Ann. Bull. RILP, No. 12, 157-166 (1978)

AUDITORY AND VISUAL PERCEPTION OF VERBAL AND NONVERBAL STIMULI IN APHASIC PATIENTS

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Our previous studies [1, 2] concerning the perceptual abilities for auditory duration in aphasic patients revealed that the majority of them showed inferior performance as compared with normals both for speech and nonspeech sounds. In these studies the perceptual abilities for speech and nonspeech stimuli were measured in terms of identification and discrimination, respectively, and the results were compared with each other. In other words, we started by assuming that the two measures were equivalent. For the purpose of comparing the perceptual abilities for speech and nonspeech stimuli, however, it is necessary to use identical test measures. Since speech is usually identified and not discriminated, while nonspeech stimuli can be either identified or discriminated, the use of identification tests both for speech and nonspeech stimuli should be preferable to the use of discrimination tests for both.

In addition, our previous studies focused on aphasics' abilities with regards to speech perception, or perception of spoken language. It is desirable, however, to expand our investigation to incorporate the study of aphasics' abilities at identifying letters, since the visual perception of letters constitutes one of the basic abilities in comprehending written language. Findings obtained on this aspect of aphasics' performance may be compared profitably with those obtained for speech perception, providing additional information for a deeper understanding of the nature of the disabilities in these patients.

Further, it is necessary to make some modification in the method of data analysis, i.e., the measures of determining the accuracy of the identification of the stimuli in aphasic patients. In our previous studies the identification abilities of aphasic patients were determined on the basis of a perceptual model constructed for normals, in which only a disturbance inherent in the identification process itself was hypothesized. However, since there is ample evidence indicating the possibility that aphasics as a group might have deficiencies of general attentiveness as well as of attending to the stimuli presented in a specific modality, i.e., a modality-specific attentional deficit, it is necessary to devise a new model for determining identification ability which can handle multiple sources of perceptual disturbances.

These considerations led us to the present investigation in which the perceptual abilities of aphasic patients on auditory duration and the visual stroke length of verbal and nonverbal stimuli were measured and compared with those of young and aged normals.

METHOD

Subjects

A group of aphasic patients and two groups of young and aged normals served as subjects for the experiment. The aphasic group included 7 fluent and 6 nonfluent aphasics, each having normal hearing and (corrected) normal visual acuities. Their ages ranged from 29 to 68 (mean 48). One fluent aphasic had a defect in the upper right visual field, but his performance on visual tasks was not affected. Table 1 shows a breakdown of the aphasic subjects in terms of their clinical types.

Table 1. Age, clinical types and severity of aphasic patients.

SUBJECT	AGE	TYPE	SEVERITY
		(FLUENT)	
1	29	conduction	mild
2	36	conduction	mild
3	54	Wernicke	moderate
4	64	anomia	mild
5	53	Wernicke	mild
6	38	anomia	mild
7	52	anomia	mild
		(NONFLUENT)	
1	46	Broca	mild
2	66	Broca	mild
3	41	Broca	mild
4	44	Broca	moderate
5	68	Broca	mild
6	39	Broca	severe

The young normal group included 7 college students whose ages ranged from 19 to 27 (mean 20). The aged normal group included 8 volunteers without brain damage, whose ages ranged from 55 to 78 (mean 70). All subjects had normal hearing acuity. Two subjects showed a mild cataract in one eye, but this was not considered crucial for the purpose of our present experiment.

Stimulus Material

Four sets of stimuli, i.e., two of verbal stimuli (verbal-auditory and verbal-visual) and two of nonverbal stimuli (nonverbal-auditory and nonverbal-visual), were used.

The verbal stimuli in the auditory modality consisted of a series of synthesized words in which alveolar stop duration (a variable stop gap plus a 30 msec interval between plosion and the next vowel onset) was varied by steps from [ita] to [itta], two meaningful words found in natural Japanese speech. The synthesis was performed with a digital computer simulation of a terminal analog synthesizer, varying the alveolar stop duration as follows.

$$Tc=170+n\cdot\Delta Tc(msec),\ n=0,\ \pm1,\ \pm2,\ \pm4,\ \pm6,\ \ \Delta Tc=10\ msec$$

The nonverbal stimuli in the auditory modality were a set of 500 Hz pure tones. The durations of these pure tones were varied as follows.

