VOT PRODUCTION IN APHASIA: CONTEXTUAL AND LEXICAL INFLUENCES.

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ABSTRACT

Two experiments revealed that the voice onset time (VOT) of initial plosives in aphasic speech may be conditioned by the voicing of medial consonants and by the lexical status of the involved stimulus.

INTRODUCTION

The voice onset time of plosives is considered to play an important role in the classification of aphasic speech errors and in the differentiation of aphasic syndromes (e.g. /1,2/).
In normal speech the VOT of (initial) stop consonants is known to be sensitive to context influences such as the quality, tenseness, and duration of the subsequent vowel or the voicing of the post-vocalic consonant (see /3/ for references). To the extent that certain aphasic patients are particularly prone to disturbances of sequential processing the role of such effects in aphasic speech deserves particular consideration.
On the other hand, linguistic variables which are not known to play a role in normal speech production may nonetheless influence voice onset time in the condition of aphasia. Among the factors considered to influence the error rates of many aphasics are for instance the grammatical class, the frequency, and the lexical status of a word (e.g. /4, 5/).
When uncontrolled, such effects may cause a systematic increase in the variability of VOT data in aphasic speech. On the other hand, the VOT may provide us with a quantitative measure to study contextual interdependences and lexical effects and thus to promote our understanding of the processes underlying the phonetic and/or phonological impairments in aphasia.
The present study focussed on two of the aforementioned effects. In a first experiment, the anticipatory influence exerted by voiced vs. voiceless medial plosives upon the VOT of initial stop consonants was investigated in aphasic patients with and without apraxia of speech.
A second experiment was designed to assess VOT differences in voiced and voiceless initial stops of word-nonword minimal pairs in speech apraxics.

CONTEXT INFLUENCES

Methods

Subjects: Context influences were examined in six aphasic patients and in a normal and a dysarthric control. All aphasic patients had suffered from occlusions of the left middle cerebral artery. Aphasia testing revealed two cases each of Broca's and Wernicke's aphasia. The two remaining patients had unclassifiable aphasic disturbances. Together with the two Broca's aphasics they presented with the clinical symptoms of apraxia of speech: Their speech was characterized by numerous substitutions and distortions of speech sounds and an inconsistency in the articulatory pattern. All of the speech apraxics had prosodic impairments.
The dysarthric patient had suffered from a midbrain hemorrhage and presented with the symptoms of ataxic dysarthria.

Materials and procedure: A pseudorandom test list was prepared, containing four bisyllabic nonwords of the form /'daCo/, /'taCo/ with C = /b,p/ interspersed with a number of dummy words. The subjects were required to repeat the test utterances upon aural presentation by an examiner. Each word was produced at least 20 times within one session. Patient examinations were performed in a sound-treated room and recorded using high-quality equipment. Preceding each session the discriminatory abilities of the patient with respect to the voicing contrast were examined in a same-different task with taped presentations of test stimuli. Each patient reported here performed well on the discrimination task, yielding almost 100% correct discriminations, yet often with delayed responses. The recordings were digitized on a LSI 11/73. Words containing an error unrelated to the voicing feature in either the initial or the medial plosive were excluded from further analysis. For the initial plosive of each target word two examiners measured the voice onset time as defined by the interval between the plosive burst and the onset of periodicity.

Results and discussion

Figure 1 presents the cumulative VOT distributions resulting from the productions of the normal subject (left) and the dysarthric patient (right). In both cases the data reveal a slight tendency towards increased VOT values in utterances with voiced medial plosives as compared to the voiceless context, an effect which proved significant in the case of the dysarthric patient's /t/-tokens (Mann-Whitney, two-tailed; $p<0.02$). The difference contours depicted at the bottom of fig.1 describe both the direction and the extent of the measured effects.

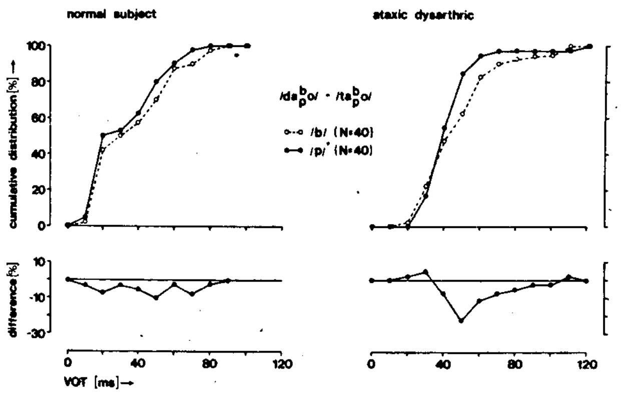

Fig.1: Sensitivity of voice onset time of initial plosives to medial stop voicing: Cumulative distributions (top) and voiceless-minus-voiced difference contours (bottom) in a normal and a dysarthric control.

