ANTICIPATORY MOTOR PROGRAMMING IN ATAXIC DYSARTHRIA

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ABSTRACT

Ataxic dysarthria has prosodic characteristics in which the production of stress and rhythm is disturbed. An experiment is reported on the production of "stress shifts" requiring anticipatory planning by 10 speakers with ataxic dysarthria, compared to 10 matched speakers with normal speech production. Comparison with normal speakers indicated that the ataxics did not take account of the position of the main stress in the following word in their production of "shift" words. This pattern is consistent with a disruption to motor programming.

INTRODUCTION

Ataxic dysarthria arises from damage to the cerebellum or the cerebellar pathways [1]. Its unique prosodic characteristics have often been termed "scanning speech", where each word or syllable appears to be produced with equal prominence, giving the listener the impression that each word is being produced seperately from the others in the utterance. It has been suggested [2] that this prosodic disturbance could arise from either difficulties in the cerebellum's regulation of the ongoing execution of movement sequences, or from impairment to its role in the anticipatory motor programming of such sequences. In order to distinguish between these 2 quite distinct disruptions to speech motor control, an aspect of prosody that is dependent on sequential lookahead for its functioning needs to be investigated.

The stress pattern of some English words in connected speech is dependent on the stress pattern of the following word. It is generally acknowledged that these shifts in the prominence pattern on some words are due to a strong rhythmic constraint to prefer the alternation of stressed and unstressed syllables and words, and to avoid the juxtaposition of stresses [3] [4]. Hence, while *ornate* spoken in a noun phrase such as *the ornate one* has the main stress on the last syllable, in a noun phrase such as *the ornate cup* there is a perception that the main stress has shifted to the first syllable of *ornate.* This rhythm rule can be formulated as an operation where stress shifts from one syllable of a word on to another in order to avoid "clashing" with an adjoining stress.

PROCEDURE

Ten subjects with multiple sclerosis, and who were native speakers of English, were selected. They had been diagnosed by a neurologist as exhibiting predominantly ataxic symptoms, and by an experienced speech pathologist as exhibiting ataxic dysarthria with "scanning speech" prosody. Each subject was recorded reading a series of sentences containing noun phrases which comprised of a potential stress shift word followed by a word with varying syllable distance to its main stress. The sentences were designed to provide a phonological context where shift and non shift environments could be manipulated. Examples of the 5 contexts used are as follows:

Two contexts where no shift was predicted:

No stress following: *There were thirteen of them at the party.*

Shift word focused: *There were THIRTEEN officers at the party.*

Three contexts where shift was predicted:

One syllable distance: *There were thirteen 'officers at the party.*

Two syllable distance: *There were thirteen o'fficials at the party.*

Three syllable distance: *There were thirteen poli'ticians at the party.*

Six potential stress shift words were used: *thirteen, bamboo, sardine, underdone, overnight,* and *japanese.* These words had been identified in a previous experiment as being particularly susceptible to stress shift in speech production.

ANALYSIS

Recorded shift words, embedded in their noun phrases, were digitised at 20.8 kHz using the Soundscope speech signal processing program. The duration of the shift word, the duration of each foot, and the duration of the pause between the shift word and the following word was measured. In order to obtain a measure of variation in the duration of the first foot compared to the second foot, the duration of the first foot as a percentage of the duration of the whole word was calculated (relative duration). The peak fundamental frequency for each foot was also calculated using a peak-picking algorithm within the Soundscope program. In order to obtain some measure of the relative changes in fundamental frequency pattern between the 2 feet over different contexts, the value for the second peak was subtracted from that of the first. Three phonetically trained linguists were asked to rate the stress levels in each shift word token as either: 1) the last stressed syllable is more prominent 2) both stressed syllables have equal prominence, or 3) the first stressed syllable is more prominent.

RESULTS

Both the ataxic group and the control group were perceived as shifting stress in the 3 Rhythm contexts, and not shifting in the 2 non rhythm contexts. A 2 way analysis of variance for group membership and context against the judges' perception of stress shift indicated that there were significant main effects for both group and context as well as a significant 2 way interaction between them (context: $p = .000$, $F = 427.3$, d.f $= 4, 596$; group: $p = .000$, $F = 50.7$, d.f. $= 1, 599$; interaction: $p = .000$, $F = 24.5$, d.f. $4, 596$). The most important difference between the 2 groups was in the pattern of stress shift over the 5 contexts. While the control group displayed a graded decrease in the perception of shift as the syllable distance to the main stress in the fulcrum word increased, the ataxic group showed no such systematic pattern. The ataxic group were perceived as shifting to the same extent in all 3 Rhythm contexts.

