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SPAN OF SHORT-TERM MEMORY FOR AUDITORILY AND VISUALLY PRESENTED WORD SEQUENCES

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1. Introduction

Both reception and production of language require the short-term retention of information at various linguistic levels, due to the sequential nature of linguistic information processing. Many investigators have explored the short-term memory for linguistic information, some of whom have proposed models of the short-term memory (henceforth STM). For example, an initial STM model suggests that the memory system consists of two precategorical sensory registers (echoic and iconic memories), and two categorical memory components, i.e., STM and the long-term memory (henceforth LTM). According to this model, auditorily presented information is maintained in the echoic memory in a raw, sensory or precategorical form. The auditory information is, then, categorized into a series of phonemes, which are held in STM for a brief time (approximately a half minute). The information in STM rapidly fades away if rehearsal of items is not performed. The longer the information is held in STM, the more effectively the stimulus information is stored in LTM.

Visually presented information, on the other hand, is hypothesized to persist in the iconic memory for a few hundred msec. The stimulus information is then transformed into a phoneme sequence to be maintained in STM. Part of this information is transferred to LTM in the same manner as auditory material. While STM was assumed to be a temporary storehouse which retained a fixed number of phonemically coded items (7±2 digits, letters, words or proverbs), LTM was assumed to be a permanent storehouse retaining a vast amount of semantic information (Miller, 1956, Conrad, 1964, and Waugh and Norman, 1965).

The results of many experiments conducted in recent years do not support the above model, however. Baddeley et al. (1975), for instance, showed that "memory span for unrelated words is not constant, but varies with the length of the words to be recalled," and that the memory span for long words falls below five "chunks" which is the lowest limit of "the magical number" (Miller, 1956). Furthermore, Posner et al. (1969) provided evidence for the existence of visual codes in STM, while Shulman (1972) provided evidence for the presence of semantic codes in STM.

In addition, two types of rehearsals were identified. One is called maintenance rehearsal in which the phonemic codes in STM are renewed repeatedly to maintain the stimulus information. The other is the elaborated rehearsal which transforms several

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phonemically coded items into a single or a few semantic components. Moreover, maintenance rehearsal does not seem to enhance transfer of information to LTM (Craik and Watkins, 1973).

Based on this evidence, the early view of human memory appears to require major modification. Loftus and Loftus (1976) proposed a model in which STM retains the addresses of items existing in LTM instead of their phonemic codes. Shiffrin and Schneider (1977) suggested that STM is an activated subset of LTM. Craik and Lockhart (1972), on the other hand, advocated a levels-of-processing theory in which short- and long-term memories are seen not as two separate memory structures but as different levels of processing. They propose that the deeper the level at which the information is processed, the longer it is retained. Although these models provide an interesting framework concerning the concept of STM, the mechanisms for processing and memorizing linguistic information are not specified explicitly.

Baddeley et al. (1984), on the other hand, measured memory span using an articulatory suppression technique in which subjects were presented a list of words for later recall while they were counting the numbers one to eight repeatedly. Their major findings were that under the articulatory suppression, both the similarity effect (memory span decreases when the stimulus words are phonetically similar to each other) and the word length effect disappeared for the visual materials, but remained for the auditory materials. Based on these results, they proposed a working memory system involving STM and the articulatory loop. The working memory assumes that phonemic codes for visual (graphemic) materials to be stored in STM must be produced by the articulatory loop whereas those for auditory materials are transferred directly to STM without such mediation of the articulatory loop. Because of the direct accessibility of auditory materials to STM, the similarity effect and the word length effect remain, regardless of whether the articulatory loop is utilized to generate phonemes of the numbers. In the visual modality, however, the articulatory loop is occupied producing numbers, so phonemic codes of to-be-remembered words can not be generated. Although the working memory hypothesis could make processing and storage of information at the phonemic level considerably explicit, little was described regarding these processes at other levels of information such as graphemic and semantic codes.

Therefore, in Experiment 1 of the present study we first investigated the levels of processing where information in the auditory and visual modalities merges, and second we showed how information at each processing level, i.e., phonemic, graphemic (or visual), semantic or other level, is related to information at other levels.

2. Experiment 1

2.1. Method

2.1.1. Subjects

The subjects were eight students of a nursing school with normal hearing and visual acuity.