$$T=200+n\cdot\Delta T(msec),\ n=0,\ \pm1,\ \pm2,\ \pm3,\ \Delta T=5,\ 10,\ or\ 20\ msec$$

The verbal stimuli in the visual modality were a series of synthesized kana letters in which the length of a vertical stroke of マ/ア was varied by steps from the shortest (マ) to the longest (ア). The vertical stroke was given by the arc of a circle with a radius of 37.2mm, and the length of the vertical stroke ℓ was as follows.

$$\ell=22.70+n\cdot\Delta\ell(mm),\ n=\pm1,\ \pm3,\ \pm5,\ \pm7,\ \pm9,\ \pm11,\ \pm13,\ 2\cdot\Delta\ell=1.95\ mm$$

Figure 1 shows letters with the shortest and longest vertical strokes, corresponding to a typical マ and ア, respectively.

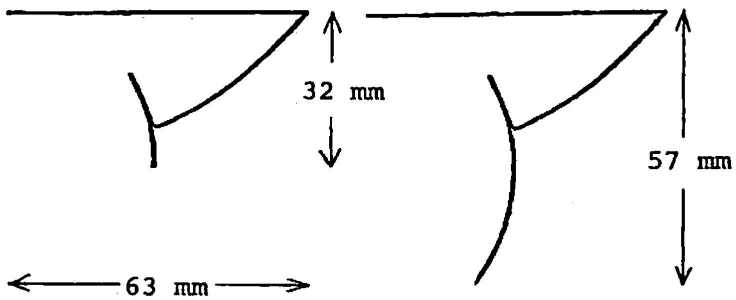

Fig. 1. Stimuli with the shortest and longest vertical strokes of a series of stimuli used for the visual identification test for the letters マ/ア.

The nonverbal stimuli in the visual modality were a set of vertical strokes from the letters マ/ア.

In this experiment it is hypothesized that the subjective or psychological representation of visual stroke length corresponds to that of auditory duration, as is implied by the fact that we feel "long" or "short" both for auditory duration and visual line length.

Procedures

In auditory experiments subjects were asked to identify the stimuli presented at the level of 50 dB above threshold. Interstimulus intervals (ISI's) for verbal and nonverbal stimuli were 5 and 4 sec, respectively.

In the visual experiments stimuli generated by a digital computer were displayed on the CRT-display for 90 msec each, with ISI's of 4 sec. The distance between the subjects' eyes and the CRT-display was approximately 1.1 m. The experiments were performed in a room where lights were kept dim.

Preceding the main experiments, subjects were required to listen to or watch a series of stimuli with various stimulus values including the maximum and minimum ones. Then each subject was given a practice session, in which he was instructed to respond by pointing to one of two cards with words (or letters) or lines for verbal and nonverbal stimuli, respectively.

In the main experiments a single stimulus was judged 20 times per session. Four different tests were given in rotation and four test sessions were repeated for each test. The measurement was based on a two-alternative forced choice paradigm. There were some occasions, however, when no response was available for a given stimulus. These occasions were excluded from data analysis.

Figure 2 shows an example each of the test results for a normal subject and an aphasic subject. The data of the normal subject shows a gradual transition from probability "zero" at one end of the stimulus continuum to probability "one" at the other end, and can be approximated fairly well by a cumulative Normal distribution.[3] In the case of the aphasic

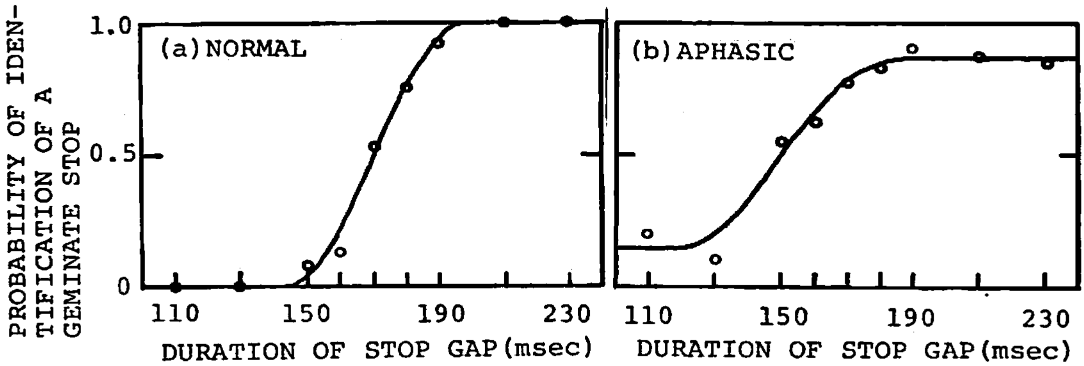

Fig. 2. An example each of the results of the identification test for a verbal stimulus in the auditory modality [ita]-[itta] for a normal subject (a), and an aphasic subject (b).

