AUDITORY PERCEPTION OF SIGNAL DURATION IN APHASIC PATIENTS

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Impairment of auditory comprehension of verbal messages, in spite of normal hearing acuity (as measured by pure tone audiometry), constitutes one of the major symptoms of aphasic patients. There is some evidence, in addition, that many such patients exhibit various degrees of impairment in phoneme discrimination and/or identification.[1, 2, 3)]

Knowledge is lacking, however, about the specific mechanisms underlying these impairments, and, in particular, little is known about the physical correlates of speech signals with which aphasic patients have specific difficulty.[4)]

Temporal duration constitutes one such correlate which has been known to play an important role in discriminating speech sounds in Japanese. The study reported here investigates this correlate as an experimental parameter in an attempt to answer the following questions:

1. How does the performance of aphasic patients on the temporal discrimination of nonspeech sounds compare with that of normal subjects?
2. How does the performance of aphasic patients on identifying segmental duration in synthetic speech compare with that of normal subjects?
3. How does the performance of aphasic patients on nonspeech tasks compare with their performance on speech tasks?

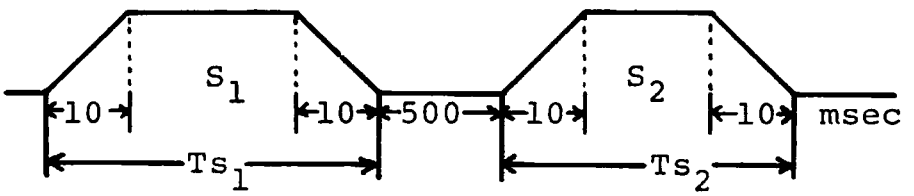
Experiment 1. Temporal Discrimination of Pure Tones

In the first experiment, temporal discrimination of 500 Hz pure tones was investigated in an attempt to answer question 1.

Stimulus Material

The specifications of the paired stimuli are shown in Table 1. It will be seen that discriminability was measured at T=100 msec (which was supposed to be comparable to the average duration of Japanese syllables) as well as at T=200 and T=400 msec.

Table 1. Stimuli in temporal discrimination test.



$Ts_1 = T + n \cdot \Delta T$, $Ts_2 = T - n \cdot \Delta T$ ($n = \pm 1, 3, 5$)

T=100msec	ΔT= 7 msec
T=200msec	ΔT= 10 msec
T=400msec	ΔT= 20 msec

The differences in duration between the paired stimuli, S_1 and S_2, were determined on the basis of the discriminability of normal* as well as aphasic subjects in a preliminary experiment. Thus, the value of $2 \cdot \Delta T$, i. e., the minimum difference between the paired stimuli for a given value of T, was set equal to σ, the accuracy of discrimination obtained with normals, [5] while the maximum difference between the stimuli was set equal to $10 \cdot \Delta T$ at each value of T. The test stimuli were generated by a digital computer with a sampling rate of 8 kHz and an accuracy of 8 bit/sample, and were compiled on a magnetic tape in such a way that it contained a randomized sequence of 60 pairs, consisting of 10 each of 6 different paired stimuli at each value of T. Linear rise and decay of 10 msec each were adopted to avoid clicks. The interval between the paired stimuli was 0.5 sec, while the interval between two successive pairs was kept at 5 sec to leave time for responding. A brief tone of 1000 Hz was inserted at intervals of 10 pairs.

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*The normal group consisted of four adults with normal hearing. The age range was from 24 to 26 with a mean of 24.8 years.

Procedures

Twenty-nine patients with aphasia due to cerebrovascular disease served as subjects of this experiment. The age range was from 25 to 70 with a mean of 44.5 years. The degree of aphasic impairment ranged from very mild to moderate, and all the patients were screened for reliability of response by means of a practice session to be described below. The hearing acuity of each patient was examined by routine pure tone audiometry, and all patients revealed less than 15dB mean loss within the speech frequency range (500 Hz, 1000 Hz, and 2000 Hz).

Practice Session

Each patient was given a practice session in which he listened to the stimuli at the most comfortable listening level and was instructed to respond by pointing to one of two cards. On one card, there were two horizontal lines, a longer one on the left and a shorter one on the right; on the other, there was an identical pair of lines but in the opposite order, a shorter line on the left and a longer line on the right. This practice session served two purposes: (1) to familiarize the patient with the experimental task, and (2) to eliminate those who could not follow such instructions reliably. Thus, only those patients who could respond consistently to the paired stimuli of the practice session were included in the experiments.

