PROSODY IN HYPOKINETIC AND ATAXIC DYSARTHRIA

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ABSTRACT - This paper contrasts patterns of speech prosody in Hypokinetic dysarthria and Ataxia. A perceptual and acoustic analysis of the metrical component of prosody in dysarthric speech is undertaken.

INTRODUCTION

Disorders of prosody are common in patients with Parkinson's Disease and Multiple sclerosis, though impressionistically the speech disturbances are quite different, as are the underlying etiologies. Parkinson's Disease is a neuromotor syndrome caused by disease of the basal ganglia. In Multiple Sclerosis, the focus of lesion lies in the cerebellum. One long-term goal of this investigation, which is part of a wider study of neurological speech disorder (Murdoch, Chenery, Bowler & Ingram, 1988), is to ascertain the respective functions of these two subcortical structures in speech motor control.

Kent, Netsell, & Abbs (1979) undertook an acoustic (spectrographic) study of dysarthria associated with cerebellar disease. Major differences between the ataxic and control groups lay in the durational characteristics of speech. They observed uniform lengthening of words composed of consonants and tense vowels, consistent with an overall slowing down of rate of articulation. However, the most significant finding involved a striking lengthening of lax vowels, particularly in unstressed syllables, which perturbed the normal rhythmic structure of their speech, and which appeared to be the principle acoustic correlate of the characteristic 'scanning' quality of ataxic speech. The importance of this feature was emphasised by the additional finding that a ratio of the duration of lax to tense vowels correlated directly with the rated severity of dysarthric symptoms. An examination of fundamental frequency contours, drawn from narrow band spectrographic analysis, showed a tendency to produce patterns in which the Fo contour declined on each syllable 'as though each syllable carries its own declarative intonation'. Kent et. al. speculated that ataxic speakers, faced with general motor control difficulties, may resort to the strategy of limiting the unit of articulatory programming from a phrase-sized unit, down to a single syllable in an effort to simplify the production task.

The prosodic features of speech associated with Parkinson's disease appear to follow from general characteristics of a hypokinetic motor disorder (Darley, Aronson & Brown, 1975), rather than reflect a specific disorder of prosody, although this view has been challenged recently (Darkins, Fromkin & Benson, 1988). Consistent with a general pattern of hypokinesis, there is a reduced dynamic range of articulatory and vocal gestures, resulting in flattened intonation contours and weakening of obstruent contrasts. Contrary rate effects have been observed in hypokinetic dysarthria, with some speakers apparently slowing down the rate of speech and others producing a possibly deceptive impression of increased rate of speech, given that articulatory undershoot is a phenomenon that listeners customarily associate with fast speech.

Unlike the situation with Ataxia, the reported characteristics of Aprosody in Hypokinetic Dysarthria, do not suggest that there is any fundamental reorganization of the motoric plan, or of speakers' strategies for phonetically realizing linguistic contrasts in running speech. Rather, it may taken as a working hypothesis, that Aprosody in Hypokinetic Dysarthria represents a levelling or masking of phonological contrasts caused by reduced amplitude of motoric gestures, in the context of hypertonicity. Darkins et. al. take a different view, assigning a specific role to the basal ganglia in speech production of 'the integration of cortical prosodic modules with motor output systems.'

In neither Ataxia nor Hypokinetic Dysarthria does there appear to be any disorder of the underlying linguistic system controling the use of prosodic features in speech. Darkins et. al. (1988) demonstrated that there was no significant loss of prosodic comprehension in a group of Idiopathic Parkinson's patients, appropriately screened for exclusion of aphasia, dementia, or psychiatric depression. The primary question from a theoretical standpoint of speech production appears to be, whether there are specific disorders of speech motor programming in the dysarthrias, or whether the observed speech characteristics are reflective of generalized motor disorders or disorders of somatotopically defined motor subsystems.

SUBJECTS

Seven patients with Ideopathic Parkinson's disease and 9 Ataxic patients were included in the present study. A control group of 10 normal speakers, matched in age and education to the Parkinson's group was used for selected comparisons in the data analysis reported below.

The Parkinson's patients were drawn from a group of 19 patients, whose respiratory function has been described in a separate report (Murdoch et. al). All had a neurological diagnosis of Idiopathic Parkinson's disease, without indications of any other accompanying neurological disorder. From this group, seven of the most severely speech disordered Parkinson's patients were selected, with particular attention to the scale of Overall Intelligibility of Speech. Despite this selection, the resulting group ranged from only mild to moderately speech impaired.

The Ataxic group were not specifically selected for speech disorder. They consisted of consecutive referrals of vounteers for the study from the MS association of Brisbane. Their perceptual speech disorder ratings indicated that they were less impaired than the selected Parkinson's group, at least by the criterion of Overall Intelligibility, though 7 of the 9 showed a clear disturbance of Prosody, described in detail below.