subject, however, the identification curve starts at some nonzero probability at one end of the stimulus continuum, and tends asymptotically to a probability value less than unity, so that an approximation by a cumulative Normal distribution is not necessarily valid. These findings suggest the existence of at least two sources of noise for aphasic subjects in the process of making a response to a stimulus. One is the noise inherent in the identification process itself, giving rise to a gradual increase in response probability along the stimulus continuum. The other is the noise in the response process, introducing response errors almost uniformly distributed over the stimulus continuum. In the case of the two-alternative forced choice paradigm, the latter process may be represented by a binary noisy channel connected in tandem with the identification process. If we denote the two categories by symbols "0" and "1", the channel can be characterized by the conditional probabilities q_{00}, q_{01}, q_{10}, and q_{11}, where q_{ij} indicates the conditional probability that the response "j" is selected when the input is "i". If we further denote by p_k the probability that the stimulus S_k is identified as "1", the probability P_k that the response "1" is selected for S_k is given by

$$P_k = (1-p_k)(1-q_{00}) + p_k \cdot q_{11},$$

where p_k's can be approximated by a cumulative Normal distribution characterized by the mean μ_I and the standard deviation σ_I. Given a set of measured data, therefore, it is possible to determine parameters μ_I, σ_I, q_{00}, and q_{11} of a theoretical identification curve that will give the closest approximation to the measured data in the sense of the least-mean-squared error. The estimation of q_{00} and q_{11} is facilitated by taking the mean error rate at both ends of the stimulus continuum. Figure 3 shows the results of the identification test for verbal stimuli in the visual modality in an aphasic subject and the closest approximation obtained by using a digital computer. The validity of the proposed model is demonstrated by the close agreement between the measured and the theoretical identification curves.

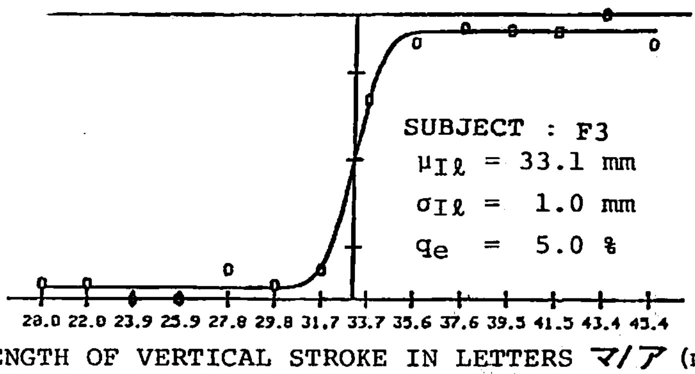

Fig. 3. An example of the results of the visual identification tests for the letters ヲ/ア, and the approximate identification curve. $\mu_{I\ell}$ and $\sigma_{I\ell}$ represent the category boundary and an index of accuracy of identification, respectively. q_e indicates the probability of occurrence of response error regardless of the stimulus value.

However, the identification test on tonal duration used for young normals was considerably difficult, since probabilities of extreme stimuli with respect to their stimulus values being judged longer were often largely apart from 0 and 1. In this situation it is almost impossible to obtain an exact value of q_e. Therefore, the value of q_e was assumed to be zero for results of this test for young normals, where the values of μ_I and σ_I were estimated based on the least-mean-squared error weighted by Müller-Urban coefficients [3].