There were acoustic-phonetic changes in the shift words that corresponded to these perceived patterns of stress shift in both groups. A 2 way analysis of variance for group membership and context against the relative duration of the first foot in each shift word indicated that there was a significant main effects for context but not for group membership ($p = .000$, $F = 67.1$, d.f. $4, 596$). As well there was a significant 2 way interaction between context and group ($p < .05$, $F = 3.4$, d.f. $= 4, 596$). Both the ataxic and control groups had similar significant increases of approximately 9% in the relative duration of the first foot in the Rhythm contexts compared to the 2 non rhythm contexts. However, the pattern of increase in relative duration was not the same for the 2 groups. The control group displayed a graded decrease in the relative duration of the first foot as the syllable distance to the main stress in the fulcrum word increased. The ataxic group showed no such systematic difference across the 3 Rhythm contexts, with the degree of durational change remaining the same. Figure 1 displays an error bar plot of the mean relative duration of the first foot across the 5 contexts for the control and ataxic groups.

There were similar results for the shift in peak fundamental frequency between the 2 feet in each word. A 2 way analysis of variance for context and group membership against shift in peak fundamental frequency between the 2 feet indicated significant main effects for both context and group, as well as a significant interaction between them (context: $p = .000$, $F = 57.6$, d.f. = 4, 596; group: $p < .01$, $F = 7.4$, d.f. = 1, 599; interaction: $p = .000$, $F = 11.5$, d.f. = 4, 596). For both the control and ataxic groups there were significant positive shifts in peak fundamental frequency in the Rhythm contexts compared to the non rhythm contexts. The ataxic group differed from the control group, however, in having no graded decrease in peak fundamental frequency shift as the syllable distance increased.

In the ataxic group, as the number of syllables to the main stress in the following word increased, so did the duration of the pause prior to the production of that word. This pattern was markedly different from what occurred in the speech of the control speakers. In the speakers with normal speech production there was no relationship between the metrical structure of the word following the shift word and the pause before the production of that word. A 2 way analysis of variance for context and group membership against pause duration indicated a significant 2 way interaction between them ($p = .000$, $F = 17.5$, d.f. = 4, 596). Figure 2 displays an error bar plot of the mean duration of the pause between the shift and fulcrum words across the 5 contexts for the 2 groups.

It may be thought that the difference in pattern between the ataxic and control groups was a reflection of their differences in rate of speech rather than any impairment to motor control as such. However, a comparison with controls speaking at a slow tempo [5] indicated that the rhythm rule pattern produced by normal speakers at a slow tempo was markedly different from the ataxic productions. The ataxic group were perceived as shifting in all Rhythm contexts, and to the same extent across those contexts. The normal subjects at the slow tempo were not perceived as shifting, nor was there any differential effect in inter-word pausing.

DISCUSSION

The results for the ataxic group indicate that they underwent stress shift in the appropriate contexts, but were unable to make graded phonetic adjustments to the number of syllables to the main stress in the following word. Anticipation of the metrical structure of the following word, however, was found in the duration of the inter-word pause. This pattern was not found amongst the normal speakers, where anticipation of a following word is reflected in the duration of the prior word rather than in the pause [6]. This pattern reflects either a voluntary or involuntary strategy to limit motor programming and production to single words without reference to the following words in an utterance. This suggests that the traditional classification of the speech disorder arising from cerebellar damage as a dysarthria (and therefore not a speech programming disorder) is highly questionable.

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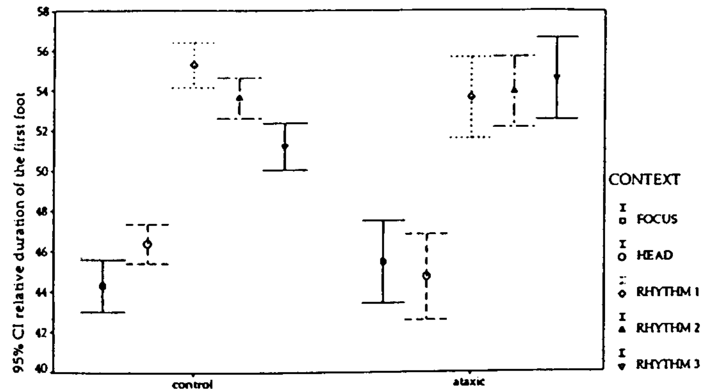

Figure 1 Error bar plot with 95% confidence intervals of the mean relative duration of the first foot across the 5 contexts for the control and ataxic groups (in seconds).

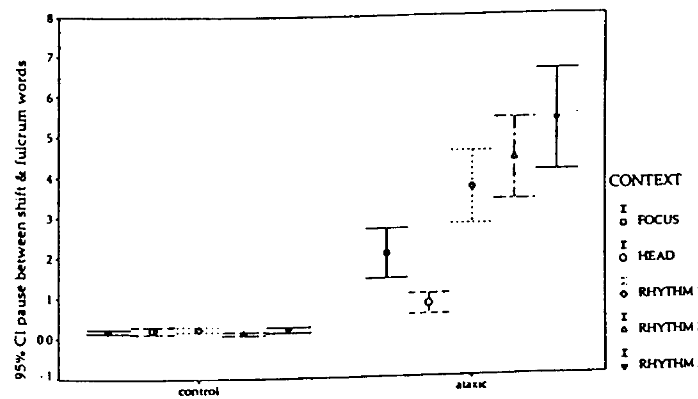

Figure 2. Error bar plot with 95% confidence intervals. Mean duration of the pause between the shift and fulcrum words across the 5 contexts for the control and ataxic groups (in seconds).