THE EFFECTS OF THE ATTENUATION OF SECOND AND THIRD FORMANT FREQUENCIES ON THE RECOGNITION OF STOP CONSONANT VOWEL SYLLABLES IN APHASIC AND NONAPHASIC SUBJECTS

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ABSTRACT - This study compares the ability of nonfluent and fluent aphasic and non- aphasic subjects to recognize six stop consonant vowel syllables (/pa,ba.ta.da.ka.ga/) under three formant frequency conditions (synthesized presentation of F_1, F_2 and F_3; attenuation of F_2; and attenuation of F_3). ANOVAs and confusion matrices are used to document and compare the voicing and place of articulation responses made by each group across all formant conditions. Results indicate that aphasic subjects demonstrate speech recognition abilities remarkably similar to those of their nonaphasic counterparts when acoustic information vital to the recognition of speech is attenuated, and imply that more intact speech production facilitates more accurate speech recognition.

INTRODUCTION

Research has shown that one of the vital cues for speech recognition is the information carried by formant transitions into or out of the consonant. The first formant contains cues for voicing and manner of articulation, particularly of stop consonants. The second formant transition contains information on place of articulation. The third formant transition also provides cues for place of articulation but in a less clear manner than those noted for the second formant (Cooper , Delattre, Liberman, Borst & Gerstman, 1952; Harris, Hoffman, Liberman, Delattre & Cooper, 1958; Stevens & Blumstein, 1978). Studies of nonaphasic and aphasic subjects have shown that the left hemisphere is specialized for speech, especially for phonetic perception, and that persons with aphasia have more difficulty recognizing place of articulation contrasts than voicing contrasts (Blumstein, Baker & Goodglass, 1977; Molfese, 1984; Perecman & Kellar, 1981; Varney, Damasio & Adler, 1989). Studies have not yet examined the effects of the attenuation of second and third formant information on the stop consonant recognition abilities of aphasic subjects and it is hoped that this work being presented will contribute to information on the models of speech perception as applied to aphasic subjects.

The purpose of the study was to investigate how well subjects with aphasia could recognize stop consonants when information vital to the recogntiion of these consonants was attenuated, and whether the performance of the aphasic subjects would mirror that of nonaphasic subjects or be different in some way. Stop consonants paired with the vowel /a/ were subsequently selected as the minimal acoustic units in which the cues for voicing and place of articulation as carried by the second and third formants could be attenuated and the effects on consonant recognition studied.

SUBJECTS

Aphasic subjects were grouped according to their level of fluency or nonfluency. Acoustic studies of speech recognition in aphasia have documented phonemic discrimination and phonological processing difficulties (Baum, Blumstein, Naeser & Palumbo, 1990; Baum, 1993; Baum & Ryan, 1993; Blumstein & Baum, 1987). More fluent aphasic subjects had greater difficulty discriminating place of articulation contrasts in comparison to voice contrasts. Nonfluent aphasic subjects showed no differences in their recognition of these two phonetic categories. Acoustic studies have also demonstrated that in speech production, nonfluent or apraxic subjects exhibit difficulties with temporal aspects of speech, a phonetic deficit, in contrast to the apparent phonological planning deficits noted in fluent aphasics. McNeil and Kent (1991) recently documented deficits of phonetic implementation in both nonfluent and fluent aphasic subjects, implying that the neural representation of speech motor control involves both anterior and posterior neural structures.

PROCEDURES

Three groups of subjects (20 fluent aphasics; 20 nonfluent aphasics; 10 nonaphasics) listened to three synthetic versions of six consonant vowel syllables (/pa,ba,ta,da,ka,ga/): 1) full formant ($F_1F_2F_3$), 2) attenuation of the third formant (F_1F_2_), and 3) attenuation of the second formant (F_1_F_3). 18 CV syllables (3 place x 2 voice x 3 formant conditions) comprised the 18 trial types and were used to make two stimulus tapes. Each tape contained four different tests: test 1 - randomized presentation of a single token of each of the 18 trial types; test 2 - randomized presentation of 5 tokens of each of the full formant trial types; test 3 - randomized presentation of 5 tokens of each of the F_1F_2_ trial types; and test 4 - randomized presentation of 5 tokens of each of the F_1_F_3 trial types. Each CV syllable was repeated three times with an inter-repetition interval of two seconds. Within each test, the intertrial interval was 5 seconds. There was an interval of 10 seconds between each test. Tape 1 consisted of tests 1,2,3,4 and a repetition of test 2. Tape 2 consisted of tests 1,2,4,3 and a repetition of test 2. Repetition of the full formant series was used to assess the reliability of each subject's responses. Each subject was tested individually on one occasion in a room assessed to have adequate ambient noise levels. Half of each group of subjects heard tape 1 and half of each group heard tape 2. Subjects were seated at a table and shown a 5x7" card containing a random arrangement of block letters representing the six consonants to be heard. Subjects were asked to point to the letter which best matched the sound they heard. The dependent variable was the recognition of the presented CV syllables as measured by the total score of correct responses.

