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IDENTIFICATION OF SPEECH, KANA AND KANJI, AND THE SPAN OF SHORT-TERM MEMORY FOR AUDITORILY AND VISUALLY PRESENTED STIMULI IN APHASIC PATIENTS

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1. Introduction

Although both the production and comprehension of language are essentially sequential processes, linguistic information can be given either sequentially or simultaneously depending on the nature of the medium, i.e., speech versus writing. Speech, for instance, is presented as a sequence of acoustic events, while the letters of a written word are presented simultaneously. The difference between the presentation modes of speech and writing may cause a difference in their perception modes. Whereas speech is always perceived sequentially as a series of phones, the letters constituting a word may be perceived either sequentially or simultaneously depending on the mode of presentation.

In the Japanese language there exist two orthographic systems known as kana and kanji. While kana characters are essentially phonograms representing syllables or morae, kanji characters are ideograms representing words. The majority of Japanese words, especially nouns, can be transcribed with one or more kanji characters, while any word can be transcribed with kana characters.

The existence of three different codes, i.e., speech, kana and kanji, with distinct characteristics presents unique problems in the information processing of Japanese aphasic patients. Sasanuma and Fujimura (1971), for instance, investigated the ability of aphasic patients to identify tachistoscopically presented kana and kanji words, and found that aphasic patients in Group III of Schuell's classification (roughly comparable to patients with a severe impairment of Broca's type) revealed selectively impaired performances in kana word identification. Based on this finding they proposed the hypothesis that the identification of kana words requires the mediation of a "phonological processor" and concluded that such Group III patients have a selective impairment of such a processor.

Although Sasanuma and Fujimura's study showed an important aspect of the defective information processing of aphasic patients, we still need a more systematic investigation with rigorous control of experimental variables across different codes. As a first attempt in this direction, we studied, in Experiment I in this paper, the ability of Japanese aphasic patients to identify speech, kana and kanji. Special care was taken to control such variables as the similarity of the stimuli, the number of morae or characters in the stimuli and the temporal duration of stimuli.

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Identification of speech, kana and kanji words may be affected by the capacities of auditory and visual channels, as well as by the modes of stimulus presentation, i.e., sequential vs. simultaneous. These two factors can be evaluated in terms of the short-term memory (STM) span for auditorily and visually presented materials.

Investigations focused upon the retention span of aphasic patients both for auditory and visual materials are rather scarce. Such studies are summarized in Table 1. Luria, Sokolov and Klimkowski (1967), for example, found a reduced retention span for auditory materials, but a normal retention span for (sequential) visual materials. Similar results were obtained by Warrington and her associates (1969, 1971), Albert (1972), and Saffran and Marin (1975). In contrast, Tzortzis and Albert (1974), and Kim (1976) showed that aphasic patients have a reduced retention span for both auditory and (sequential) visual materials in comparison with normal controls, though retention performance on the auditory materials was better than that on the visual materials. Heilman, Scholes and Watson (1976), on the other hand, did not find such a difference between auditory and visual materials. The inconsistency of these results may be due in part to methodological differences.

In Experiment II of the present study we investigated characteristics of the retention span of both aphasic patients and normal subjects for computer-generated stimuli in auditory presentation as well as in simultaneous visual and sequential visual presentations.

2. Experiment I

2.1 Method

Subjects

The subjects were 17 aphasic patients and 10 aged normals. The aphasic group consisted of 10 patients with Broca's aphasia (mild to severe in degree of impairment) and seven with Wernicke's aphasia (moderate to severe in degree of impairment). They had normal hearing and (corrected) visual acuities, as well as normal visual fields. Their ages ranged from 20 to 73 years old for the Broca's patients, and from 47 to 74 years old for the Wernicke's patients. The aged normal group consisted of 10 volunteers with normal hearing and (corrected) visual acuities from local senior-citizen's groups. Their ages ranged from 62 to 72 years old, and none of them had a history of brain damage.

Stimuli

The auditory and visual stimuli are listed in Table 2. The auditory stimuli consisted of minimal pairs of meaningful one- or two-mora words uttered by one of the authors who speaks Tokyo dialect. For the preparation of the stimuli, these words were read into a computer through an A/D converter with a sampling rate of 12 kHz and an accuracy of 12 bits, and were read out in a randomized order through a D/A converter. The stimuli were recorded on an audio-tape for use in off-line experiments.