2.1.2. Materials

As shown in Table 1, seven categories of stimulus words, i.e., digits, one-, two-, three- and five-mora existing words, three-mora nonexistent words (nonwords), and homophonic kanji characters (or homonyms), were used to evaluate the following variables which may affect memory span: (1) word length, or number of morae contained in the words, (2) stimulus modality, (3) word/nonword difference, or whether the word is an existing one, (4) presence/absence of a phonemic cue in kanji. Each word category included ten words, nonwords or digits. Whereas the existing words consisted of high frequency words, the homophonic kanji characters consisted of nonwords and less frequently used words.* The nonwords were derived from the existing three-mora words by interchanging the syllable order. Since each mora of the words used in the present experiment can be represented using one kana character, the one- to five-mora kana words were written with one to five kana characters, respectively. On the other hand, the one- to three-mora kanji words are represented with one kanji character but the five-mora kanji words are written with two kanji characters. All the stimulus words except those in the homophonic kanji category have different phonemic codes.

Table 1. Stimulus words used in Experiment 1.

		EXISTING WORDS					NONWORDS	
		1-MORA	2-MORA	3-MORA	5-MORA	DIGITS	3-MORA	HOMONYM
AUDITORY MATERIALS	SPEECH	ya,i, ,wa	yama, ,buta	sakana,	katagu-ruma,	zero, ,kyu:	kanasa,	
VISUAL MATERIALS	KANA	や,い, ····,わ	やま, ··,ぶた	さかな, ·····	かたぐるま,··	ぜろ, ··きゅう	かなさ, ,つじひ	
	KANJI	矢,胃, ···,輪	山,星, ···,豚	魚,机, ···,羊	肩車, ··,柏餅	0,1,2, ···,9		気,奇, ··· ,軌
	LINE DRAW-INGS							

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* Each kanji character possesses some meaning, but it does not always constitute a real, existing word, by itself.

The existing words were presented to the subjects auditorily (using speech) and visually (using kana, kanji and line drawings). The digits were presented auditorily, and visually using kana and Arabic numerals. The nonwords were presented using speech and kana.

In the preparation of the auditory stimuli, ten stimulus words in each word category were pronounced by a male speaker and read into a VAX-11/730 computer through an A/D converter with an accuracy of 12 bits and a sampling rate of 20 kHz. A randomized sequence of stimulus words followed by a 500 Hz pure tone signaling the beginning of the response (response marker) was then generated by the computer. Thirty such sequences were converted into analog signals through a D/A converter,. and presented to the subjects using a loudspeaker. The visual stimuli consisted of randomized sequences of the word list represented using computer-generated kana or kanji characters (displayed using a 48 X 48 dot matrix) and line drawings (112 X 112 dot matrix) followed by the response marker "?".

2.1.3. Procedures

The experimental set-up is illustrated in Fig. 1. The exposure duration of the visual materials was the same as the mean duration of the 10 auditorily presented words in the corresponding word category. The exposure duration is summarized in Table 2. Each item was presented at a constant rate of 1.0 sec/word.

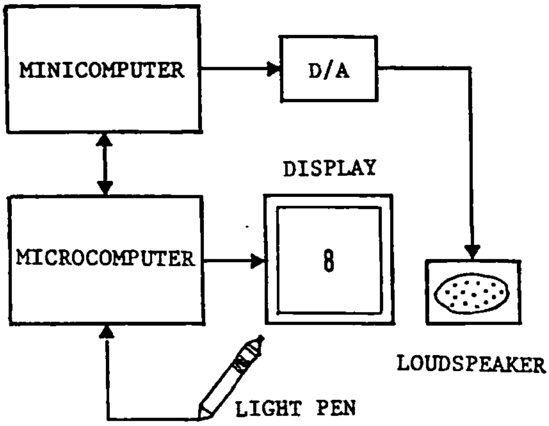

Fig. 1. Diagram for presenting a list of words represented with speech, kana, kanji and line drawings.

Characters and line drawings were displayed in a 2 X 2 cm or 4 X 4 cm square, respectively, on the CRT display placed at a distance of approximately 50 cm away from the subjects. Each character in the two- through five-mora kana word category and the five-mora kanji word category was simultaneously displayed in a vertical array.

