PRODUCTION OF STOP CONSONANTS : NEUROLINGUISTIC STUDY IN A CONDUCTION APHASIC

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ABSTRACT

The stop consonant transition durations of a french-speaking conduction aphasic and a control subject, have been compared in a word repetition task with and without masking noise. Contrary to the control, the voiced and unvoiced transition durations of the aphasic tended to be poorly differentiated, and in noise, when auditory feed-back was precluded, all his transitions became shorter. The error rates of the aphasic were also analysed. It was much higher for unvoiced stops than for voiced stops. It was higher in masking noise than without noise. The results are discussed with respect to the possible roles of auditory and kinesthetic control of speech production.

1. INTRODUCTION

It is clinically widely accepted that conduction aphasia is associated with posterior cortical damage centered on the parietal lobe and with linguistic deficits that are focused on production mechanisms. The impairments are especially important in word repetition but also in spontaneous speech. Segmental errors and substitutions are very common. On this basis, it has been proposed that a phonological level of speech production is deficient [4]. A few VOT studies have also shown some phonetic disturbances [1, 7]. Blumstein et al. have suggested that these disturbances are related to a timing deficit. However, its origin was not well defined. Kent [2] has proposed that conduction aphasia is related to impairments of phonetic sequencing and deficient central integration of peripheral sensory informations that result in disturbances of sensory trajectories and poor motor control of speech. McNeilage [3] has insisted on the importance of motoricly defined acoustico-articulatory targets during speech production and their implication in a premotor level of speech control. On this basis, Poncet et al. [6] have suggested that the targets are part of an internal linguistic model involving a representation of the buco-phonatory system, and that within it, they are specified spatially and kinestheticly as premotor schemes. At the neurological level, such schemes have been associated with the left parietal lobe which is the cortical area classicly considered to be implicated in conduction aphasia. Internal laryngeal and supra-laryngeal buco-phonatory coordinates may play an essential role in these schemes. However, buco-phonatory gestures are displayed in time. Temporal coordinates must also be taken into account. Auditory temporal discrimination and feed-back are likely to play an important role in the control of the articulatory gestures involved in speech production. At the premotor level, the timing of speech sounds could be coded both kinestheticly and auditorily. The respective roles and interplay of these two types of temporal coding of speech production are not well known. The study of timing factors is possible through the investigation of voiced and unvoiced stop consonants. Contrary to voiced stops, at the articulatory level the realization of an unvoiced stop necessitates the inhibition in time of the vibration of the vocal folds. In addition, differences in transition length are important acoustic elements for the distinction between voiceness and voicelessness. In order to study production timing factors in conduction aphasia, we investigated the stop transition durations of a conduction aphasic and a control subject. We used the stop transitions rather than the VOT because, contrary to English, in French, all voiced stops are always prevoiced and voicing occurs over the entire duration of the closure, and usually also during the plosion. Moreover, in order to investigate the respective roles of the kinesthetic control and the auditory control mechanisms, we tested our subjects under normal condition and under speech masking noise condition. In this latter condition, the noise precluded the auditory control leaving only the kinesthetic control available.

2. SUBJECTS

Two right-handed men with normal audiograms took part in the experiment. They were matched for educational level and pronunciation characterisitics. The control subject was thirty two years old. The Aphasic subject was fifty years old. At the onset, his impairments included global aphasia and right hemiparesia. Within a few days, they evolved to right hemianesthesia and conduction aphasia associated with discrete reading, and writing problems as well as acalculia. MNI showed a hypodensity in the left sylvian territory suggesting a sylvian ischeamic accident. The damage was centered on the inferior parietal lobule and extended to the superior parietal lobule, to the *plis courbe* and the periphery of the somesthesic paracentral parietal areas. In depth, the lesion extended to the upper surface of the posterior part of left lateral ventricule.

3. PROCEDURES

The subjects were tested in an anechoic chamber on a single word repetition task. An experimenter who could not be seen, read each word before the repetition. The subjects did the task two months after the accident of the aphasic. They were tested three times with the same list of words. During the third repetition of the list, a 100 dB spl loud speech masking noise was diffused through audiometric ear-phones. In this last condition, the subjects were specificly asked to speak normally in order to avoid a raising of the intensity of the voice. The list consisted in 552 words with 90 target words randomly distributed among them. They were chosen in order to study and compare all the six stop consonants of French. The stops were either at the initial position for monosyllabic words or at initial and intervocalic positions for bisyllabic and trisyllabic words. A total of 108 stop consonants were included in the target words.