Results

The test results were analyzed by calculating for each patient the value of the mean, μ (which indicates the time-order error in stimulus perception), and the standard deviation, σ (which can be regarded as an index of the accuracy of comparative judgement necessary for temporal discrimination). The method of the least-mean-squared error with Müller-Urban weighting to determine μ and σ was adopted. Fig. 1 shows the mean performance of the subjects at T=100 msec, plotted on a normal scale. The ordinate indicates the probability of the first tone being judged longer than the second, and the abscissa the difference in duration between the paired tones. The two lines in the figure, a thick one representing the performance

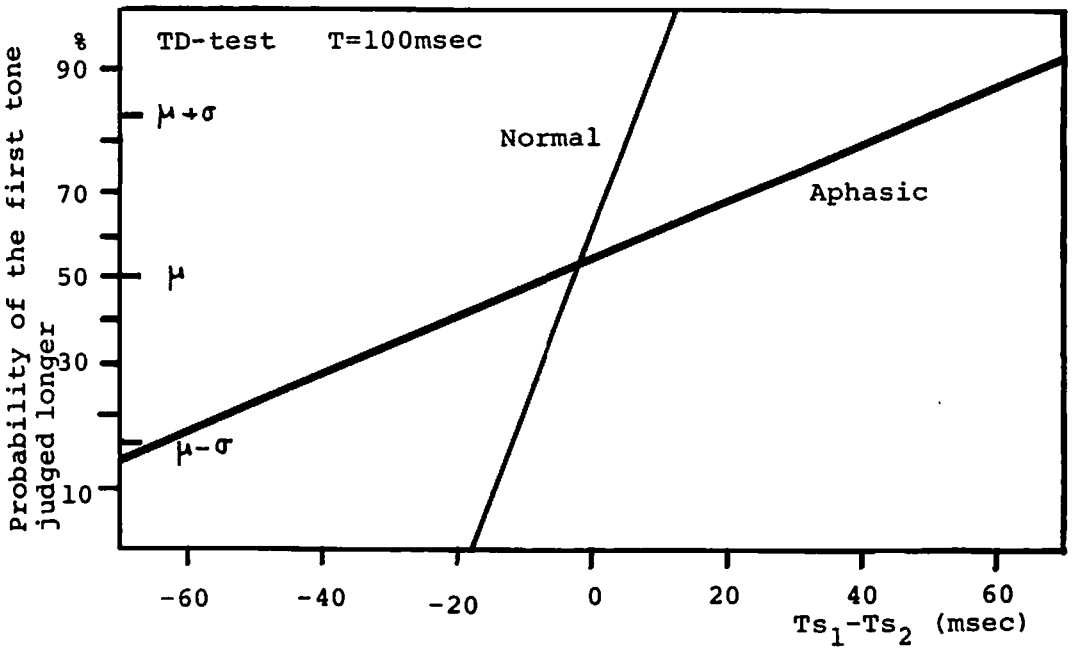

Fig. 1. Temporal discrimination as a function of Ts_1-Ts_2 (T=100 msec).

of the aphasic group and a thin one the performance of the normal group, are based on the means of the μ's and σ's of the respective groups.

It will be seen that the gradient of the line for the aphasic group is markedly less steep than that of the normal group (i. e., the value of the σ's, or the index of the accuracy of temporal discrimination, for the aphasic group is significantly larger than that for the normal group), indicating clearly poorer discrimination. It is also seen that the value of Ts_1-Ts_2 at the point of 50 per cent probability of judgement (i. e., the time-order error in stimulus perception) for the aphasic group, on the other hand, is only slightly larger and shifted only a little further in the negative direction than the corresponding value of the normal group. Similar results were obtained at T=200 msec and T=400 msec.

Figure 2 shows the accuracy of temporal discrimination (σ's) at each value of T for the two groups. It will be seen that (1) the values of σ's for the aphasic group (upper curve) are three to four times as large as those of the normal group (the lower curve), and that (2) the larger the value of T, the smaller the relative difference between the σ's of the aphasic and normal groups.