A possible explanation of this effect which has been described earlier /3/ might be that the two controls, in the sense of an "elaborate pronunciation", attempted to increase the syntagmatic contrast between the two plosives in the test words.
The difference contours given in figure 2 demonstrate consistent contextual effects in two patients with apraxia of speech and two Wernicke's aphasics. Unlike the two controls of fig.1, the aphasics' samples with voiced medial plosives tended to have shorter VOT than when the medial plosive was voiceless. In three of the six cases the measured effects were rather marked and proved significant (Mann-Whitney, two-tailed; $p<0.001$). In the remaining patients the same effect was present, yet not statistically significant.

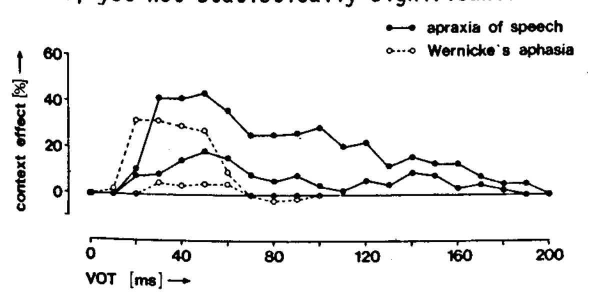

Fig.2: Difference contours as in fig.1 for two Wernicke's aphasics and two patients with apraxia of speech.

Following this pattern, the aphasic patients were, unlike the two controls, influenced in the sense of an assimilation of the initial plosive to the voicing feature of the subsequent medial plosive. Notably, this assimilation occurred across place differences between the two neighboring stop consonants.

A major difference between apraxic and non-apraxic aphasics was that the former covered a broader overall VOT range in their productions. Moreover, the two groups differed in the pattern of context sensitivity (fig.3).
The diagrams of fig.3 describe VOT distributions for the examined word pairs as approximated by two-component least-squares fit models /2/. In none of the cases was the approximation error greater than 5%. In the normal speaker (left), the distributions obtained for /tabo/ and /tapo/ were similar in their shape with a slight shifting of the former towards higher VOT values. The patient with apraxia of speech (middle) presented /dabo/-samples with increased VOT values, concentrated at almost equal proportions in two modes around 50 ms and 80 ms. In the condition of voiceless context the 80 ms peak became overproportionate and a number of outliers above 100 ms occurred at the expense of VOT values below 40 ms. It should be pointed out that this patient's /t/ productions occupied a range above 100 ms, meaning that neither of the two peaks in the /d/-distribution of /dabo/ or /dapo/ can be considered as representing literal paraphasias (for a broader discussion of this issue see /2/). The measured context effect therefore is presumably not a result of phonemic changes in the voicing category.
In the Wernicke's aphasic (right), on the other hand, the effect exerted by context variation produced a dual pattern in the VOT distributions of /dabo/ and /dapo/: the majority of /d/-productions in the voiced context assumed values between 5 and 25 ms, i.e. within a normal range, and a smaller proportion of voice onset times was distributed around 50 ms. In the voiceless context, these relations were reversed. It is of importance to know that the peaks near 50 ms were characteristic of this patient's realizations of /t/. In contrast to the speech apraxic the context influence observed in the Wernicke's aphasic may therefore be described as a triggering of literal paraphasias in the voicing dimension.

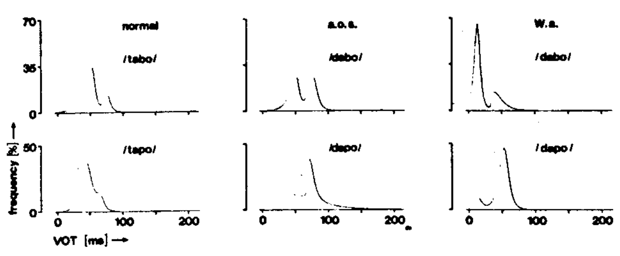

Fig.3: VOT distributions (least squares fit models /2/) for /d/ or /t/ with varying medial plosives for a normal subject and two aphasic patients.

LEXICAL INFLUENCE

Methods

Subjects: In a second experiment, three normal subjects and six aphasic patients (two Broca's, one conduction and three patients with very mild, unclassifiable aphasic symptoms) were involved. Again, all patients had suffered from occlusions of the middle cerebral artery. All patients were diagnosed as presenting the symptoms of apraxia of speech.
Materials and procedure: The test words used in this experiment consisted of the two minimal pairs /dynə/ ("dune") - /tynə/ (nonword) and /dyrə/ (nonword) - /tyrə/ ("door"). The first of these two pairs will in the following be referred to as the 'word-nonword pair', the second as the 'nonword-word pair'. The test words were arranged in a pseudo-randomized order with interspersed dummy words and repeated upon taped presentation for at least 20 times each. Testing was performed as described above, again with an examination of auditory discrimination preceding each session. The VOT of the initial plosive of each target word was measured according to the criteria mentioned earlier.