RESULTS AND DISCUSSION

Figure 4 shows successive changes in the relative accuracy of identification, which is defined as the ratio of the accuracy of the identification to its category boundary μ_I, obtained with young normals (for each stimulus and for each session of the four experiments). The abscissa represents the cumulative number of days from the day of the first experiment. Three

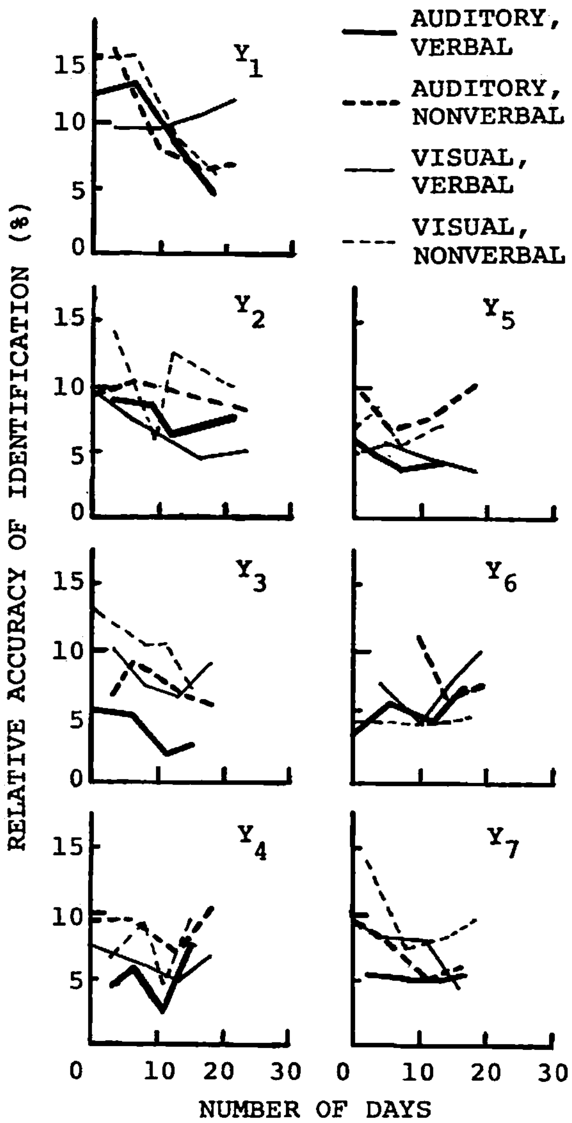

Fig. 4. Day to day changes in the relative accuracy of identification for verbal and nonverbal stimuli presented in the auditory and visual modalities for young normals Y_1 through Y_7.

observations can be made from the figure: 1) There are general tendencies that day to day changes in the relative accuracies of identification obtained from the four tests are almost parallel, indicating that the ratioes of the relative accuracies of identification of verbal stimuli to those of nonverbal stimuli, and of auditory stimuli to those of visual stimuli, are almost constant; 2) the relative accuracy of identification for verbal stimuli is better than that for nonverbal stimuli regardless of modality; 3) and the relative accuracy of identification in the auditory modality is superior to that in the visual modality.

The first observation implies that the mechanisms and precesses involved in the identification of the four types of stimuli are similar or almost identical, supporting our hypothesis that the physiological representation of stimulus information of auditory duration is almost identical to that of visual stroke length. The second observation suggests that the category boundary for verbal stimuli is more stable than that for nonverbal stimuli. With respect to the third observation, since the exposure durations for presenting auditory and visual stimuli were not equal in the present experiment, the validity of the finding needs to be checked in a later study under the same experimental condition.

Since σ_I's derived from the first and/or second experimental sessions showed a greater variability, as is shown in Fig. 4, the results of the last two or three experimental sessions were pooled together in order to determine individual values for μ_I, σ_I, and q_e.

Figure 5 shows four types of comparison for accuracy of identification. σ_I's for verbal stimuli are compared with those for nonverbal stimuli in (a) the auditory and (b) visual modalities, while σ_I's in the auditory modality are compared with those in the visual modality for (c) verbal and (d) nonverbal stimuli. The diagonal line in each graph indicates equal values of σ_I's represented on the ordinate and abscissa.

Figure 5-(a) compares the accuracy of identification for verbal stimuli in the auditory modality σ_{Iw} with that for nonverbal stimuli in the same modality σ_{It}. The majority of normals are distributed on the lower portion of the diagonal line, with practically no difference in performance between the young and aged normals either for σ_{Iw} or σ_{It}. In the aphasic group, on the other hand, there are a few patients who show a drastic increase of σ_{Iw}'s indicating the deterioration of performance on verbal stimuli, while the distribution of σ_{It}'s tends to overlap with that for the normals. This finding, however, does not agree with the results of our previous study [2]. In our earlier study aphasics' abilities to identify the duration of speech sounds and to discriminate the duration of nonspeech sounds were investigated with the results that perceptual abilities of most aphasic patients were inferior to those of normals both for speech and nonspeech sounds. Although more investigation is necessary to explain this discrepancy, a difference in the memory load required for discrimination and identification and/or a difference in the subjects of our two experiments are possible sources of the discrepancy.