Subjects sat in front of the loudspeaker or CRT display. Immediately after the stimulus presentation, ten line drawings in the same word category as the presented word list for the existing words (the Arabic numerals for digits and kana characters for the nonwords instead of the line drawings) were displayed simultaneously on the CRT screen of a PC-9801 microcomputer. The subjects were required to point, using a light pen, to as many line drawings (the Arabic numeral or kana characters) as they could remember, starting from the first member of the sequence. Vocalized rehearsal was prohibited. Since the number of items the subjects could retain at one time varied from trial to trial, the memory span was defined as the mean number of correctly reported items in 30 trials.

Table 2. Exposure durations of existing words and nonwords.

	EXISTING WORDS					NONWORDS	
	1-MORA	2-MORA	3-MORA	5-MORA	DIGITS	3-MORA	HOMONYM
DURATION	254	356	450	673	401	471	254

(UNIT: MSEC)

2.2. Results

In Fig. 2-(a) the mean memory spans for one- through five-mora existing words and digits in one subject are plotted against the number of morae (the mean number of morae for digits is 1.8). The results from the other subjects were essentially similar. The word length effect occurred irrespective of the stimulus modality, i.e., memory span reduces with an increase in the word length. However, the memory span for long words does not approach zero but two or three words. It can be also seen from the figure that visual materials tend to be retained better than auditory materials regardless of word length or the word/nonword difference (the modality effect).

The memory span for the one-mora (existing) kanji word with a different phonemic code is compared with that for the homophonic kanji on the left in Fig. 2-(b). The former is clearly larger than the latter, but the span for homophonic kanji is not zero.

The difference between the memory spans for the three-mora existing words and nonwords is shown on the right in Fig. 2-(b). The memory span for the existing words is slightly greater than that for the nonwords (word/nonword difference).

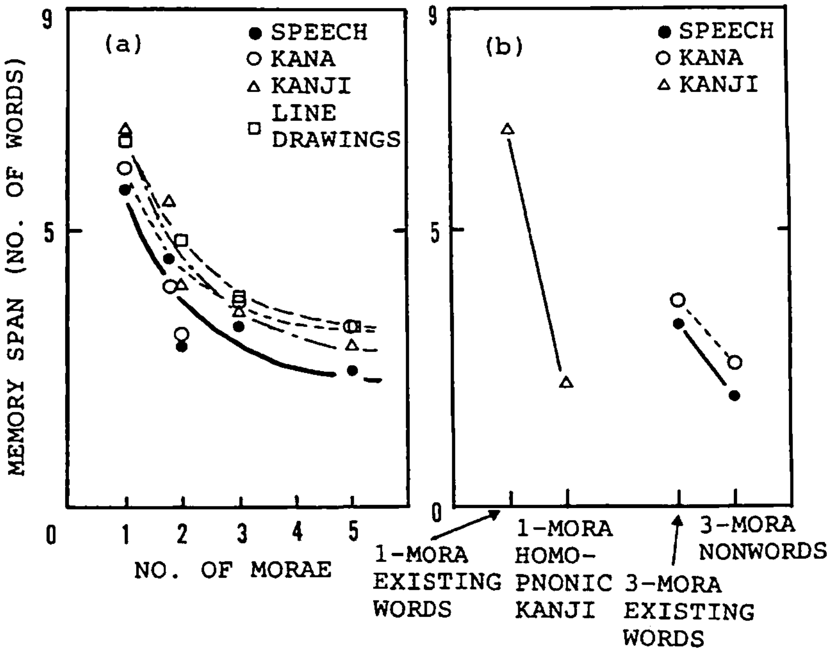

Fig. 2. An example of results of memory spans for existing words and nonwords.

2.3. Discussion

The fact that the word length effect was observed not only for auditorily presented words but also for visually presented kana, kanji and line drawings indicates that the incoming information is primarily retained in the form of phonemic codes as suggested by Conrad (1964) and Baddeley et al. (1975). However, the finding that short-term retention was possible even for homophonic kanji characters implicates the existence of a storehouse for graphemic information also, although of limited capacity. The advantage of visual over auditory presentation, i.e., the modality effect, suggests that graphemic memory plays a supplementary role even in ordinary memory span tasks. Similarly, the longer memory span for existing words, or the word/nonword difference, appears to indicate that there are memories storing information specific to existing words (lexical information) and that information in these memories also assists retention of the word sequence (Tatsumi et al., 1982 and Tatsumi et al., 1983).

