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A STUDY ON THE TIME REQUIRED TO IMAGE OR TO WRITE JAPANESE CHARACTERS[1]

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The time required to retrieve and to utilize the memory representations of Japanese characters was studied in two experiments. First, the time required to image or to write or to speak a set of characters was measured. The results showed that the time to speak silently was less than 200 msec per character and the time to image was about 1 sec per character, whether the experimental material was English alphabets or Japanese Kanji characters (Subject's own address). The time required to write a character increased in proportion to the number of strokes. Next, the process of writing characters was studied in three experimental tasks; Writing subject's own address and name, Transliteration of familiar phrases from Hiragana into Kanji, Transcription of unfamiliar Kanji characters. As a result, the processing of visual features for writing took longer time than the processing of memory representatons did. And it seemed that the process of preparing graphic information to write characters was distinguished from the process of imaging the character.

Key words: Kanji characters, Image, Handwriting.

It has been said that the memory representations of visual language consist of graphic, phonetic, and semantic representations: The human information processing system retrieves and utilizes the appropriate representations which accord with the demand of the task at that time (cf. Carr, T.H., 1986).

The Japanese characters which represent visual language consist of Kanji, Hiragana, Katakana, and alphanumerical characters. These characters vary in the correspondence to the memory representations, together with the graphic features. An individual character of English alphabets has not necessarily the correspondence to the word or meaning. On the other hand, Japanese characters are logographic (Kanji) or syllabic (Kana) symboles. Especially, even one Kanji Character can represent some meanings. Although there is not a severe rule of orthography in Japanese, Kanji characters are used as full words or content words. Kana characters are divided into Hiragana and Katakana, according to its context: Hiragana are used as function words, and Katakana as foreign words and names (cf. Hung & Tzeng, 1981). It is said that the number of Kanji characters used in everyday communication is over 3000 in Japanese. The number of strokes of Kanji characters ranges from 1 to 33, while that

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of Kana characters ranges from 1 to 4. And there are relatively severe rules about the writing-order of strokes in Japanese.

The purpose of this study is to measure the time required to retrieve or to utilize the memory representations of these Japanese characters, mainly graphic representations.

EXPERIMENT I

First, it was attempted to measure the time required to retrieve graphic representations directly ; i.e. imaging.

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Experimental materials : Subject's address which is represented by Kanji characters was adopted as a material. And the sequence of 26 characters of English alphabets (A-Z) was used to compare with the former study (Weber & Castleman, 1970). As above two types of the characters were supposed to have been used very frequently by subjects and stayed in their long-term memory, it was expected that the frequency of using characters would not affect the experiment.

Procedures and Apparatus : (1) Writing task : Subject was instructed to write his own address on B4 white paper with black felt-tip pen, vertically in the usual way in Japanese ; Alphabets were to be written from left to right. And he was instructed to write characters in the usual size and at the usual speed. This behavior was recorded by video-camera attached with 1/100 sec timer. And the writing-duration was measured ; from the time when the pen touched the paper to write the first character of a material to the time when the pen detouched the paper after the subject had written the last character.

(2) Imaging-all-characters task : Subject was faced to the CRT display of microcomputer at a distance of about 40 cm. On the display, a random pseudo-characters pattern was presented before and after the imaging. Subject was instructed to press the key of the computer and simultaneously to begin imaging the characters in order, as if he was seeing a film from frame to frame. When he completed the imaging, he was to press the key again. This time-interval was measured by means of the computer. During the imaging, a rectangle of white line in the size of 11.3×12.8 cm was presented on gray background of the CRT.

(3) Stop-imaging task : The procedure was almost the same as that of the imaging-all-characters task. In this task, a beep signaled to stop imaging in the midst

Fig. 1. An example of Kanji characters written in Writing task. (origianlly, in vertical)

of it. The interval between the start of imaging and the stop-beep was selected at random among 2, 4, 6, 8 sec in each trial. When the beep sounded, the subject was to write down the character or the part of the character which he imaged at that time.

(4) Silently-speaking task: Subject was instructed to press the key of the computer and simultaneously to begin speaking silently the material in order. When he completed speaking, he was to press the key again. This time-interval was measured by means of the computer.

Subjects: Six undergraduate students took part in the experiment. They had been inexperienced in any psychological experiments before.

Results

The task of imaging characters serially was fatiguing for the inexperienced subjects. The variance of reaction became larger and larger in accordance with the trials. So, the results of the first five trials of each subject in each experimental task were regarded as the data. A sample of characters written by a subject in the writing-task is presented in Figure 1. The average times of the three experimental tasks (except for the stop-imaging task) on six subjects are presented in Table 1.

The result of speaking-task almost corresponds to that of Weber & Castleman (1970); the time required to speak silently was about 200 msec per character. And the time required to write a Kanji character also almost corresponds to that of the former study (Nihei, 1984); 300-400 msec/stroke. The writing-time of a character increased in proportion to the number of strokes. The time required to image a charcter seems to be invariable whether the material was English alphabets or Kanji characters which have usually more strokes than alphabets.

