PHYSIOLOGICAL, ACOUSTIC AND PERCEPTUAL ASPECTS OF HYPOKINETIC DYSARTHRIA

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ABSTRACT - The methodology of a study of speech disorders in Parkinsons disease is described and illustrated with three case studies.

INTRODUCTION

The standard reference work on the subject (Darley, Aronson and Brown, 1975) defines dysarthria as a "collective name for a group of related speech disorders that are due to disturbances in muscular control of the speech mechanism resulting from impairment of any of the basic motor processes involved in the execution of speech". Parkinson's disease is a neuromotor syndrome thought to be caused by neurochemical disorder or damage to the extrapyramidal system and the basal ganglia in particular. It is classically recognized by the symptoms of hypokinesia which include, marked reduction in the amplitude of voluntary movements, slowness, initiation difficulties, muscular rigidity, and resting tremor.

The speech characteristics customarily associated with Parkinsons patients are labelled 'hypokinetic dysarthria' and follow largely from the generalized pattern of hypokinetic motor disorder. These comprise: reduced vital capacity and poor respiratory control, limiting the duration of sustainable phonation and the available dynamic range for stress and intonational effects; reduced amplitude of articulatory movement, produucing a variety of consonantal weakening effects such as spirantization of stops, which in more severe cases produce an impression of slurring and loss of intelligibility; poor postural laryngeal control resulting in weak or abnormal voice quality, limited pitch control or ability to sustain phonation.

In fact, one finds a wide range of speech performance and specific symptoms of speech disorder in any group of Parkinsons patients and the descriptive label 'hypokinetic dysarthria' should only be taken as a general expectation for some of the more prominent and typical symptoms that occur. Parkinson's disease may produce not a single mechanism of speech impairment, but one of several qualitatively different problems of speech motor control, (or essentially no speech difficulties at all), depending upon the precise site and extent of the underlying neurological disorder and a host of other relevant factors.

Also relevant is the consideration that symptomatologically similar patterns of speech impairment, from the standpoint of clinical or impressionistic perceptual assessment, may derive from quite distinct disorders of speech motor control that can only be distinguished by close instrumental observation of speech behaviour.

Disordered behaviour in speech has been reported for all three of the principle sub-systems of the speech production mechanism: the breath control mechanism, the laryngeal mechanism and the articulatory mechanism (McNeil et.al., 1984). It is therefore necessry to monitor the behaviour

of all three subsystems and allow for the possibility of differential impairment within each in individual cases. Also, an important aspect of speech assessment concerns the co-ordination of the voice, airstream and articulatory mechanisms for the attainment of segmental and supra-segmental linguistic targets in running speech.

There have been few instrumental investigations of the speech of Parkinsons patients and most studies have focused upon only a limited aspect of performance. It is therefore difficult to compare the results of various studies or to form a picture of how different variables are interrelated. What is needed for progress in the area, is the acquisition of a comprehensive set of performance indices based on physiological, acoustic, and perceptual measures, derived from a single pool of subjects.

This is the major, long term goal of our research. This paper is intended to explore the potentials and limitations of our methodology through a description of our assessment procedures and an illustration of their application to three cases.

ASSESSMENT PROCEDURE

Our assessment procedure may be viewed from two distinct but complementary perspectives, the physiological and the functional-linguistic. From the physiological perspective, we seek to monitor key behavioural variables of the three principle subsystems of the speech production mechanism: 1) the respiratory or airstream mechanism, 2) the larynx and the voice control mechanism, 3) the articulatory mechanism.

From the functional-linguistic perspective, the assessment procedure seeks to monitor the integrity of various linguistically significant components of speakers' speech performance, such as segmental contrasts of voice, place, manner of articulation and suprasegmental features of stress, rhythm and intonation. Also, from the functional perspective, our assessment procedures need to address both the kind of perceptual judgments that are typically employed in clinical speech diagnosis, and the fine grained phonetic observations that will help to clarify questions of underlying articulatory mechanisms that may be operating in dysarthric speech.

Physiological systems assessment

Subjects undergo a standard clinical spirometric assessment of respiratory function which yields measures of respiration rate, tidal volume, vital capacity, FEVI, and expiratory and inspiritory reserve volume. Respiratory behaviour during speech and non-speech tasks is monitored by a strain gauge system that permits separation of the thoracic and diaphragmatic components to changes in lung volume. Changes in circumference of the rib cage and abdomen are measured by two strain-gauge belt pheumographs, the output of which is transduced and displayed on an X-Y plot using a storage oscilloscope.

By this means it is possible to assess the relative contribution of thoracic and diaphragmatic muscles prior to and during expiration for speech, as well as the presence of respiratory muscle tremor.

Phonation and voice control (the second of the three principal subsystems) are instrumentally assessed from the Lx trace of a laryngograph and from acoustic analysis of the radiated waveform.

Key parameters of articulatory behaviour are assessed at the present time by auditory feature analysis, supported by spectral and time series analyses using a sound spectrograph (Kay Elemetrics Digital Sonagraph Model 7800) and a digital signal processing facility (ILS running on an IBM XT).

Our instrumental procedures for the voice and articulation mechanisms are therefore indirect but non-invasive, with the advantages and disadvantages that follow from this. Also, in the case of articulation, we rely upon impressionistic phonetic judgement to guide the selection of relevant acoustic features for observation and measurement.

