on acoustic, aerodynamic, or auditory perceptual analyses. Both speech and nonspeech movements provide important information on the neuromotor functioning of the patient and facilitate assessment of disease states. Further, information related to the movement impairment can be easily assimilated by members of an interdisciplinary rehabilitation team. Quantitatively, movement transduction provides a reliable estimate of motor performance and can objectively monitor changes in performance associated with various forms of therapeutic intervention or changes in disease state. An improved understanding of movement deficits that underlie a specific motor disorder may lead to the development of novel treatment approaches that might not otherwise be considered.

REFERENCES