Figure 5-(b) compares the accuracy of identification for verbal stimuli $\sigma_{I\ell}$ with that for nonverbal stimuli σ_{Ic} in the visual modality. It is clear from the figure that a difference in performance among the three groups is not found either for $\sigma_{I\ell}$ or σ_{Ic}, all groups showing a superior performance on the verbal task as compared to the nonverbal task.

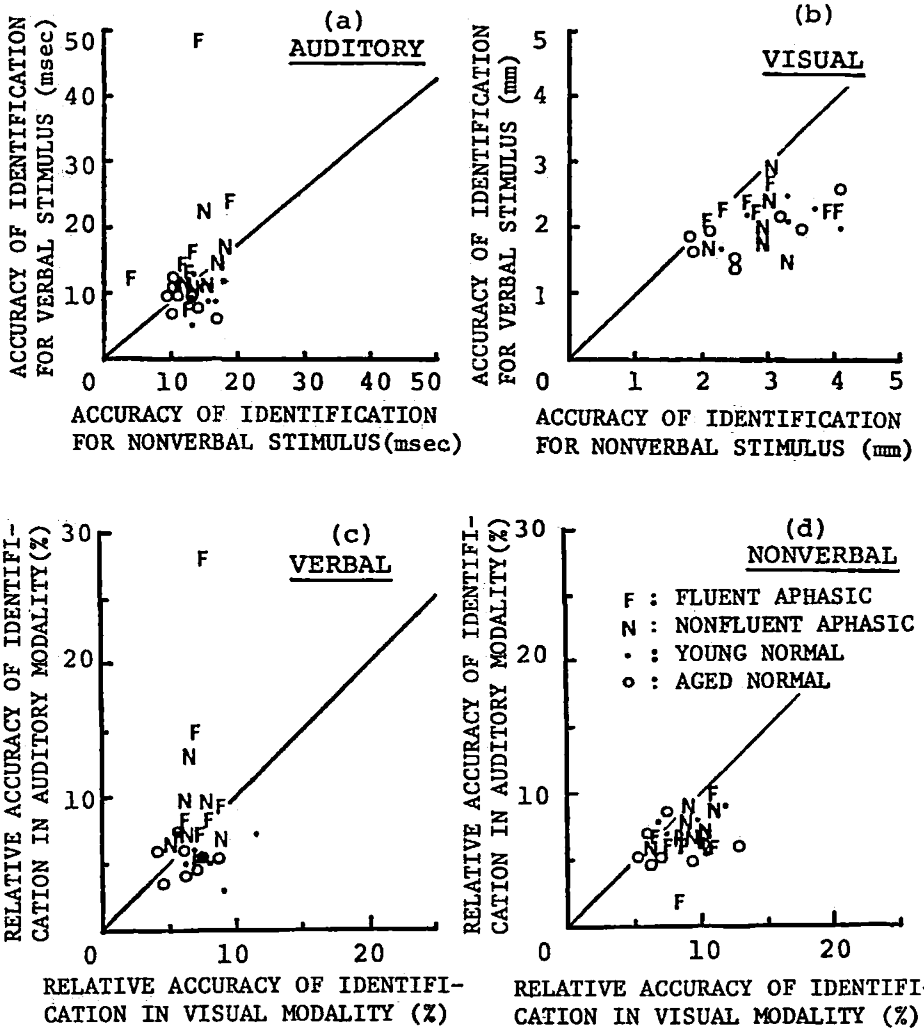

Fig. 5. Four types of comparison of the accuracy of identification σ_I. σ_I's for verbal stimuli are compared with those for nonverbal stimuli in (a) the auditory, and (b) visual modalities, while σ_I's in the auditory modality are compared with those in the visual modality for (c) verbal, and (d) nonverbal stimuli.

Further examination of Fig. 5 - (a) and (b) reveals no difference in performance in terms of two clinical types of aphasia, i.e., fluent and non-fluent aphasia. Since only two Wernicke's aphasics were included among the fluent aphasics, however, further investigation seems to be necessary regarding this point.