Table 1 *Summary of investigations of retention spans for auditory and visual materials (continued on the next page).*

INVESTIGATORS	SUBJECTS	MODALITY	STIMULUS	MODE OF STIMULUS PRESENTATION	RATE	RESPONSE MODE	RESULTS
Luria, Sokolov Klimkowski (1967)	acoustic-mnestic X 2	auditory	2-5 {phonemes words digits tones	sequential (oral)	?	recall (oral) and recognition (pointing ?)	Selective impairment of retention ability for auditory material.
		visual	2-5 {figures phonemes words digits	sequential (pointing ?)			
Warrington and Shallice (1969)	conduction X 1 (normal ?)	auditory	1-4 {digits letters words	sequential (oral)	1 s.	recall (oral)	Same as the above.
		visual	1-4 {digits letters	sequential (card & t-scope)			
Warrington, Logue and Pratt (1971)	conduction X 3 (normal ?)	auditory	1-4 {digits letters words	sequential	1 s.	recall (oral)	Same as the above.
		visual	1-4 {digits letters	sequential			
Albert (1972)	LBD[1] (aphasia X29 nonaphasia X14) RBD[2] X 32 control X 30	auditory	2- object names	sequential (tape recorder)	?	recognition (pointing)	Span length for auditory material: control > RBD ≈ LBD (nonaphasia) > LBD (aphasia). No significant difference for visual material.
		visual	2- objects	sequential (pointing)			

Results which were not concerned with the short-term memory retention span were excluded from this table.
1 LBD: left brain-damaged patient.
2 RBD: right brain-damaged patient.

Table 1 *Summary of investigations of retention spans for auditory and visual materials (continued from the previous page).*

INVESTIGATORS	SUBJECTS	MODALITY	STIMULI	MODE OF STIMULUS PRESENTATION	RATE	RESPONSE MODE	RESULTS
Tzortzis and Albert (1974)	conduction X 3 Broca X 1 Wernicke X 1 normal X 3	auditory	1-4 {digits, letters, words	sequential (oral)	1 s.	recall (oral) and recognition (pointing)	Impaired memory for sequence, independent of modality, response mode and type of stimuli (for patients with conduction aphasia).
			meaningful sounds	sequential (tape recorder)	6 s.		
		visual	1-4 {digits, letters, designs	sequential (t-scope)	1 s.		
Saffran and Marin (1975)	conduction X 1	auditory	4-6 digits 1-4 {letters, words, syllables	sequential(oral)	1 s.	recall (oral) and recognition (pointing)	No recency effect for auditorily presented digits. Recency effect for visually presented digits. Span length ?
		visual	8 digits	sequential (memory drum)			
Heilman, Scholes and Watson (1976)	conduction X 7 Broca X 7	auditory	1- digits	sequential(oral)	1 s.	recall (oral) & recognition (pointing)	No significant difference between groups, modalities or response modes.
		visual	1- digits	sequential(card)			
Kim (1976)	LBD[1] (expressive aphasia) X 20 RBD[2] X 20 normal X 20	auditory	2-8 {digits, words, forms	sequential(oral)	1 s. 2 s. 3 s.	recognition (pointing)	Span length: normal > RBD > LBD, auditory material > visual material, and digits > words > forms.
		visual	2-8 {digits, words, forms	sequential(card)	1 s. 2 s. 3 s.		

Results which were not concerned with the short-term memory retention span were excluded from this table.
1 LBD: left brain-damaged patient.
2 RBD: right brain-damaged patient.

Table 2 *Speech, kana and kanji stimuli used in identification experiments (Experiment I).*

stimulus	one-mora (character) words		two-mora (character) words	
speech	i / u	stomach/cormorant	iʃi / uʃi	stone/cattle
	me / ne	eye/root	mori / nori	wood/seaweed
	ka / ga	mosquito/moth	tani / dani	valley/tick
	ta / ka	rice field/mosquito	baʃa / daʃa	coach/batter
kana	け / は	hair/leaf	あし / めし	leg/boiled rice
	ね / わ	root/eye	うき / つき	float/moon
	は / ほ	leaf/ear of rice	はし / ほし	bridge/star
	ね / め	root/eye	きじ / さじ	cloth/spoon
kanji	月 / 目	moon/eye	上流 / 下流	upper / down-stream / stream
	木 / 本	tree/book	天井 / 天丼	ceiling/Japanese food
	島 / 鳥	island/bird	王子 / 玉子	prince/egg
	針 / 釘	needle/nail	天人 / 夫人	celestial/wife

