PHONETIC VARIABILITY IN SPEECH DISORDERED CHILDREN: A COMPARISON OF REAL AND NONSENSE WORDS

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ABSTRACT - A speech production experiment is reported where the timing and formant variability for the vowels / a /, / i / and / ɔ /, used in the naming of real words and the imitation of nonsense words, are compared across 4 subgroups of speech disordered children. The first group exhibited normal speech development, the second group exhibited delayed speech development, the third group exhibited unusual but consistent speech patterns, while the fourth exhibited highly inconsistent speech patterns. Multiple Analysis of Variance indicated no differences in timing variability across groups or contexts. The Inconsistent group of children, however, exhibited significantly greater vowel formant variability in naming real words compared to the other 3 groups. No such difference occurred between the groups in the imitation of nonsense words. The results indicate that the Inconsistent subgroup of speech disordered children do not exhibit a generalised motor disturbance, but suggest a highly selective type of phonetic disturbance where a particular parameter of the phonetic specification of a lexical item is less specific than in the other groups of children, or is more difficult to access. The implications for models of speech production and their development are discussed.

INTRODUCTION

This study investigates the phonetic characteristics of the speech output of children with highly variable speech patterns. The purpose is to determine the type of deficit underlying their speech output: does it involve the pre-motor representation of words, the level of speech motor programming, or does it lie in the articulatory execution of the motor program. Such information about different subgroups of speech disorder would contribute to our understanding of the processes underlying normal speech production and its development, especially the relationship between phonological and phonetic representations and their development. It would also contribute to more principled management of speech disorders, enabling intervention to be targeted at specific levels of deficit in the speech production process.

Current models of speech production (Levelt, 1989; Hewlett, 1990) allow for more specification of levels in the process of speech production than the traditional division between underlying phonological representations and surface phonetic realisations. Hewlett's (1990) developmental model of speech production suggests that there are a number of levels: phonological processing (output lexical representations), motor processing, motor execution, and vocal tract shape. In this model a motor programming component initially takes an auditory-perceptual representation of a word and creates a motor plan. Over time such a motor representation can provide the basis for the mapping rules between input and output lexical representations. Such rich models of speech production provide for a wider range of possibilities for describing the locus of deficit in different subgroups of speech disorders that have been identified on the basis of their surface speech errors (Dodd & McCormack, 1995)

Such subgroups have been identified by Dodd, Leahy, & Hambly (1989), and Williams & Chiat (1993), and form the basis of the groups of children studied in this experiment. The first subgroup exhibit delayed speech development that follows a normal developmental path (Delayed), the second group exhibit unusual but consistent speech patterns, often not following a normal developmental path (Consistent Deviant), while the third subgroup exhibit highly inconsistent speech output that varies not only from context to context, but also within the same context (Inconsistent Deviant). This last group do not exhibit any obvious sensori-motor deficits that could account for their inconsistent speech.

The measurement of the level of sub phonemic phonetic variability in these different subgroups of speech disordered children, and in children with normal speech development, could provide a means for investigating if there are differences in the loci of speech processing deficits that underlie the differences in surface speech output that are used to classify these children. Generalised differences in phonetic variability would indicate generalised speech motor difficulties, while no differences in phonetic variability would need to look to non-motor explanations for the differences between the groups. On the other hand, differences only in discrete aspects of phonetic variability would indicate that specific parts of motor programming, or of pre-motor phonetic specifications were involved.

EXPERIMENT

A speech production experiment is reported where the timing and formant variability for the vowels / a /, / i / and / O /, used in the naming of real words and the imitation of nonsense words, are compared across 3 subgroups of speech disordered children and a matched group of children with normal speech development. In order to distinguish phonetic variability from phonological variability, only tokens of words were analysed where perceptually judges agreed that the target vowels had been realised as allophones of / a /, / i / and / ɔ /.

Subjects

Details of the 4 groups of children in this study are outlined below. There were 41 children, and all children had Australian English as their first and only language, had normal oromotor function, and normal hearing and vision. The assignment to subgroups was based on the analysis of surface speech errors following the procedures of (Dodd, Leahy, & Hambly, 1985).

Group	Number	Gender	Age
Control	10	4F, 6M	4;4
Delayed	10	2F, 8M	4;4
Consistent	10	3F, 8M	4;4
Inconsistent	11	3F, 7M	4;3

Table 1. Subject description

Materials

Both the real and nonsense words involved the use of the vowels / a /, / i / and / ɔ /. The real words involved naming pictures pasted on to a block that was rolled by the child ("shark", "sheep", "shorts"). The nonsense words involved imitating the researcher's productions ("tarsh", "teesh", "torsh"). Multiple tokens of each vowel in each context was sought. For the phonetic analysis only 5 tokens were used where it had been established perceptually by experienced phonetic transcribers judges that the target vowels had been realised as allophones of / a /, / i / and / ɔ /. This was to ensure that only sub-phonemic phonetic variability was being measured.

Analysis Procedure

The variability of two phonetic parameters of each vowel segment was analysed: a) the duration of the vowel (timing parameter), and b) the first and second formants of the mid-point of each vowel segment (spatial parameter). The data was digitised at 20,000 Hz using the MacSpeech computerised speech signal processing program. LPC coefficients were derived for the estimation of formant values. Variability in timing was measured as relative variance (standard deviation divided by the mean) because of the direct positive relationship between the magnitude of duration and the magnitude of its standard deviation. The longer a speech sound, the longer its standard deviation. However, there is no such direct relationship between sound frequency and its standard deviation. Variability for formant targets, therefore was measured in terms of standard deviation.