METHOD

A sentence imitation task was used to assess speakers' prosodic performance. Three tokens each of the following sentences were elicited from tape recorded targets, in the course of a comprehensive speech assessment protocol (Ingram, Murdoch & Chenery, 1986):

1. The dog was dead.
2. The picture was exciting.
3. The shipwreck washed up on the shore.
4. The politician's explanation was unsatisfactory.

These items were not specifically selected for their prosodic features, but simply because they encode a range of articulatory complexity and because three of the sentences have been used in previous studies, thereby facilitiating comparison of findings.

A two-stage procedure was adopted to the analysis of prosodic features:

a phonological/perceptual analysis of selected prosodic features of the target sentences and the speakers' imitations of them;

an analysis of likely acoustic correlates of the prosodic features, based upon normalized fundamental frequency contours, waveform energy envelopes, and the temporal patterns of syllable onsets and vowel durations.

Phonological/Perceptual Analysis

Prosody is traditionally partitioned into stress, rhythm and intonation. However, in view of the joint importance of stress and rhythm for the distinctive characteristics of Ataxic speech (dysrythmia, 'mono-stress', 'scanning speech'), and in deference to recent developments in phonological theory ('Prosodic Phonology'; Liberman & Prince, 1977; Hayes, 1982; Selkirk, 1984), it may be useful to consider stress and rhythm as a sub-system, referred to as the metrical structure of an utterance.

Metrical structure refers to the pattern of syllabic prominences in an utterance, which is perceptible by all native speaker/listeners, with varying degrees of clarity and delicacy. The metrical properties of particular utterances are jointly determined by linguistic factors and non-linguistic considertions - rhythmic constraints - presumably derived ultimately from motor control mechanisms.

Rhythmic organization seems to be characteristic of complex motor behaviour, not just speech. It is a fundamental thesis of Metrical Phonology, that linguistically determined prominence relations within utterances are often modified by rhythmic constraints.

Formally this is expressed by having linguistic rules of prosodic structure assignment have their output modified by subsequent rhythm rules, referred to as rules of 'eurithmy' or 'stress clash resolution'. Competing formulations of different prosodic phonologists did not appear to have any crucial bearing on the particular utterances considered here, but common priciples of 'eurithmy' or 'stress clash' were relevant for the metrical description of target utterances (2) and (4).

An example of rhythm-induced modification to metrical structure occurs in target (4) where the highest level of lexical stress in 'unsatisfactory' shifts to the initial prefix: 'unsatisfactory', presumably to promote the favoured quadrisyllabic stress pattern that is generated on the utterance as a whole.

Rhythmic considerations appeared to result in an unstable metrical structure for sentence (2), with a primary stress (downbeat) falling inconsistently on the first element of the phrasal verb ('washed up'), or on the second element ('washed up') and with a pause inconsistently appearing between subject and verb. The reason for the metrical instability of (2), which was observed in the target sentences and the control speakers imitations, seems to be related to the awkward piling up of unstressed syllables which results from the assignment of a downbeat to 'washed':

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 w    s    w     s    w  w   w  s
The shipwreck washed up on the shore.
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Perceptual ratings, in the form of foot structure assignments were undertaken of the target sentences and the imitations. The task was to identify the primary stressed syllables (downbeats) in an utterance, thereby imposing a strong - weak division on syllables, consistent with the perceived stress and rhythm of the utterance. The ratings were made by the first author (JI) and a phonetically trained research assistant (PM). Ratings were performed independently. Disagreements (less than 10%) were resolved by JI on second listening.

Acoustic Analysis:

Utterance tokens were digitized (10 kHz sampling rate, 8 bit quantization) and analysed with the aid of a PC-based signal analysis system (Ultrasound; Jordon, 1988). Fundamental frequency contours were obtained from a routine based on the SIFT algorithm (Markel and Gray, 1976). The amplitude trace was obtained by taking the (sign ignored) sum of all amplitude values within successive 25 msec windows of the digitized signal. Timing measurements were taken with the aid of a screen cursor edit/playback facility, principally on the waveform display, but supplemented where needed with an on-screen spectrographic display.

It was necessary to parametricize and normalize the Fo, Amplitude and Timing measurements for individual speaker and group comparisons. The syllable was used as the basic unit for parametricizing Amplitude, Fo and Timing relations within the utterance.

Peak amplitude measurements were taken for each syllable. These were then expressed as a proportion of the peak amplitude of the strongest syllable in the utterance, thus normalizing for absolute variations in signal strength but preserving the pattern of relative syllable amplitudes within the utterance.

Fo readings were also taken at points corresponding to peak amplitude values in each syllable. These measurements were then subtracted from the utterance mean Fo value, the intent of this normalization being to remove intrinsic speaker differences in voice fundamental but to preserve range variation.