These considerations led us to hypothesize the STM model shown in Fig. 3. The model consists of two sensory registers that hold precategorical information, and six STMs that hold categorical information such as phonemic, graphemic, pictorial and lexical information.

This model requires the following assumptions: (1) Lexical information is utilized to retain existing words, (2) In ordinary memory span tasks the stimulus information is retained primarily in phonemic memory by phonemic codes, and (3) While phonemic codes of auditory materials can be transferred directly into the phonemic memory, those of visual materials need to be generated by the speech production mechanism from graphemic information, graphemic word shape or meaning.

Speech information is first analyzed auditorily and stored in the echoic memory in precategorical form. Then the information in the echoic memory is categorized into a series of phonemes to be held in phonemic memory by referring to LTM (phoneme identification). Based on the phoneme sequence, identification of lexical items (decision of which lexical item the phoneme sequence corresponds to) is carried out by consulting the lexicon in LTM. We regard this process as the identification of phonological word shape, since a word, or a lexical item, is identified in terms of its phonological configuration, i.e., phoneme sequence together with suprasegmental features. The meaning of the lexical item, held in semantic memory,* can be retrieved by looking it up in the lexicon. The lexicon is a dictionary existing in the subjects' LTM which specifies the phonological and graphemic word shapes, meaning, and syntactic properties of each lexical item.

In the memory span task, where retention of the unrelated words is required, the stimulus information is stored primarily in the phonemic memory. The information can stay there while (maintenance) rehearsal continues. Otherwise, it decays during an interval of approximately 30 sec. The rehearsal process can be seen as an alternate process, in which the speech reception mechanism, shown at the top of Fig. 3, identifies the phonological word shapes from the phoneme sequence in the phonemic memory and the speech production mechanism, shown in the middle of Fig. 3, generates the phoneme sequence from these phonological word shapes.

On the other hand, visual materials are first analyzed visually and stored in the iconic memory in a precategorical, raw form. Subsequently, the information is categorized into graphemes to be maintained in the graphemic memory. When subjects are given those kana words that are usually written with kanji, such as those used in the present experiment, the speech production mechanism generates phoneme sequences of the kana words by referring to LTM after identifying graphemes. The speech reception mechanism, then, accepts the phoneme sequences, and identifies their phonological word shapes together with meanings in the same way it identifies the auditory materials. In contrast, when these words are presented using kanji, the

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* The term "semantic memory" seems to be confusing because Tulving (1972) also utilized the same term to refer to a different concept. In the present paper, however, we shall use the term to indicate the semantic STM, whereas the semantic memory of Tulving represents the semantic LTM.

phoneme sequence can not be generated directly from the grapheme. Instead, the graphemic word shape is extracted from the graphemes by consulting the lexicon. The retrieval of the phonological word shape and meaning from the lexicon follows. The speech production mechanism generates the phonemes from its phonological word shape.

Although the process generating a phoneme sequence of line drawings is similar to that of kanji words, the reception mechanism is quite different. Instead of character identification, pictorial features are identified, and converted into semantic information. The phoneme sequence is generated from this semantic information via the phonological word shape.

Based on this model, the data from Experiment 1 can be explained as follows:

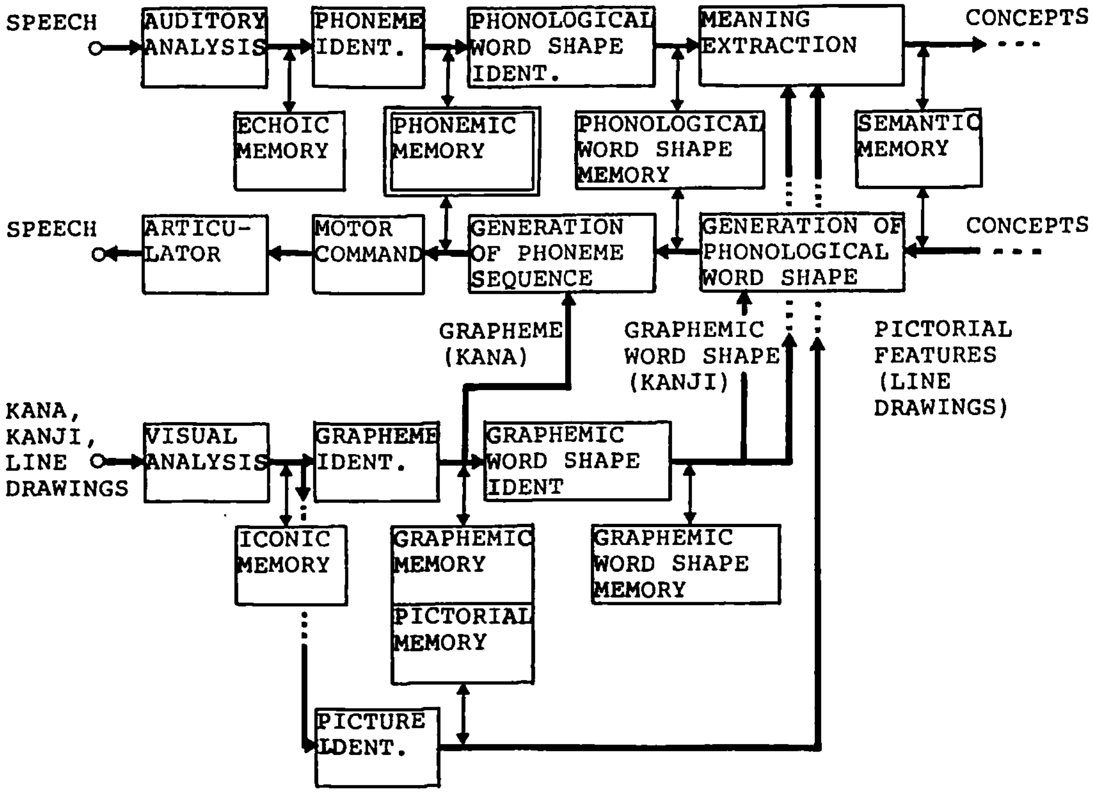

Fig. 3. A functional model of word information processing and short-term memory (IDENT.: identification).

(1) Word length effect: In the memory span task the incoming information is primarily retained in the phonemic memory, irrespective of the modality. The number of words maintained in the phonemic memory at one time is restricted. Since long words occupy much space in the phonemic memory, the memory span for these words decreases. Therefore, the word length effect appears. But the memory span curve does not approach zero, because information in memories for phonological word shape and meaning (for existing words) can be utilized to retain word sequence.

(2) Modality effect: The homophonic kanji characters (with no phonemic and only minimal semantic cues) can be retained, since information in graphemic memory (and that in graphemic word shape memory for existing words) is available. In the auditory modality successively incoming phonemic codes of a word list are directly transferred to the phonemic memory without the mediation of the speech production mechanism. Such a direct access mode to the phonemic memory may cause an interruption between phonemic codes of incoming auditory materials and those already stored in the phonemic memory. In the visual modality, on the other hand, successively incoming information may be temporarily stored in graphemic memory (and graphemic word shape memory for existing words). This indirect access mode to phonemic memory may help to avoid an interruption between phonemic codes of incoming words and those in phonemic memory. That is, the graphemic memory acts as a buffer memory for the phonemic memory. In addition, information in graphemic memory (and graphemic word shape memory) may be utilized for remembering the word list. Therefore, memory span in the visual modality is larger than that in the auditory modality.

(3) Word/nonword difference: The memory span for existing words is greater than that for nonwords, since information in phonological word shape memory and semantic memory is available for existing words whereas such information is not available for nonwords.

In the above model we hypothesized that while phoneme sequences of auditory materials can be sent directly to phonemic memory, visual materials require (conscious) generation of phonemic codes for short-term retention. This hypothesis was derived from the findings of Baddeley et al. that under the articulatory suppression condition the word length effect and the similarity effect disappeared for visual materials but remained for auditory materials. In Japanese there are two different orthographic systems, one of which is the phonogram (kana), and the other of which is the ideogram (kanji). While the experiment of Baddeley et al. was performed using English words, no research has been undertaken using kana and kanji words thus far. Therefore, in Experiment 2 of the present study the memory span for Japanese words presented auditorily, and presented visually with kana, kanji and line drawings was examined under the articulatory suppression condition.

3. Experiment 2

3.1. Method

3.1.1. Subjects

The subjects were one of the eight participants in Experiment 1, and one of the authors.

3.1.2. Materials

The materials were one- and three-mora existing words used in Experiment 1.