Functional-linguistic assessment

Subjects engage in a variety of speech and non-speech tasks. A comprehensive clinical profile of their speech performance is provided by the Frenchay Dysarthria Assessment (Enderby, 1980) and an extended set of perceptual speech scales based on those originally developed by Darley, Aronson, and Brown (1975). The perceptual scales, 32 in all, covering the domains of prosody, respiration, resonance, phonation, articulation, and intelligibility are applied by a team of 9 speech pathologists to recorded readings of 'The grandfather passage'.

For detailed phonetic analysis of patients' speech performance we use a controlled elicitation procedure with items for imitation pre-recorded on a test tape. These items comprise:

1. Sentence repetition with target sentences graded for articulatory complexity. (9 items)
2. Imitation of natural speech intonation contours on an innocuous carrier phrase such as: "How are you today?' (7 items, graded in difficulty)
3. Sentence repetition with carrier phrases containing stop consonants in a constant phonological frame for assessment of VOT. (9 items)
4. Reiterant speech, using da-da-da syllables on patterns similar to items in 2. above, in order to assess intonation and rhythm in isolation from segmental complexities. (7 items)
5. Nursery rhyme completion, in order to elicit non-imitated but quite predictable sequences of highly overlearned speech. (1 item)

COMPARATIVE CASE STUDIES

To date, 23 Parkinsons patients have been assessed. Control data are not yet available. However, some trends have emerged. As anticipated, there is wide variation in the degree of speech impairment. Compared with their performance on a Sentence Imitation task, subjects' speech usually declines significantly under Free Speech, with a general increase in tremor and decline in intelligibility. We attribute this to the task specific stress of unrehearsed speaking into a microphone.

Also, we have observed in some patients that gross abnormalities in the pattern of respiratory control may be apparent without significant impairment of speech or voice quality. Breath requirements for speech purposes apparently impose demands that are within the compensatory mechanisms available even to the more seriously impaired patients. Respiratory tremor, on the other hand, does appear to have deleterious consequences for speech.

The three illustrative cases, Mrs. B., Mr. C. and Mr. S., present contrastive patterns of respiratory, voice and articulatory impairment.

Respiration

Figure 1 shows the comparative respiratory behaviour of the three subjects during the production of a sustained vowel sound /ah/. (Space requirements preclude reproduction of figures, available on request from authors.)

For Mrs. B., changes in lung volume are accomplished almost entirely by activity of the thoracic muscles. Mr. S. on the other hand, shows a more expected pattern of both thoracic and abdominal/diaphragmatic components to expiration, however there is a high level of muscular tremor as shown by the small amplitude irregularities present in the X-Y trace. (The implications of this tremor for voice and articulation are taken up later.) Mr. C. shows greater contribution to the abdominal/diaphragm system than the thoracic in the prolongation of vowels. No tremor was noted and clinical respiratory signs, apart from reduced total lung capacity (75%), were within the normal range.

Voice

Mrs. B. has a weak voice with intermittent creak and a highly restricted pitch range. Mr. C. has quite a different pattern of vocal impairment, with the major difficulty of sustaining phonation beyond a few syllables in speech or 4-5 seconds for sustained vowels. The voice dies rapidly to a whisper. The subject shows signs of a compensatory strategy of breaking longer utterances down into short breath groups. His inability to sustain phonation is compounded by difficulties with voice initiation. Mr. S. also has poor vocal control with a husky voice quality, restricted pitch range and voice amplitude variation, possibly a consequence of respiratory tremor.

Figure 2. shows the three subjects f_0 contours for imitation of the phrase:

How are you today

Mrs. B. and Mr. S. show constricted voice pitch ranges, consistent with clinical perceptual ratings. Mr. C. shows remarkable preservation of pitch contour in view of his difficulty of sustaining phonation.

Articulation

Mrs. B.'s articulation shows the classical pattern of hypokinetic dysarthria with selective weakening of consonantal gestures. There is reduction of force and amplitude of constriction gestures with stops spirantizing to fricatives intervocalically or reducing to glottal stops in final position. This glottal substitution appears to represent the replacement of a more motorically demanding oral gesture by a less demanding glottal closure. Fricatives tend to weaken to approximants and the latter, tend to vocalize or disappear. However, interestingly, this consonantal weakening process is confined almost entirely to non-primary stressed syllables in Mrs. B.'s speech.

Mr. C. shows a slight tendency towards consonantal weakening, but his articulatory difficulties are apparently epiphenomenal to his problem of sustaining vocalization. Mr. S. shows profound difficulties of articulatory control. His pattern is not simply one of reduced amplitude of certain gestures, but of abnormal temporal patterning. We tentatively

attribute this breakdown to disruption by excessive tremor. Figures 3, 4, and 5 show spectrograms of utterances that illustrate these features.

In summary, we have three contrasting cases of hypokinetic dysarthria. Mrs. B. comes closest to the classical pattern with modest impairment in all three physiological subsystems and weakened segmental and suprasegmental contrasts in speech. Mr. C.'s major difficulty seems to lie in initiating and sustaining an appropriate postural setting of the vocal cords to sustain phonation, though phasic control for moment by moment pitch regulation seems remarkably unimpaired. Mr. S. shows a general lack of speech motor control that extends to postural and phasic levels of control with disruption of segmental timing in addition to reduced amplitude of gestures. His performance pattern seems to show the disrupting effects of a critical level of tremor in the system.

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