Timing relations within the utterance were initially parametricized by measuring the time of onset of each syllable, defined as the point of clearest transition between C and V in syllable onsets. Intervals between syllable onsets were then expressed as proportions of the total utterance time, to obtain speech-rate independent measures of relative syllable duration, a basis for hopefully capturing key features of temporal patterning within the utterance.

A program was written for graphically displaying the normalized parametric values of imitation utterances, and for calculating the degree of matching to the parametric representation of the target utterance. The target-matching score for a given utterance on a given parameter was simply the mean sum of squared differences from the target parametric values. The target matching scores were used as dependent variables for acoustic comparisons of the performance of the Parkinson's and Ataxic groups.

RESULTS

Perceptual Findings

The Ataxic speakers used a slower rate of articulation than the Parkinson's and Control groups who did not differ signficantly in this respect. Seven of the nine ataxic speakers showed varying degrees of a distinctive stereotyped rhythm - 'scanning speech' - which emerged clearly in the analysis of foot structure, reported below. The Ataxic group were less impaired, more homogenous, and internally consistent in their speech characteristics than the Parkinson's patients.

The Parkinson's group were more dysfluent than the Ataxics. Perceptual ratings of the Parkinson's group showed frequent initiation difficulties or blocking on the more complex utterances, voice disorder, subjective impression of impaired respiratory support for speech, restricted vocal pitch range, and imprecision of consonant production - all expected characteristics of hypokinetic dysarthria.

The most prominent feature of the Ataxic speakers, clearly distinguishing them from the Parkinson's group and the control group, emerged from the analysis of foot structure, which is one way of capturing the basic rhythmic pattern of an utterance.

The Ataxics showed a strong tendency to use a monosyllabic or bisyllabic foot structure. Their speech was not arythmic,indeed a rhythmic pattern often seemed to dominate and obscure the promimence relations dictated by linguistic features of constituent structure. However, the ataxic pattern might be described as a simplified and somewhat stereotyped rhythmic structure.

Dysfluency masked the rhythmic structure of the two most complex utterances for the Parkinson's speakers, but for sentences 1 and 2 where foot structure ratings could be reliably assigned, the Parkinson's speakers matched the metrical structure of the target utterances.

Foot ratings indicated that the Control speakers preserved the metrical structure of the target utterances, with minor variations, except for the metrically unstable sentence 3.

Acoustic findings

The parametricised and normalized Fo, Amplitude, and Timing patterns of the Ataxic and the Parkinson's groups were compared with respect to degree of success at matching relevant acoustic parameters of the target sentences. Only sentences 1 and 2 could be used in these comparisons because of dysfluencies of the Parkinson's speakers. A series of one-way ANOVAS were used with Target Matching Scores for Fo, Amplitude, and Timing as the dependent variables.

Results of the ANOVAS indicated that the Ataxics had significantly poorer Target Matching scores than the Parkinson's speakers on only the Amplitude parameter. This result was somewhat surprising as it was expected that the Timing parameter would be more closely related to perceptually observed metrical properties of ataxic speech.

One obvious possibility was that the simple parametricization based upon the relative timing of syllable onsets was inadequate to capture the temporal component of rhythmic structure. Consequently, an alternative parametricization was explored, based upon the measurement of vowel durations. Subsequent results suggest that this parametricization, although it poses some measurement problems, provides a basis for successfully distinguishing the Ataxic from the Control speakers.

	Sentence 1.		Sentence 2.	
Dependent Variable	F-ratio	Probability	F-ratio	Probability
TM score: Fo	1.073	.31	0.182	.68
TM score: Amplitude	5.841	.02 *	4.503	.05 *
TM score: Timing	1.666	.21	0.000	.99

Table 1. ANOVA Results: Ataxic vs Parkinson's Groups

CONCLUSIONS

The central finding of the research so far is that the Ataxic speakers showed, to varying degrees, a pattern of dysprosody that can be described with reference to the metrical subcomponent of prosody. Despite the interfering effects of dysfluency, prosodic structure in speech of the Parkinson's group was basically intact. One can only speculate on the nature of the underlying disorders to the speech motor control mechanism in these two disorders, bearing in mind that observed speech charactersitics may be as much a reflection of particular strategies that patients learn to employ in order to circumvent specific disabilities, as they are a reflection of the disabilities themselves.However, it is consistent with our observations thus far to see the simplified and stereotyped metrical structure of ataxic speech as a consequence of reduced capability to encode perhaps more than a single level of constituent structure, along with a limited sequential look-ahead of not more than a couple of syllables. Parkinson's patients appear to employ strategies of quite a different kind for circumventing their motor difficulties. They appear to have particular difficulty in initiating and sustaining motor activity. Parkinson's patients therefore attempt to encode longer articulatory sequences than may be optimal, and to deliver them rapidly.

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