3.1.3. Procedures

The procedures were the same as those in Experiment 1, except that the subjects were required to repeat one to eight subvocally while receiving the word list. To habituate the subjects to counting from one to eight repeatedly, they were asked to repeat the numbers aloud first. After this practice session they repeated the numbers subvocally to shut off an auditory feedback loop. Immediately after the presentation of a word list, they stopped counting and gave a response.

3.2. Results and Discussion

An example of the results is shown in Fig. 4. The straight lines indicate the memory span under the control condition where the subjects received the word lists without counting the numbers, and the dashed lines the memory span under the articulatory suppression condition. It can be seen from the figure that the word length effect and the modality effect are observed under the control condition. That is, the span declines with word length, and the span for visual materials is superior to that for auditory materials. However, both phenomena vanished under the articulatory suppression condition. The subvocal repetition of one through eight drastically impaired the performance for visual materials, although it did not seriously influence the performance on auditory materials. Accordingly, the word length effect for visual materials diminished, and a reversal of the modality effect, i.e., an advantage of memory span for auditory over visual materials, emerged. The other subject showed a tendency similar to this subject.

The above results support Baddeley et al.'s hypothesis that while the stimulus information is transferred directly to phonemic memory in the auditory modality, phonemic codes for visual materials must be generated by the speech production mechanism. In the memory span task the stimulus information is held primarily in the phonemic memory regardless of the stimulus modality. Based on the STM model shown in Fig. 3, the auditory materials are analyzed auditorily and converted into phonemic codes. Since the speech production mechanism does not play essentially any role in generating the phonemic codes of the auditory materials, the phonemic codes extracted are sent on directly to the phonemic memory. On the contrary, the short-term retention of visual materials requires the mediation of speech production mechanism. The grapheme reception mechanism, illustrated at the bottom of Fig. 3, perceives visual materials, and produces graphemes, graphemic word shape and meaning. Subsequently, the speech production mechanism generates phonemic codes to be stored in the phonemic memory, from the graphemes, graphemic word shape or meaning.

Under the articulatory suppression condition the speech production mechanism is utilized for the generation of an unrelated word sequence, the numbers one through eight. In the case of auditory materials, however, the word length effect remains, because of the direct accessibility to the phonemic

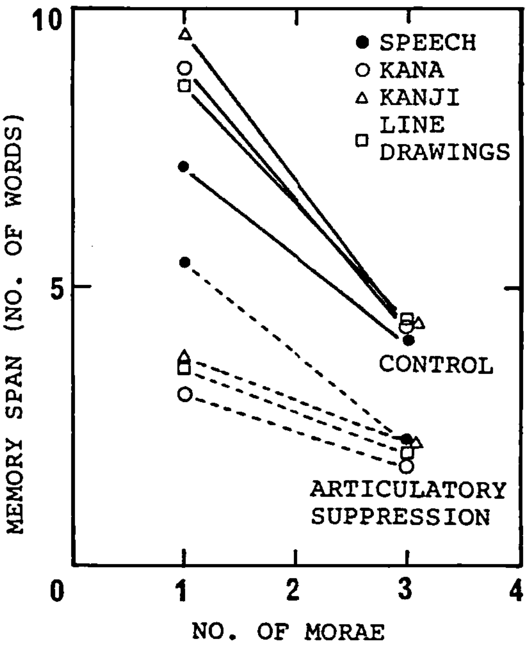

Fig. 4. Memory spans for speech, kana, kanji and line drawings under two conditions in which the subject received a word list mutely (control) and while counting numbers repeatedly (articulatory suppression).

memory of the auditory materials. Yet, since the phonemic codes of one through eight interfere with those of a to-be-remembered list in the phonemic memory, the performance is slightly impaired.

In the visual modality, on the other hand, the speech production mechanism is busy with the generation of phonemic codes of the numbers one to eight, so conversion of the word list into phonemic codes is suppressed. Consequently, the word length effect disappears.

Although the articulatory suppression technique revealed the difference in the information flow of the auditory and visual materials and the level where these two types of information merge, it could not reveal any differences in information flow between the three visual materials, i.e., kana, kanji and line drawings. According to the STM model in Fig. 3, the main difference among the processes of memorizing kana, kanji and line drawings is the number of intervening processes required to generate their phonemic codes. It seems likely, therefore, that the time required to generate phonemic codes may also vary with the type of the visual material. If that is the case, a faster presentation rate should create the systematic differences among memory spans for kana, kanji and line drawings. In the third experiment we examined the effect of the presentation rate upon memory span.