Results and discussion:

The curves plotted in figure 4 were obtained by subtracting the cumulative percentage of word-nonword samples from that of nonword-word samples within 10 ms VOT bins for three of the speech apraxics and a normal subject. In the latter, the difference contour oscillated around 0, indicating that there was no systematic difference between the VOT distributions of the word-nonword and the nonword-word pairs. In contrast, the three patients presented considerable positive deviations from 0 in their difference contours, meaning that in their productions the nonword-word pairs tended to have larger VOT values than the word-nonword pairs.
This was corroborated by testing the differences between words and nonwords for each of /d/ and /t/ separately (Mann-Whitney, two-tailed; N=80). Among the patients a significant ($p<0.005$) bias of nonwords towards words was obtained in four out of six cases, yet always in only one of the two stop cognates. The respective median values in these cases differed by approximately 10 ms (8 ms to 13 ms). In a further patient a less marked effect was found ($p<0.025$), which, however, remained stable when this subject was re-examined (N=160). Only the patient with the mildest aphasic and apraxic symptoms demonstrated an opposite tendency.
Notably, a significant bias in the nonword-word direction occurred also in one of the three normals. This effect, although small, was preserved upon increasing the data base (N=160).
These results reveal that, obviously, the meaningful words in the two pairs played the role of "attractors", causing in their meaningless counterparts a measurable change in plosive VOT towards the "word" - target. These deviations consisted of gradual shiftings of the entire distribution rather than categorical jumps of single tokens and could therefore not be explained by a literal paraphasia model. Hence the lexical effect must arise at a stage of processing where the motor patterns pertaining to the target word are specified in their phonetic detail. In terms of the two-route model hypothesized by McCarthy & Warrington /4/ one could speculate that the auditory-phonological and the semantic-phonological transcoding process are simultaneously active in the repetition of test words. When the input is a nonword, its phonetically "neighboring" lexical entries, including presumably the voicing counterpart of the test stimulus, are activated. Yet, at the level of VOT specification the articulatory programs implemented along the lexical route and the direct route interfere with each other, yielding the described bias. However, this interference becomes effective only if the desired stimulus, i.e. the "word"-member of the respective word-nonword pair, actually receives the highest activation load among several potential candidates in the mental lexicon. It was probably due to this weakness in the paradigm that the effect could be measured in only either /d/ or /t/. If an appropriate paradigm were available that controls lexical access effectively a more significant influence would possibly result.
The observations made regarding one of the normal subjects suggest that the hypothesized interaction may in principle be effective in normals, too, which would provide an analogy to the lexical effects observed in word perception experiments /6/. Nevertheless, in the examined speech apraxics the bias in favor of words against nonwords was considerably greater, meaning that these patients are more vulnerable to lexical influences in speech production. One might speculate that a similar effect is present in words of differing frequency.

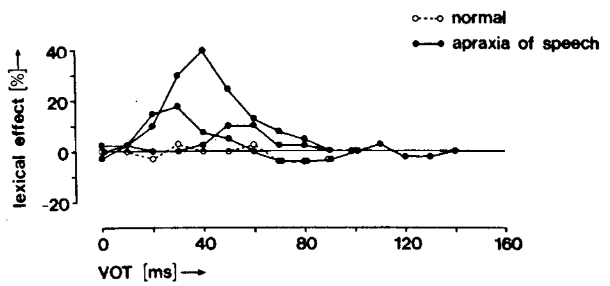

Fig.4: Difference contours resulting from cumulative VOT distribution functions (10 ms intervals) as explained in fig.1 (nonword-word minus word-nonword). Open circles: normal subject; closed circles: patients with apraxia of speech.

CONCLUSIONS

The outcome of both experiments reported here strongly suggests that plosive VOT in aphasic speech is sensitive to linguistic variables. With regard to the influence exerted by neighboring voiced vs. voiceless consonants on a target plosive the measured effects were opposite to expectations from normal speech. Apraxic and non-apraxic aphasics, in their own way, tended to reduce the syntagmatic voicing contrast. The lexical effect observed here included a VOT bias of meaningless stimuli towards meaningful counterparts. This effect was interpreted along the lines of a two-route model of word repetition.
Our results stress the requirement of controlling the speech materials used in VOT studies of aphasic speech with respect to linguistic variables.

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