The visual stimuli consisted of meaningful words transcribed with one or two kana and one or two kanji characters. Each of the kana (or kanji) words was paired with one of the other kana (or kanji) words so that the paired words might be discriminated by only a few geometric cues. The stimuli generated by the computer were presented on a CRT-display for a duration of 280 msec (for one character words) or 400 msec (for two character words), each corresponding to the mean duration of one- or two-mora words, respectively, in the auditory modality. These stimuli were then recorded on a video-tape for off-line experiments. Subjects sat at a distance of 50 to 70 cm away from monitor TV, on which each character was displayed within a 4 x 4 cm square and arranged horizontally in the case of the two-character words.

Procedure

Each subject had a few practice sessions preceding the test. The subjects were instructed to identify a test word presented on a monitor TV by pointing to one of a pair of pictures placed in front of them. A response interval of 4 sec was adopted, but this was prolonged when the subject required a longer response time. Each word of the speech, kana and kanji stimuli was presented five times, and the percentage of correct responses to all trials was computed for each subject. Instances of "no response" were excluded from the analysis.

2.2 Results and discussion

The performance of each subject for the speech, kana and kanji identification task is illustrated in Fig. 1. In the speech identification task, two pairs of words including [m] or [n], i.e., [me/ne] and [mori/nori], were excluded from the analysis because the normal subjects also confused these words frequently.

As shown in Fig. 1 (a), the aphasic patients exhibited a wide variety of identification abilities for both speech and kana, while the majority of the aged normals

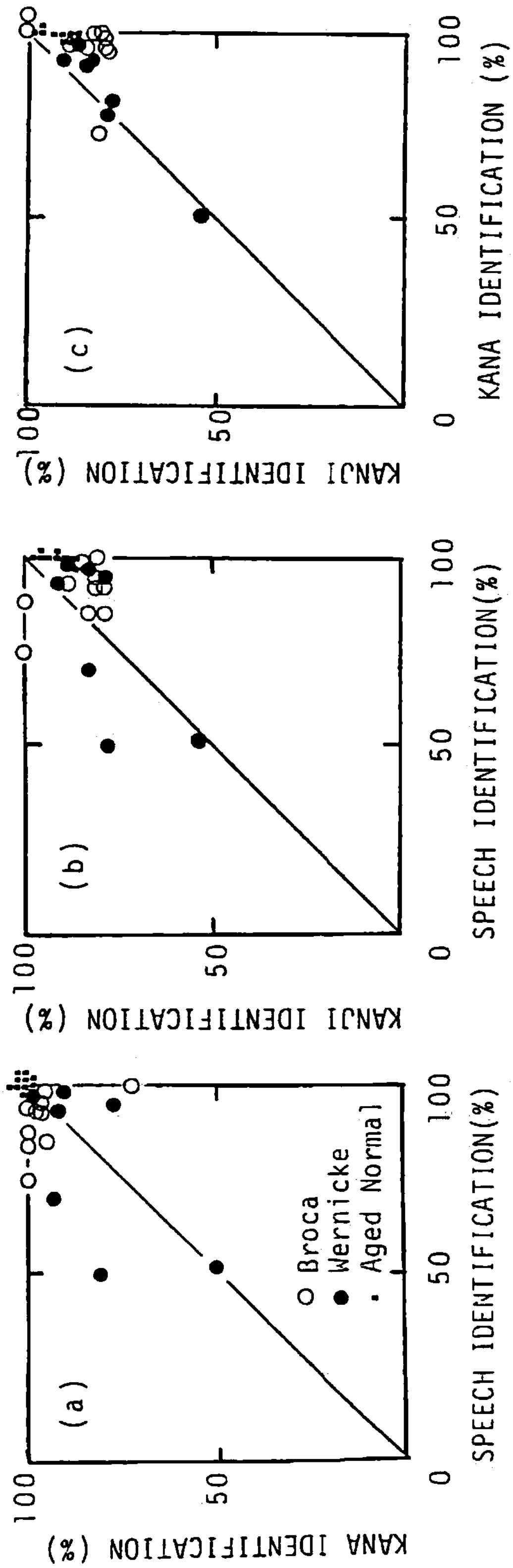


Fig. 1 *Performance on the speech-, kana- and kanji-word identification tests.*

identified both speech and kana perfectly. Apparently, speech was more difficult for most aphasic patients as compared to kana. In addition, it is evident that the patients with Wernicke's aphasia performed the kana identification task more poorly than those with Broca's aphasia.