And an example of the times required to do the experimental tasks with Kanji characters on a subject is presented schematically in Figure 2. The data of the imaging-all-characters task and that of the stop-imaging task agree with each other. This shows that these data are reliable, regardless of the small number of the date. It seems that imaging a character was done not in the same serial way as writing, but in parallel way (at a time). However, there may be some reservations. A few subjects reported that they cannnot complete the imaging when the stop-beep sounded (for example, 氵 of 海). This seems to show the possibility that imaging is a serial process. Though there is not enough evidence, it is supposed that this result would be derived

Table 1. Mean processing time per character (SD) in second

Materials	Experimental tasks		
	Writing	Imagining	Speaking
Kanji (address)	2.36 (0.45)	1.00 (0.38)	0.20 (0.06)
Alphabets	1.24 (0.48)	1.07 (0.37)	0.21 (0.07)

N = 30 (sum of six subjects)

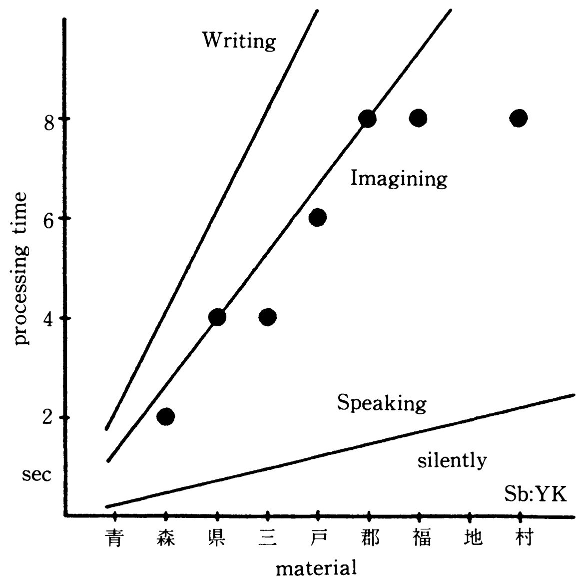

Fig. 2. Schematic illustration of an example of the processing time in each experimental task.
● ; Characters reported in Stop-imagning task.

from the way of report ; i.e. writing which should be a serial process.

Experiment II

Next, the process of writing was studied further. In the former experiment, it was suggested that the unit of imaging character would not be a stroke but a whole character. The reserved question about this notion is the effect of the process of writing. Then, is the process of writing a serial process ? Certainly, the behavior of writing is serial. But, there are some articles reporting that the unit of the program for writing is also a whole character (cf. Teulings, Mullins, & Stelmach, 1986).

In this experiment, the duration of witing a Kanji character and the time-interval between characters were measured under several experimental conditions ; writing subject's own address, transliterating a phrase represented by Hiragana into Kanji, and transcription of unfamiliar Kanji characters.

It was expected that the difference of these experimental tasks would affect the input-process of graphic information before writing and the feedback process during the writing. In the input-process, the memory representations are only information in the task of writing address, while the visual information is to be processed in the transliteration and in the transcription task. In the transliteration task, Hiragana should be the cue information to retrieve appropriate Kanji. And in the feedback process matching the graphic pattern written by subject to the memory is necessary in the writing task and in the transliteration task, while the visual matching of two

Table 2. The phrases adopted as materials of the transliteration task.

Stimulus (Hiragana)	Appropriate Kanji
あんぜんちたい	安全地帯
かしょうひょうか	過小評価
こうぎょうだいがく	工業大学
こうそくどうろ	高速道路
こくごじてん	国語辞典
こくさいでんわ	国際電話
ししゃごにゅう	四捨五入
しんあんとっきょ	新案特許
しんようくみあい	信用組合
せいりょくはんい	勢力範囲
たりゅうじあい	他流試合
とうほくほんせん	東北本線
はんしんふずい	半身不随
ほごぼうえき	保護貿易
みんしゅしゅぎ	民主主義
ゆうめいむじつ	有名無実
ゆだんたいてき	油断大敵
よっきゅうふまん	欲求不満
りがいかんけい	利害関係
れんたいせきにん	連帯責任

Mean number of strokes of appropriate Kanji characters = 8.9

Table 3. Kanji characters adopted as materials of the Transcription.

丼	舒	弍	亞	廾	弩	彗	彷
亢	俤	僉	兮	慙	懆	戈	扁
冀	册	冉	几	扎	攸	斟	斫
凰	剋	勹	區	无	旻	朿	朳
卆	卍	夘	彪	梵	歹	殷	毫
厠	叮	咨	咸	呡	氣	汞	衍
囮	圦	址	坩	糺	爻	玻	甦
夬	夭	孛	宦	甬	畚	疣	發
尹	屁	岷	崑	皓	皰	盂	眇
巫	巫	廖	廸	帛	胐	犹	炮

Mean number of strokes = 8.1

graphic patterns is necessary in the transcription task. It was expected that the difference of input-process would affect the time before writing ; i.e. the time-intervel between characters, and the difference of feedback process would affect the duraion of writing itself. And it was expected that the time before writing would not be affected by the number of strokes of following character, if the unit of preparing for writing is a whole character.