4. Experiment 3

4.1. Method

4.1.1. Subjects

Two students who participated in Experiment 1 served as subjects.

4.1.2. Materials

Materials were one- and three-mora existing words represented with kana, kanji and line drawings used in Experiment 1.

4.1.3. Procedures

Procedures were the same as those in Experiment 1 except that the list item was presented at rates of 0.2, 0.3, 0.4, 0.5 and 1.0 sec/item, and that the exposure duration of each item was 70 msec. To confirm that the subject could identify each of the successive list items at the fastest rate, an identification test was performed in which the subject was given a target word orally and asked to judge whether or not the target word was present in the subsequent five word list displayed at a rate of 0.2 sec/word.

4.2. Results

While one subject missed one target word (in 30 trials) in each of one-mora kana, three-mora kanji and three-mora line drawing identification tests, the other subject identified kana, kanji and line drawings perfectly. This result indicates that each list item can be almost perfectly identified even at a rate of 0.2 sec/word.

Figure 5 shows an example of the results concerning the memory span at various presentation rates. The other subject revealed essentially similar results. The open symbols (circle, triangle and rectangular) represent memory spans for one-mora words and the filled symbols memory spans for three-mora words. As is seen from the figure, memory spans for both one- and three-mora words approach the respective asymptotic values irrespective of kana, kanji and line drawings, when the list item is presented at rates slower than 0.5 sec/word. At rates faster than 0.5 sec/word, however, performance declines in both one- and three-mora words. Specifically, memory span for line drawings decreases rapidly while memory span for kana is least impaired. An intermediate performance is obtained for kanji words.

It can be also seen from Fig. 5 that the span of STM for three-mora words is always inferior to that for one-mora words, regardless of the types of the visual materials.

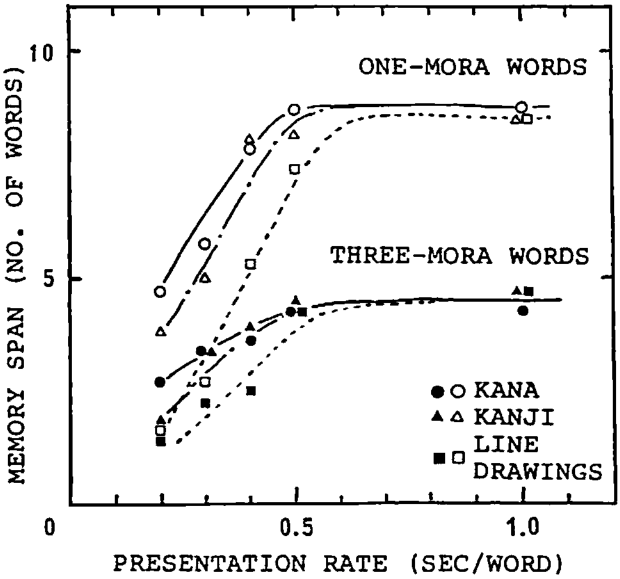

Fig. 5. Effect of presentation rate of list items upon memory span.

4.3. Discussion

4.3.1. Time required to identify visual materials

The fact that kana, kanji and line drawings could be identified almost perfectly at a rate of 0.2 sec/word suggests that identification of these materials may be completed during this interval, and that the interference between successive list items is negligible.

4.3.2. Time required to memorize visual materials

A constant value of the memory span at presentation rates slower than 0.5 sec/word implies that the processing for retention of visual materials is accomplished during an interval of 0.5 sec/word for one- and three-mora words. Since virtually no difference was found between the memory spans of kana, kanji and line drawings, the value of memory span below a 0.5 sec/word rate corresponds approximately to the capacity of the phonemic memory.

The difference in the time necessary for identification and retention can be interpreted as suggesting that the retention requires not only the identification of graphemes, graphemic word shapes and pictorial features but further encoding processes, i.e., generation of phonemic codes. At the presentation rates faster than 0.5 sec/word, the memory span decreases since the speech production mechanism can not successively generate the phonemic codes of incoming list items.