The results of the speech identification task are compared with those for the kanji identification task in Fig. 1 (b). None of the aged normals could achieve a perfect score on the kanji task, but their performance level as a group was superior to that of the aphasic patients. It is of interest, moreover, to note that the majority of the aphasic patients could identify kanji words to some extent even though their ability to perceive speech was severely impaired.

In Fig. 1 (c), the scores on the kana tasks are plotted against those on the kanji tasks. The figure clearly indicates that it was not kanji but kana that the majority of the aphasic patients (including the Broca's patients) could identify more easily. This result disagrees with that reported by Sasanuma and Fujimura (1971), in which the selective impairment of kana word identification was found in patients of Group III of Schuell's classification. This discrepancy may be due to the following methodological differences: (1) In the present study, pairs of characters with similar geometric patterns were used as stimuli, while Sasanuma and Fujimura (1971) used characters for which the graphic forms were clearly different from each other. (2) Each of the kana and kanji words contained one or two characters in our study, while Sasanuma and Fujimura (1971) employed two-character words for kanji and three- to four-character words for kana. (3) Our patients with Broca's aphasia were not identical with Sasanuma and Fujimura's Group III patients with respect to severity of aphasia. Experimental conditions (1) and (2) seem to be crucial for determining the superiority of performance in either kana or kanji identification.

3. Experiment II

3.1 Method

Subjects

Six Wernicke's aphasics, nine Broca's aphasics and 10 aged normals, all of whom participated in Experiment I, served as the subjects.

Stimuli

The stimuli used in Experiment II are summarized in Table 3. The auditory stimuli were 10 isolated digits and monosyllables uttered by the same speaker as in Experiment I. The visual stimuli consisted of 10 digits and 10 kana characters displayed on the monitor TV in a square 4 x 4 cm in size. Each of the kana characters had a phonological form identical to that of an auditorily presented monosyllable. The method utilized for the preparation of the test items was similar to that used in Experiment I.

Procedure

The two stimulus presentation modes are illustrated in Fig. 2. Figure 2 (a) represents the sequential mode of presentation, which was used for both auditory and

Table 3 *Auditory and visual stimuli used for measurement of retention span (Experiment II).*

modality	mode of stimulus presentation	digits	monosyllables or kana characters
auditory	sequential	0–9	ya, hi, to, ko, i te, ke, ta, me, ki
visual	sequential	0–9	や、ひ、と、こ、い て、け、た、め、き
	simultaneous	0–9	や、ひ、と、こ、い て、け、た、め、き

visual stimuli. In this mode a randomized sequence of two to five digits or monosyllables was presented every 0.5 sec so that one test item was presented for a duration of 1 to 2.5 sec. The simultaneous mode of presentation, which can be used only for visual stimuli, is shown in Fig. 2 (b). In this mode, two to five digits or kana characters were displayed simultaneously for a duration of 1 to 2.5 sec. Each test consisted of 20 such items, and the total number of digits, monosyllables and kana characters were balanced over the entire test. The test items were presented

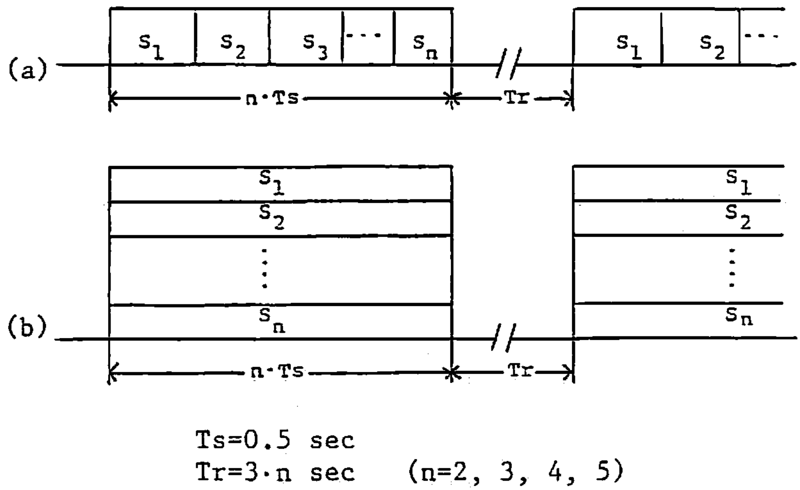


Fig. 2 *(a) sequential and (b) simultaneous modes of stimulus presentation.*

with a loudspeaker for the auditory stimuli or a monitor TV for the visual stimuli. The length of the sequences of digits, monosyllables and kana characters appropriate for each subject was determined during practice sessions. Subjects were asked to point to as many digits or kana characters printed on a card as they could retain, starting from the first member of the sequence in the sequential presentation, or from the leftmost symbol in the simultaneous presentation. The number of correctly recognized symbols from the beginning was defined as the short-term memory (STM) span.