RESULTS

Significant main effects were found for the speech recognition abilities of fluent aphasic, nonfluent aphasic, and nonaphasic subjects (F (2,47)= 43.70, p <.001), for formant conditions (F (2,47) = 17.93, p <.001), and for stop consonants (F (5,47) = 19.99, p <.001). Significant interactions were noted for formant conditions x stop consonants (F (10,235) = 22.89, p <.001) and for groups x stop consonants (F(10,235) = 2.14, p <.05)). Post hoc testing for groups showed that nonaphasic subjects had more accurate speech recognition than fluent aphasics who in turn demonstrated more accurate speech recognition abilities than nonfluent aphasics. A significant Spearman correlation coefficient (r =.51; p <.01) was found in an analysis of the relationship between level of severity of aphasia and accuracy of consonant recognition across groups. A subsequent analysis of covariance was performed to factor out the effect of severity of aphasia and showed that the significant differences in consonant recognition between groups remained (F (2,37)=4.22, p <.05). All three formant conditions were significantly different from one another: $F_1F_2F_3 > F_1F_2\_ > F_1\_F_3$. Post hoc testing for formant conditions verified an expectation that the $F_1\_F_3$ condition would exert the most adverse effect on consonant recognition (Figure 1). Differences in speech recognition between groups were not affected by the type of formant condition under which the speech recognition task was presented. Post hoc testing of the significant main effect for consonants showed /d/ to be the most accurately recognized, followed by /p,b/t/, then /k,g/. Formant conditions did exert a significant effect on consonant recognition but it is not true to say that the attenuation of F_2 exerted an adverse effect on the recognition of all consonants. Post hoc testing of the significant group x stop consonant interaction showed nonaphasic subjects more accurate than both aphasic groups in their recognition of the majority of stop consonants (Figure 2). Interestingly, recognition of /d/ was the only consonant to differentiate between the two aphasic groups with fluent aphasics showing more accurate recognition.

Confusion matrices were developed to examine the similarities and differences noted in the consonant recognition responses of the nonfluent aphasic, fluent aphasic, and nonaphasic subjects. Analysis of the voicing and place of articulation responses made by each group across all formant conditions revealed that nonaphasic errors centered on substitutions along the place of articulation continuum. Both aphasic groups demonstrated this place of articulation substitution pattern but errors were more numerous with additional substitutions of voice and combinations of voice and place of articulation errors, particularly in the nonfluent aphasic group.

CONCLUSIONS

The conclusions derived from this investigation are:
1. Aphasic subjects demonstrate speech recognition abilities remarkably similar to those of their nonaphasic counterparts when acoustic information vital to the recognition of speech is attenuated,
2. The differences in speech recognition that were noted between fluent and nonfluent aphasics may argue for the existence of different abnormalities in their perceptual systems, and
2. The finding that more intact speech production appears to facilitate more accurate speech recognition may be interpreted as support for the Motor Theory of speech perception (Klatt, 1991; Liberman & Mattingly, 1985) and provide exciting avenues for future research, particularly in the neural networks underlying fluent and nonfluent aphasia, the link between nonfluent aphasia and apraxia of speech, and the possible continuum of sequenced gestures that is relied upon by aphasic subjects in their attempts to recognize speech and to function effectively in daily communication