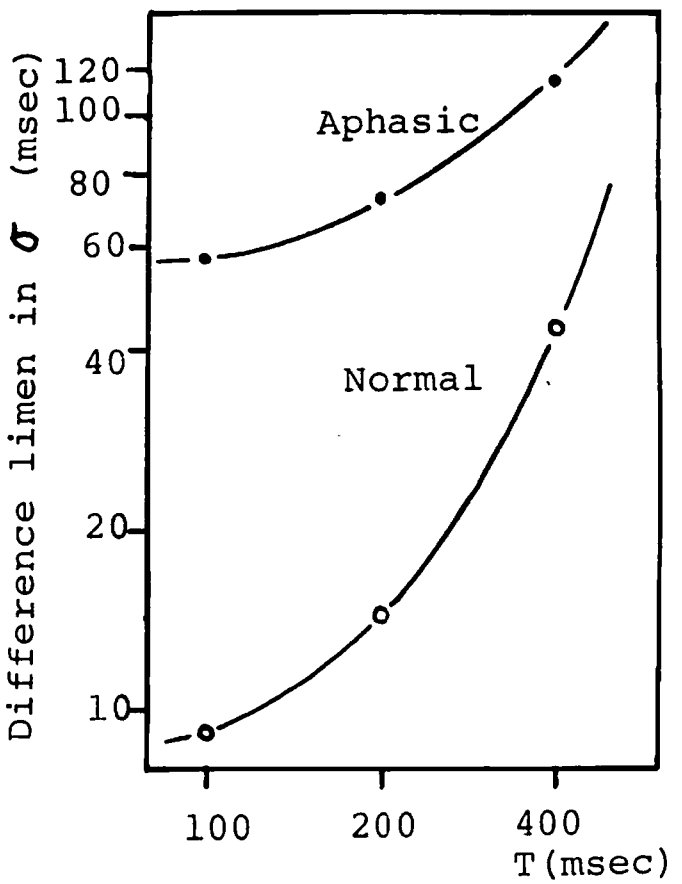

Fig. 2. Values of σ at T=100, 200, and 400 msec.

Experiment 2: Word Identification Test

Experiment 2 was undertaken to answer question 2, i. e., to investigate aphasic performance on identifying segmental durations of synthetic speech as compared to that of normals; as well as to compare the speech and nonspeech performances of the aphasic group, which relates to our question 3.

Stimulus Material

Two pairs of words, ita/itta and oi/ooi, which are discriminated according to segmental duration, were synthesized with a computer simulation of a terminal-analog synthesizer. In the case of ita/itta, the duration of the stop gap of the consonant as the parameter was controlled from 110 to 230

msec, while for oi/ooi the duration of the sustained portion of the vowel /o/ constituted the parameter and was controlled from 120 to 240 msec with a 10 or 20 msec step. These synthesized words then were sampled at 8 kHz with an accuracy of 8 bit, and were recorded on magnetic tape through a 3.4 kHz low pass filter. In both cases 10 each of 9 different stimuli were included making up a total of 90 stimuli.

The subjects in this experiment were the same group of aphasic patients as in Experiment 1. A practice session was given for each subject in which he listened to the stimulus tape and was instructed to point to one of two cards on which a word 'ita' or 'itta', or 'oi' or 'ooi' were written in kana symbols.

Results

The data obtained were processed in the same manner as in Experiment 1, calculating for each subject the mean μ (which indicates the phoneme boundary) as well as the standard deviation σ (which can be regarded as an index of the accuracy of categorical judgement necessary for identification). Figure 3 illustrates the mean performance of the aphasic group as

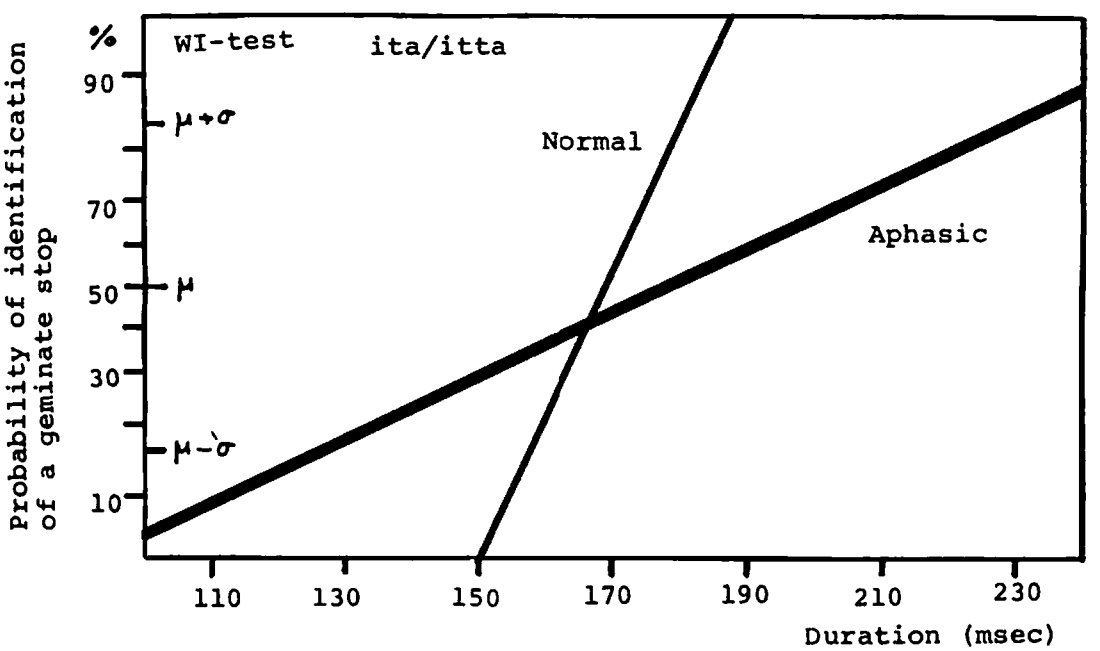

Fig. 3. Word identification as a function of consonant duration.