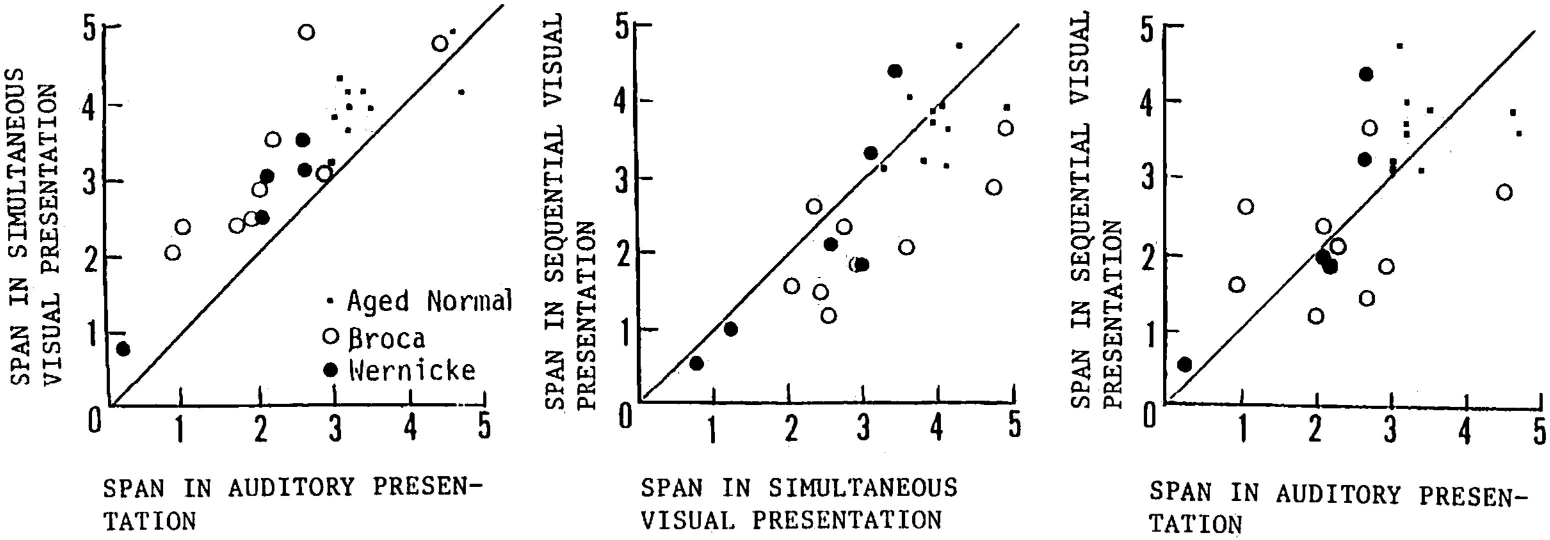
3.2 Results and discussion

The STM spans for the auditorily and visually presented digits are shown in Fig. 3. The mean retention span of the aged normals for digits was 3.46 digits in auditory presentation, 3.66 digits in sequential visual presentation and 3.97 digits in simultaneous visual presentation. According to Fujisaki, Mizuno and Tazaki (1973), who measured the STM span for digits using methods almost identical to those in the present study, the mean span of young normals was 4.9 digits in auditory presentation, 6.77 digits in sequential visual presentation and 8.15 digits in simultaneous visual presentation. Thus, the present results can be interpreted as indicating that the STM span declines with age.

The retention span of the aphasic patients, on the other hand, varied widely from patient to patient, indicating that an analysis of individual retention spans would be more adequate than the analysis of the mean span employed by Albert (1972), Kim (1976) and Heilman, Scholes and Watson (1976).