Out of these stops consonants, 18 came from monosyllabics, 36 came from bisyllabics and 54 from trisyllabics. The vocalic surrounding was /a/ and in a few cases /ɛ/ or /ɔ/. In our acoustico-phonetic analysis, we considered only the correct productions of the aphasic, and only the second repetition (with no speech masking) and the third repetition (with masking noise) were taken into account. The segmentation was done with the phonetic Bliss Sytems program [5]. The stop transition durations were taken between the beginning of the stop plosure and the first noiseless vocalic period following the stop. These measures constituted the dependent variable. A completely between analysis of variance was performed for each type of word length: monosyllabic, bisyllabic and trisyllabic. The individual stop consonants constituted the random variable. The experimental factors that we studied, were the type of subject (aphasic or control), the voiceness of the stop (voiced or unvoiced) and the repetition condition (with or without speech masking noise). An additional factor, i.e., the position of the stop in the word, was studied for the bisyllabic words (2 positions) and the trisyllabic words (3 positions). The three parametric analyses were performed using a SAS general linear model procedure for analysis of variance. In the phonological analysis, we considered all the target words and the number of errors. The control subject did not make any error. Only the data of the aphasic subject were considered. We compared his performances on the basis of the voiceness or unvoiceness of the stop consonant in target words and the presence or absence of speech masking noise during the repetition. Performance differences based on word length were also examined. The analysis was performed using a SAS categorical analysis procedure for dichotomous variables.

4. RESULTS

The results of the phonetic analysis showed significant effects of the interaction between subject and voiceness for the three types of word length (F's ≥ 5.30, p≤0.03). In all cases, the differences between voiced and unvoiced stop transitions were minimal for the aphasic. On the contrary, the voiced stop transitions of the control subject were much shorter than his unvoiced stop transitions (Table I).

Table I Voiced (V+)and unvoiced (V-) transition durations in milliseconds

	Aphasic		Control	
	V+	V-	V+	V-
Monosyllabics	10.4	15.3	6.8	20.2
Bisyllabics	10.8	15.7	6.8	19.4
Trisyllabics	10.6	16.4	7.1	19.6

These results seem to indicate that voiced and unvoiced stop consonants are poorly differentiated by the aphasic subject. The phonetic analysis also showed significant effects of the interaction between subject and noise condition for the three types of word length (F's ≥ 3.85, p≤0.05). In all cases, the stop transition durations of the aphasic became much shorter in noise while those of the control subject tended to remain the same in noise and without noise (Table II). These results seem to indicate that the aphasic has more difficulty maintaining the duration of stop transitions without auditory feed-back.

Table II Stop transition durations in noise (N+) and without noise (N-)

	Aphasic		Control	
	N+	N-	N+	N-
Monosyllabics	7.6	15.9	13.7	13.7
Bisyllabics	10	16.1	14.4	12.3
Trisyllabics	9.9	15.1	13.8	12.9

In addition to these effects, in the bisyllabics and trisyllabics of the aphasic, significant differential effects of noise could be detected with respect to voiced an unvoiced stops (F's ≥ 4.6, $p \leq 0.04$). The unvoiced stops transitions always became shorter in noise while the voiced stop transitions did not change much in noise. On contrary, in monosyllabics both voiced and unvoiced stop tansitions became smaller in noise (Table III).

Table III Interaction between noise and voicing for each type of word length

	Noise +		Noise-	
	V+	V-	V+	V-
Mono Aphasic	5.3	10.4	13.8	17.8
Mono Control	6	19.9	7	20.4
Bi Aphasic	9.3	10.7	13.1	18.9
Bi Control	6.6	21.3	7	17.6
Tri Aphasic	8.5	11.3	11.8	20.6
Tri Control	5.7	21.8	8.1	17.9

In the bisyllabic words of the aphasic, a significant effect of the position of the stop consonant in the word was found in conjunction to the effect of noise on voicing ($F(1, 107) = 7.59$, $p<0.007$). Voiced and unvoiced patterns of change in noise and without noise differed only for the intervocalic stop position. At that position in noise, voiced stops did not change while unvoiced stop durations shortened dramaticly and tended to become undifferentiated from those of voiced stops (Table IV).