well as that of the normals on ita/itta, plotted on a normal scale. The abscissa indicates the duration of the stop gap of the consonant, and the ordinate the probability of identifying a geminate stop. It is clear that the mean of the σ's for the aphasic group is markedly greater than that of the normal group. In contrast, however, the difference between the μ's of aphasics and normals is extremely small. These results may be interpreted to mean that the aphasic patients as a group show little impairment in recognizing phoneme boundaries in these two words in spite of severe perturbation in categorical judgement of segmental duration. Figure 4 shows the result of the oi/ooi identification experiment. It will be seen that here too the recognition of phoneme boundaries remains almost normal, in contrast to the demonstrated gross impairment of durational judgement.

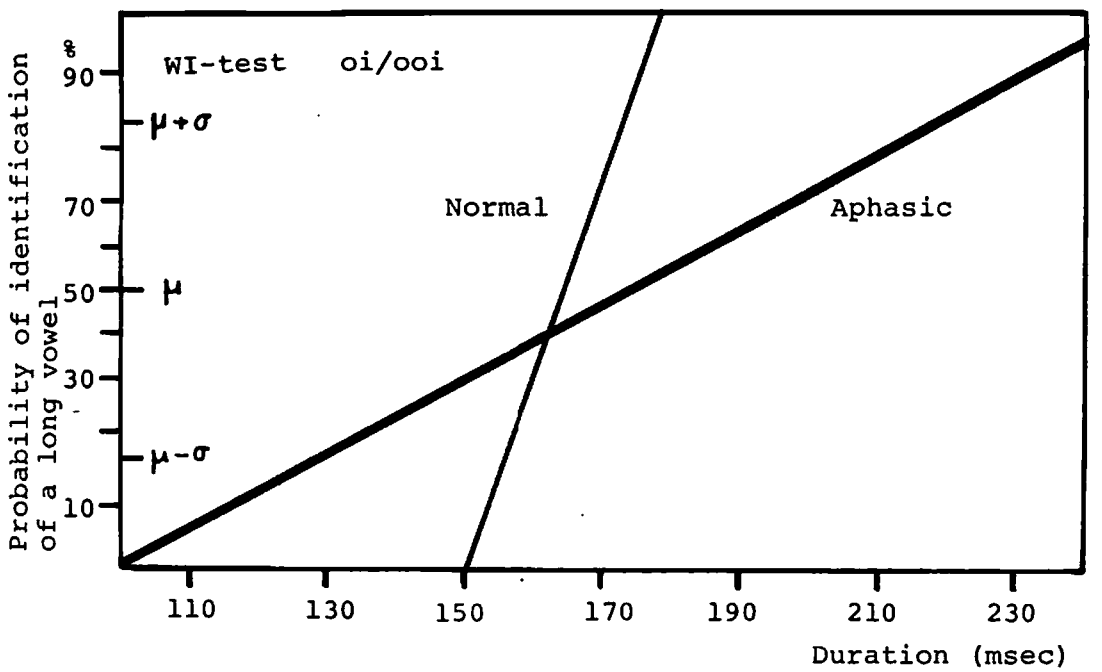

Fig. 4. Word identification as a function of vowel duration.

Summary

Twenty-nine aphasic patients were asked to make temporal discriminations of nonspeech stimuli, which were 500 Hz pure tones (Experi-

ment 1), as well as to identify the segmental durations of the synthesized words, oi/ooi and ita/itta (Experiment 2). The two major findings were: (1) the performance of the aphasic group as indicated by the σ values in both experiments was significantly inferior to the normal group, but (2) the phoneme boundary in Experiment 2 remained almost the same as that of the normal group.

Finding (1) calls attention to itself inasmuch as it seems to indicate the presence of a certain kind of "noise" or defect in the auditory system of aphasic patients even at a stage preceding speech comprehension. Finding (2) is of interest because we know that aphasic impairment by definition takes place after the acquisition of one's first language; hence pre-existing linguistic knowledge must still be operative in this group of patients. A part of their competence obviously remains despite aphasic impairment.

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