4.3.3. Differences between memory spans for kana, kanji and line drawings

The memory spans for the three visual materials decrease when the list items are given at the presentation rates faster than 0.5 sec/word. Based on the STM model shown in Fig. 3, the phonemic codes for kana words are extracted from their graphemes. However, since two additional processes (identification of graphemic word shape and a retrieval of phonological word shape) are required to memorize kanji words, the time taken to produce phonemic codes of kanji may be longer than that for kana. The stimulus information of the line drawings must pass through an even more circuitous route to generate phonemic codes compared to the routes of kana and kanji. Thus, the performance on kana, kanji and line drawing tasks declines in that order.

4.3.4. Difference in memory span between one- and three-mora words presented at a rate of 0.2 sec/word

Consider the difference between the memory spans for one- and three-mora kanji words. While the subject could remember four one-mora kanji words at a rate of 0.2 sec/word, she remembered only two three-mora kanji words. Since the capacity of the phonemic memory for three-mora words is estimated to correspond to the asymptotic value of the memory span curve, i.e., approximately 4.5 words, a reduction of the memory span is not due to a constraint on the memory capacity. Rather, the difference between the memory spans for one- and three-mora words may be explained in terms of the difference in the time which elapses in generating phonemic codes. That is, the time it takes to generate phonemic codes for the three-mora words may be longer than that for one-mora words. Landauer (1962) found that both subvocal and vocalized (or covert and overt) rehearsals take almost the same amount of time. As mentioned earlier, the rehearsal process of the STM model shown in Fig. 3 was supposed to be an alternate process of identifying phonological word shape from phonemic codes and of generating the phonemic codes from the word shape repeatedly. Given that the rate of generating phonemic codes from phonological word shape is comparable to actual speech rate, generation of phonemic codes for three-mora words may be a time consuming process compared with that of one-mora words. Therefore, the memory span for one-mora words is superior to that for three-mora words.

So far we have shown how the present STM model can account for differences in the information processing of kana, kanji and line drawings. It is worth noting, however, that all kana words do not always pass through the route from grapheme identification to phoneme generation. For instance, those words of foreign origin that are always written with kana can be comprehended without the mediation of phonemic codes. That is, these kana words may be processed in the same way as kanji words, although kana characters always provide phonemic information at least in part. Likewise, a retrieval of the meaning and/or reading of kanji is not always possible, since it is almost impossible for most people to retain the meanings and/or readings of all kanji characters in LTM.

5. Concluding remarks

Three experiments explored the subjects' ability to retain word lists of speech, kana, kanji and line drawings. Based on the results of these experiments, an STM model was constructed, which involves two sensory (auditory and visual) registers and word information processors at various linguistic levels, as well as six STMs, i.e., phonemic memory, graphemic memory, pictorial memory, graphemic and phonological word shape memories, and semantic memory.

As noted earlier, phonemic memory plays a major role in the memory span task in which subjects are required to memorize a list of unrelated words in the correct order. It is the phonemic memory that most investigations of STM have studied using the memory span task. In contrast, little is known regarding the characteristics of the other memories, particularly the semantic (short-term) memory. In an initial version of STM models, for example, it was assumed that only phonemic information can be held for a brief time. However, if we can maintain and manipulate only phonemic information as is asserted in the classical model, it seems virtually impossible either to produce a meaningful sentence or to comprehend spoken and written sentences. Manipulation of information, restricted to a phonemic level, will never lead to production and comprehension of a meaningful sentence. There must be mechanisms, or work spaces, that can retain and manipulate various levels of linguistic information, especially semantic and syntactic codes as well as phonemic, graphemic and word-shape codes. Moreover, it should be noted that the different memories utilize different encoding systems in retaining the stimulus information. In the phonemic memory phonemes are arranged serially along one dimension so that the memory span task is particularly appropriate for measuring its capacity. In the semantic memory, on the other hand, items held there are structured, or organized, in such a way that the items are associated with each other through this structure and transformed into a small number of semantic items. It is likely that the term "elaborated rehearsal" indicates building such a structure among the different items. Thus, the unrelated word list in the memory span task would hardly be retained in the semantic memory, since the list items are ordinarily selected so as to have no structure among them.

Furthermore, it seems probable that the capacity and decay characteristics for each memory are different from the corresponding characteristics for all other memories. The semantic memory can maintain a large amount of information, and its decay time, when the stimulus information is appropriately encoded, appears to be much longer than those of the other memories. It will be necessary, therefore, to develop a new experimental paradigm suited for measuring characteristics of each memory.

Note

The forerunner of this study was presented in Ann. Bull. RILP, 17 (Tatsumi et al., 1983).

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