The majority of the aphasic patients revealed a reduced retention ability regardless of the modality and mode of stimulus presentation. The correlation coefficients for these retention spans were calculated for the aphasic patients. The highest correlation was obtained for the auditory vs. simultaneous visual presentations ($r = 0.82$). These results indicate that the majority of the aphasic patients have an impairment in the modality- and mode-independent mechanisms for retaining auditory and visual information, viz. an impairment in STM.

However, the correlation was lower for STM span with a sequential visual presentation, i.e. $r = 0.75$ when the test items were presented in the same modality (sequential visual vs. simultaneous visual), and $r = 0.5$ when in different modalities (auditory vs. sequential visual). For the majority of the aged normals the span for digits was found to be greatest in the simultaneous visual presentation and smallest in the auditory presentation, indicating the advantage of the visual over the auditory channel, as well as of the simultaneous over the sequential mode of presentation as pointed out by Fujisaki, Mizuno and Tazaki (1973). This was the case for only half of our aphasic patients. For the remaining half the span was smallest in sequential visual presentation. These results suggest that these patients may have an impairment in sequential visual information processing superimposed on the impairment in STM. A similar phenomenon was observed by Swisher and Hirsh (1972) who examined the ability of normals and brain-damaged subjects (including aphasic patients) to discriminate the order of yellow and blue lights separated by various intervals. They found that aphasic patients had a deficient sequencing ability when two lights appeared at the same place, but had an ability comparable to that of



(a) auditory vs. simultaneous visual

(b) simultaneous visual vs. sequential visual

(c) auditory vs. sequential visual

Fig. 3 *Spans of short-term memory for auditorily and visually presented digits.*

control subjects when two lights appeared in different places.

The majority of the aphasic patients also had an impairment in the retention of auditorily presented monosyllables and visually presented kana characters.

Figure 4 illustrates the STM retention span for auditorily presented digits and monosyllables. The majority of the aphasic patients were able to retain number of monosyllables comparable to that for digits, and the correlation between these materials was significantly high (r = 0.88). These results indicate that information is retained in terms of chunks as pointed out by Miller (1956). Similar results were obtained for the retention of the visually presented digits and kana characters.

In the light of the major finding in the present study that the majority of our aphasic patients have a modality- and mode-independent impairment of the retention span, the results listed in Table 1 indicating a selective impairment in the auditory retention ability of aphasic patients should be reassessed. Warrington and Shallice (1969), for instance, examined the retention span of one patient (K.F.) with conduction aphasia to investigate the underlying mechanisms of his repetition difficulty. Figure 5 illustrates K.F.'s retention span for auditorily and visually presented digits and letters. The ordinate represents the number of correctly reproduced strings and the abscissa the number of digits or letters presented. Based on this result, Warrington and Shallice (1969) concluded that K.F. had a selectively impaired retention span for auditorily presented materials, which might account for his inability to repeat verbal materials (see also Shallice and Warrington (1970)). However, the difference between the auditory and the visual retention spans for digits (or letters) can be estimated as one digit (or one letter) approximately, because the two curves are almost identical if the curve for the auditory retention span