That level of interaction could not be detected in trisyllabics, even though patterns of changes for initial and inter-vocalic stops did not seem to differ from those of bisyllabics.

Table IV Effect of the position of the syllable in the bisyllabics of the aphasic subject

	Noise +		Noise -	
	V+	V-	V+	V-
Syllable 1	9.3	12.4	16.3	17.3
Syllable 2	9.3	9.6	8.1	21.3

At the phonological level, the analysis showed a significant effect of the word length ($X^2 = 12.55$, $p<0.02$). The error rates increase slightly from monosyllabics (25%) to bisyllabics (27%), and becomes much higher in trisyllabics (43%). These effects further suggest that longer words which include intervocalic stops, are more difficult to realize for the aphasic. The results of the phonological analysis also showed that the error rate for unvoiced stops (33%errors) is significantly higher ($X^2 = 4.83$, $p<0.03$) than that for voiced stops (22%errors). This seems to indicate that, for the aphasic, unvoiced stops are more difficult to realize. The phonological results also showed a significant higher error rate $X^2 = 7.29$, $p<0.007$) in the condition with masking noise (43%) than in the condition with no noise (26% errors). This seems to further indicate, that when auditory feed-back is suppressed, phonation is more diffcult for the aphasic.

5. DISCUSSION

At the acoustico-phonetic level, the poor differentiation of voiced and unvoiced stop consonants of the conduction aphasic, suggests that his timing coordinates are affected. The differential duration parameters for the realization of voiced and unvoiced stops seem to be blurred. This deficit suggests that temporal coding is likely to be an important part of premotor speech production schemes. In the phonological analysis, the higher error rate of the aphasic for unvoiced stops, further suggests that timing could play a specific role. The realization of unvoiced stops is likely to involve a temporally programmed inhibition of the vibration of the vocal folds. This is not necessary for voiced stops and this could be why they are less prone to errors than unvoiced stops.The shortening of the stop transitions of the aphasic in masking noise, when auditory feed-back is not possible, suggests that articulatory timing can be controlled auditorily. The preclusion of this control could explain that durations are not maintained. The results further seem to indicate that non-auditory control of phonation, i. e., kinesthetic control, is deficient in conduction aphasia, but auditory control could compensate for it to a certain extent. The higher error rate of the aphasic in masking noise also support this view. The results showed a very peculiar effect of masking noise for the aphasic. Unvoiced stops transitions are significantly shortened in bisyllabics and trisyllabics,while voiced stop transitions tend to remain similar in noise and with no noise. It suggests, that in words with more than one syllable, adequate vocal folds inhibition is diffcult to control audio-temporally. This could be specificly related to intervocalic stops because their presence constitutes the major difference between polysyllabic words and monosyllabic words. The role of auditory timing control of phonation might start to increase with increasing complexity and length of words. In addition, the very high error rate of the aphasic in trisyllabics seems to further indicate that successful word repetition is more difficult in longer words that necessitate important cross-syllabic integration. The audio-motor speech control system could be more specific of inhibitory control, in some cases at the intrasyllabic level, as for the production of unvoiced stops, but mostly at the cross-syllabic level for integrated cross-syllabic production. Conversly, the kinesthetico-motor sytem could be linked to an excitatory system, which might be more devoted to the command of the articulators for the initialization of speech and for the successive intra-syllabic integration during ongoing phonation. The performance of the kinesthetico-motor system for the production of a complete word might rapidly decrease with increasing integration needs such as for words with more than one syllable. In normal conditions, the two systems could operate synergistically for the control of the articulatory and acoustic characteristics of speech sounds. They both might encode speech timing but each specializing at a different level : (i) with an intra-syllable focus for the kinesthetic control system which is likely to be more automatic and removed from volontary control, (ii) and with a cross-syllabic focus for the auditory control system with some possibility to overtake intrasyllabic control especially when the kinesthetic system is deficient. Within that context, conduction aphasia can appear as a deficit centered at the intra-syllabic level of speech production and both auditory and kinesthetic timing coordinates seem to be affected. Secondary effects might result at the cross-syllabic level, especially when auditory control is removed.

6. REFERENCES

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