RESULTS

Timing:

Figure 1 displays the mean absolute durations of the vowels for each subgroup across the two contexts. Figure 2 displays the mean relative variances for vowel duration for each subgroup. While the mean duration and relative variance of duration for the Inconsistent group are higher than for the other groups across both contexts, a Multiple Analysis of Variance indicated no significant differences in duration or relative variance across groups or contexts. Unlike the other groups, however, the Inconsistent group did produce longer vowels in the nonsense words compared to the real words.

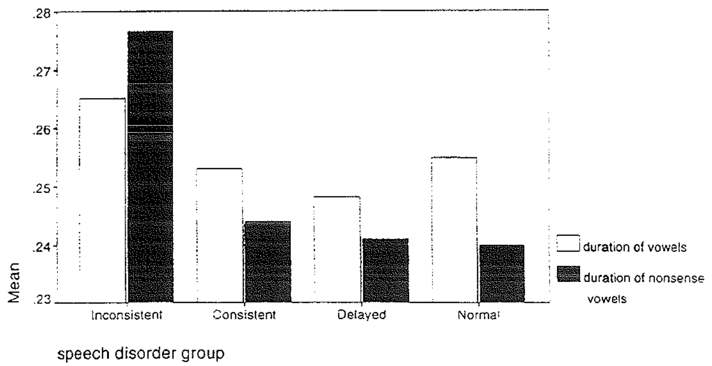

Figure 1. Mean absolute durations of the vowels for each subgroup.

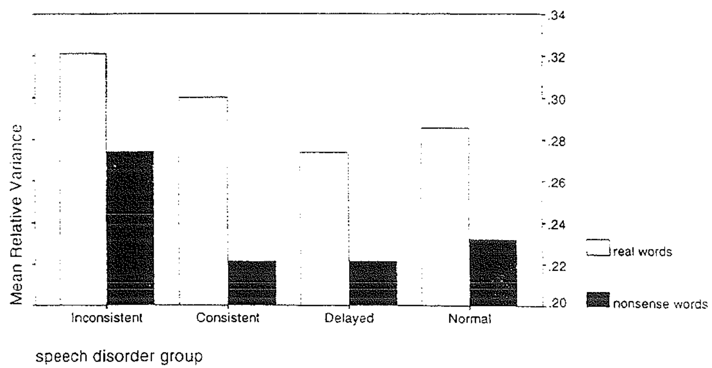

Figure 2. Mean relative variance of the vowel durations for each subgroup

Formant Variability

Figure 3 displays the mean formant standard deviation for the vowels (the standard deviations for formants 1 and 2 have been collapsed into the one figure as there were no significant differences between them). A Multiple Analysis of Variance indicated a significant main effect for group membership, but not context (real word naming vs nonsense word imitation), and a significant interaction effect between group and context (group: df. 3,70; $F = 11.1$, $p = .000$; group X context: df. 3,70; $F = 4.9$, $p < .01$). The Inconsistent group of children exhibited significantly greater vowel formant variability in naming real words compared to the other 3 groups. The other groups were no different from each other. No differences occurred between any of the groups in the imitation of nonsense words.

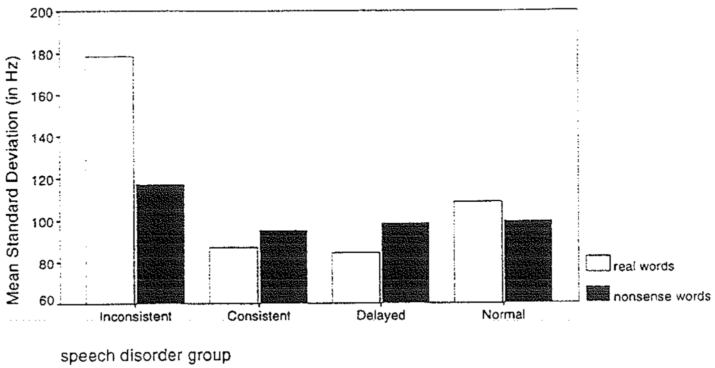

Figure 3. Mean formant standard deviation of the vowels for each subgroup

DISCUSSION

The results indicate a phonetic disturbance in the Inconsistent group. The variability in their formant targeting was significantly higher than in the other three groups in the naming context. However, the particular pattern of disturbance, where formant variability in imitated nonsense words is not affected, and where speech segment timing is not affected in either context, suggests that the locus of deficit lies neither in speech motor programming nor in the execution of the program. Firstly, a general speech motor disturbance is ruled out as timing is not affected in either the real or nonsense output. One would expect a general speech motor disturbance to be reflected in both the timing and spatial targeting of speech segments. Secondly, the accuracy of vowel spatial targeting (as measured by formant variability) is superior in the context that does not rely on the phonological representations of words stored in the lexicon. The accuracy of vowel spatial targeting in the imitation of nonsense words is essentially the same in the Inconsistent group as in the other 3 groups. If the disturbance was at the speech motor programming level then one would not expect to find a difference in accuracy dependent on whether the input to the speech motor programmer was from the lexicon or from some form of "on-line" process of phonological assembly (Levelt, 1989). On the contrary, one would expect similar formant variability differences between nonsense and real words.

There are two possible explanations suggested by the authors. Firstly, the phonetic characteristics of the speech output of the Inconsistent group reflects a difficulty in generating appropriate phonetic parameter specifications for the phonological plans of lexical items. This would explain why phonetic variability is normal in the imitation of nonsense words since such a procedure does not require access to lexical representations. Alternatively, the locus of difficulty may lie not so much with inappropriate phonetic parameter settings in the underlying representations but with difficulty in accessing them for the stages of phonological and speech motor assembly. These hypothesis needs to be tested further. In this experiment, the nonsense words were imitated while the real words were spontaneously named by the subjects. A further experiment is required to disambiguate the effects of imitation from words being either real or nonsensical.

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