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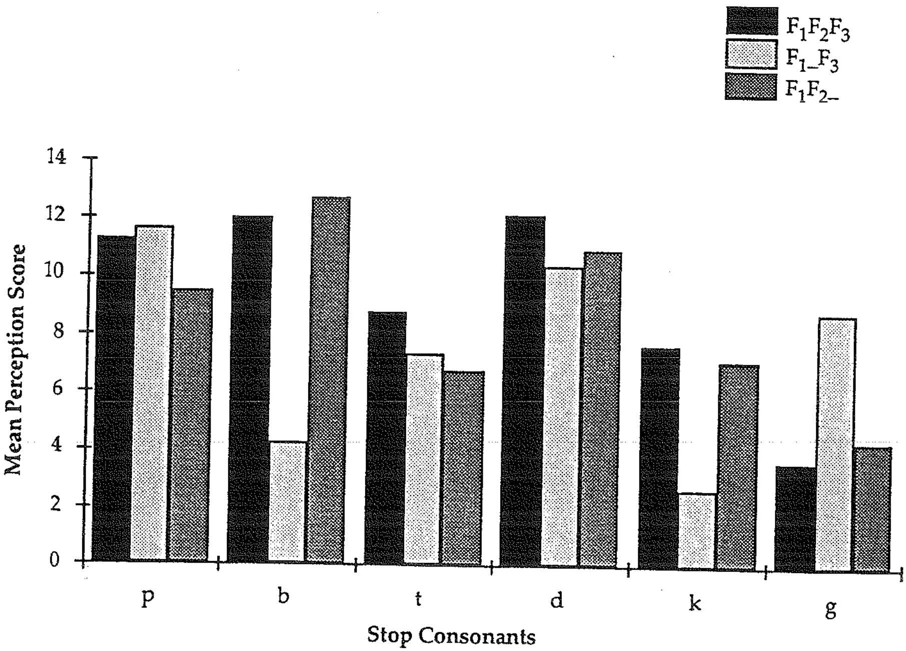

FIGURE 1. Effect of Formant Conditions, Collapsed Across Groups, on the Recognition of Stop Consonants.

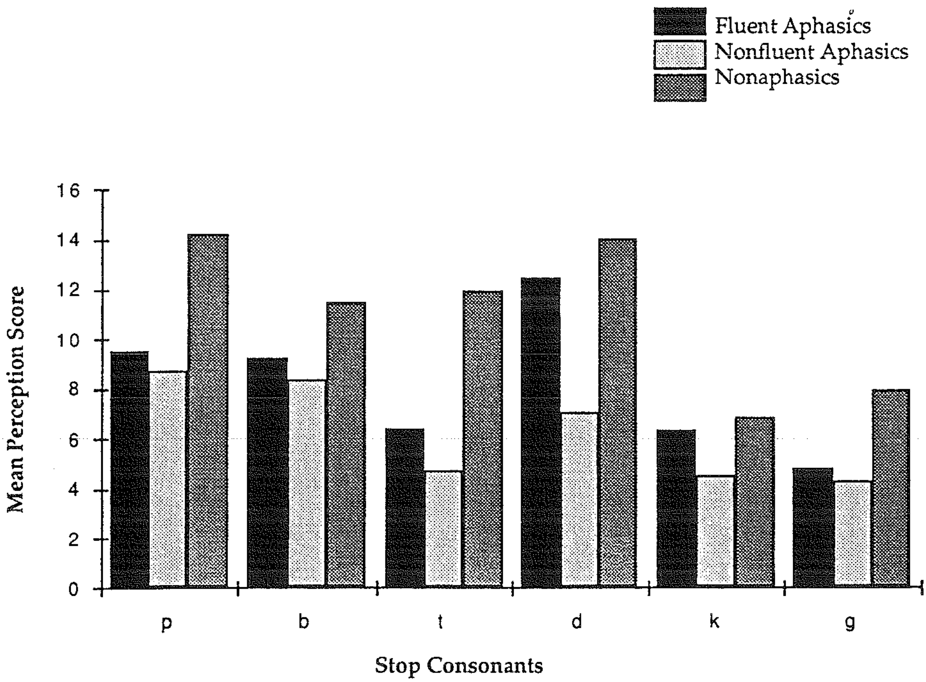

FIGURE 2. Mean Recognition Score for Stop Consonants, Collapsed across Formant Conditions, for Fluent, Nonfluent and Nonaphasic Groups.