In Fig. 5 - (c) a comparison is made of the relative accuracy of identification for verbal stimuli between the auditory and visual modalities. In normals, accuracy of identification in the auditory modality is superior to that in visual modality. On the other hand, the majority of aphasic patients show a deterioration of performance in the auditory modality but not in the visual modality.

Fig. 5 - (d) shows a comparison of the relative accuracy for non-verbal stimuli presented in the auditory and visual modalities. Subjects of all groups show uniform identification abilities in the auditory modality, while they reveal considerable individual differences in the visual modality. In addition, performances in the visual modality tend to be poorer than those in the auditory modality in all groups.

Fig. 5 - (a) through (d) also indicate that the correlation between the two identification abilities shown in each of the four groups is rather weak, implying that the ratio of the two σ_I's represented on the ordinate and abscissa tends to vary from subject to subject, although the ratio for a given subject is almost constant as shown in Fig. 4.

Fig. 6 gives scattergrams of q_e's in the auditory and visual modalities. Though we considered q_e as the mean rate of error in the response

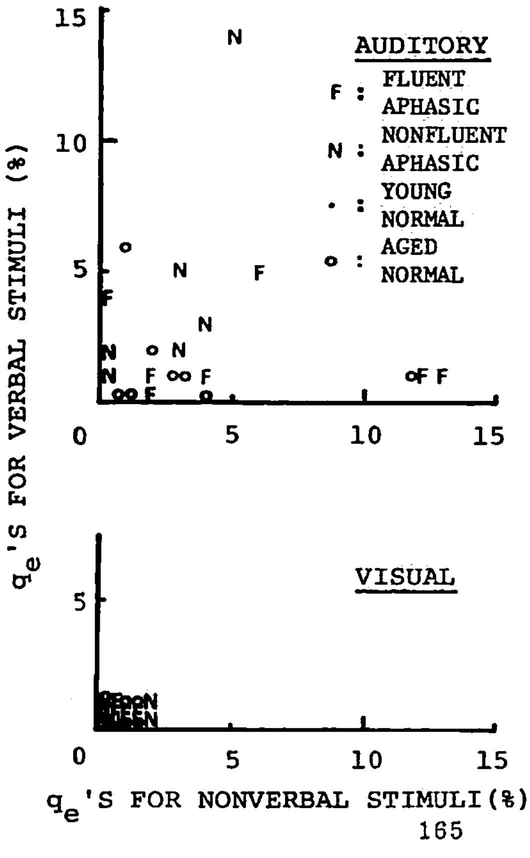

Fig. 6. Scattergrams for q_e's in the auditory and visual modalities.

process generated by a disturbance which is independent of stimulus value or stimulus modality, it appears that there is another type of disturbance which is independent of the stimulus value but modality-specific in the sense that it is caused by an inability to attend to stimuli in a specific modality. In this case, q_e may be considered as the probability of occurrence of response error due to the existence of unattended stimuli.

Further inspection of Fig. 6 reveals that the q_e's for aged normals are approximately zero in the visual modality, but not zero for some of them in the auditory modality. It is not clear whether the larger q_e's in the auditory modality are due to the subjects' inability to attend to stimuli in the auditory modality, or to the fact that the range of stimulus values normalized by the minimum stimulus value in the auditory modality is narrower than that in the visual modality. There exists a general tendency that the narrower this range is, the larger the value of q_e becomes. The q_e's for the aphasic subjects, on the other hand, are also approximately zero in the visual modality, implying that the response process which follows the identification process is intact. However, their q_e's in the auditory modality are often larger than those for the aged normals. This implies an impaired attention mechanism in the auditory modality.

SUMMARY

To investigate the underlying mechanisms of language comprehension difficulties in aphasic patients, identification tests of auditory duration and visual stroke length for verbal and nonverbal stimuli were administered to a group of aphasic subjects and groups of young and aged normals. The results obtained can be summarized as follows: 1) In young normals day to day changes in the accuracy of identification for the four test stimuli were almost parallel, indicating that the mechanisms involved in the identification of the four types of stimuli are similar or almost identical. 2) The aphasics showed an impaired performance only for verbal stimuli in the auditory modality. 3) An analysis of the probability for errors in the response process indicated that the aphasics as a group may have an impaired attention mechanism in the auditory modality, but an intact response process.

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