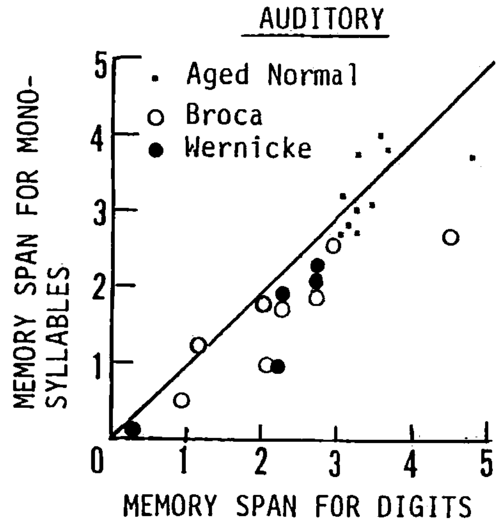


Fig. 4 *Memory spans for auditorily presented digits and monosyllables.*

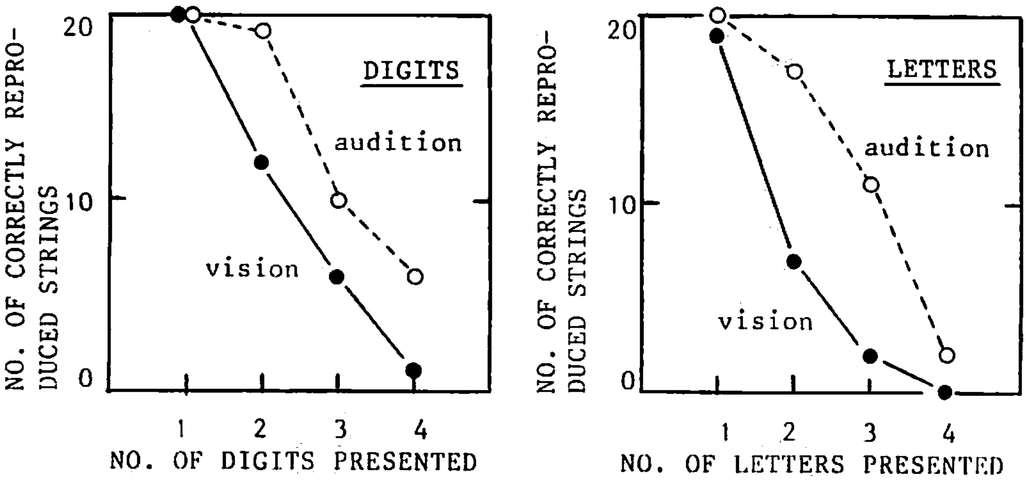


Fig. 5 *Examples of results of the retention span of a patient with conduction aphasia for auditorily and visually presented digits and letters (plotted after data by Warrington and Shallice (1969)).*

is moved rightward by one unit. Such superiority for the (sequential) visual retention span was common in our normal subjects, though the rate of stimulus presentation was not the same. Although Luria, Sokolov and Klimkowski (1967), and Saffran and Marin (1975) have also found a selective impairment in auditory retention span, normal data are lacking in their investigations. Albert (1972) examined the retention ability of both normal and aphasic subjects for auditorily presented object names and visually presented objects, but he did not report their performance on a visual task.

Tzortzis and Albert (1974), on the other hand, found a modality-independent impairment of memory for sequence in three patients with conduction aphasia, but the impairment was quite mild in one Wernicke's and one Broca's aphasics. They "tentatively" concluded that the underlying disorder of the repetition defect in conduction aphasia is an impaired memory for sequence. However, our results clearly reveal that the majority of Wernicke's and Broca's aphasics also have a poor performance in this area and that they exhibit a wide variety in retention performance.

The lack of an advantage for sequential visual over auditory information processing observed in the present study is in accord with the results of Heilman, Scholes and Watson (1976), but is different from those of Kim (1976) who reported an advantage for auditory information processing for both normals and aphasic patients. This difference may be due to difference in the methods used, specifically to the rate of stimulus presentation, i.e., 0.5 sec/digit in the present study vs. 1 sec/digit in the study by Kim (1976). Further study is needed to determine the influence of the stimulus presentation rate on retention span.

4. Summary and conclusions

Two experiments were administered to patients with Wernicke's and Broca's aphasia as well as aged normal subjects. In the first experiment, the identification ability of each subject for speech, kana and kanji stimuli was examined to investigate the underlying mechanisms of the comprehension disorders of aphasic patients. The majority of the aphasic patients exhibited the most impaired performance in kanji identification, whereas exhibiting the least impaired performance in kana identification. These results disagreed with those reported by Sasanuma and Fujimura (1971). The possible sources of the disagreement between the two studies were discussed.

In the second experiment, the ability of aphasic patients to retain auditorily presented digits and monosyllables, as well as visually presented digits and kana characters, was examined to assess the effect of the following two factors which might affect the identification performance: (1) the information processing capacity of auditory and visual channels; and (2) the mode of stimulus presentation (simultaneous or sequential). The results showed a wide variety in the retention abilities of the aphasic patients. The majority of the aphasic patients exhibited a retention disturbance irrespective of modality, mode of stimulus presentation and type of stimulus. This result, together with a high correlation between the short-term memory (STM) span for auditory and simultaneous visual presentation, suggest that the majority of the aphasic patients had an impairment in the modality- and mode-independent mechanisms for retaining auditory and visual information, viz. an impairment in STM. A further correlational analysis, and the fact that the STM span of half of the aphasic patients was smallest in the sequential visual presentation, indicated that these patients had an impairment in sequential visual information processing superimposed on the impairment in STM. These results were compared with those reported by other investigators, specifically Warrington and Shallice (1969), who claimed a selective impairment in auditory retention span in conduction aphasia.

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