Method

Experimental task : (1) Writing task : Subject was instructed to write his own address and name except the lot numbers. There were 5 lines consisting of 6 characters on a sheet of writing paper. There were 10 trials.

(2) Transliteration task : Subject was to transliterate a phrase represented by Hiragana into Kanji. The materials were familiar phrases originally consisted of 4 Kanji characters, which were selected from the dictionary for shool children (Table 2). There were two phrases on a sheet of writing paper. The total number of phrases was 20 words, that is 80 characters in 10 trials.

(3) Transcription task : Subject was instructed to transcribe unfamiliar Kanji

characters which were selected from JIS second level characters (Table 3). In a sheet of writing paper, there were 8 characters in 2 lines. The total number of characters was 80 in 10 trials.

Procedure: As there were 10 trials for each experimental task, theer were 30 sheets of writing paper fastend for each subject. There were headings of the task on each sheet of paper. The order of the sheet of paper was arranged at random with each subject. Subjects were instructed to write characters according to the headings, from left to right at the usual speed by black felt-tip pen. There was 20×20 mm frame of writing each character on the line. The writing behavior was recorded by means of videocamera system with 1/100 sec timer.

Subjects: Five adult persons took part in this experiment.

RESULTS

Data which subject could not complete writing the character were deleted. The writing-time means the interval from the time when pen touched paper to the time when pen detouched after writing a character. The time-interval between characters means the interval from the termination of writing a character to the start of writing a next character. So, the time-interval could not be derived from the first or the last character of a line.

Though there were individual differences in the writing-time and the time-interval, the tendency of the effects of the experimental tasks was consistent through the subjects. Table 4 represents the correlation coefficients between writing-time and the number of strokes of character. The time required to write a character increased in proportion to the number of strokes, and this is consistent with the result of the experiment I. Figure 3 represents the simple regression of writing-time to the number of strokes of character in the three experimental tasks, on one subject.

There was no correlation between the writing-time and the time-interval between characters; the correlation coefficient was less than 0.2 in each experimental task, on each subject. This result seems to show that the preparing process of writing a character does not correspond with the number of strokes of the character.

Table 5 represents the mean writing-time per stroke and the mean time-interval between characters in each experimental task. The writing-time per stroke is adopted

Table 4. Correlation coefficients between the writing-time of a character and the number of strokes of it.

Subject	Writing	Transliteration	Transcription
M.E.	0.98 (n=210)	0.93 (n=77)	0.83 (n=80)
T.U.	0.94 (n=160)	0.92 (n=70)	0.82 (n=80)
S.U.	0.97 (n=138)	0.93 (n=61)	0.89 (n=80)
H.I.	0.93 (n=158)	0.70 (n=59)	0.83 (n=80)
J.S.	0.96 (n=210)	0.75 (n=53)	0.67 (n=79)

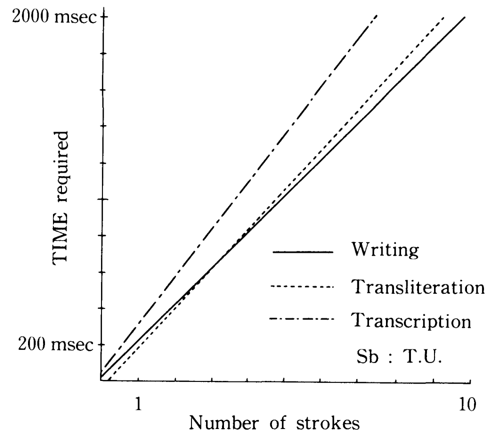

Fig. 3. An example of the simple regression of the writing-time to the number of strokes of the characters.

Table 5. Mean writing-time/stroke and mean time-interval between characters. (in msec)

		Writing	Transliteration	Transcription
Writing-time/stroke	mean	315.9	337.5	458.8
	S.D.	96.5	138.6	171.0
	n	876	320	399
Time-interval between characters	mean	707.3	1056.2	1189.9
	S.D.	186.6	232.3	380.7
	n	707	211	296

as a measure, because the written characters were different among subjects,especially in the Writing-address task. As the writing-time/stroke was derived from the writing-time of a character and empirical number of stroke, the time required to feedback process is considered to be included in this measure. The mean writing-time/stroke of the Writing task takes about 0.3 sec, which is the same as the result of the experiment I. On the writing-time, there is no difference in the time between the Writing and the Transliteration. But, it takes longer time to transcribe unfamiliar characters. On the other hand, there is less difference in the time-interval between the Transliteration and the Transcription, and the time-interval in the Writing task is the shortest in the tasks.

It was supposed before experiment that the writing-time should be affected by the feedback process and the time-interval should reflect the preparing process of writing.

There might be a difference of frequency of writing between the material of the Writing and that of the Transliteration. And there should be an added process of retrieval of Kanji in the Transliteration. It seems that these differences did not affect the writing-time itself but the time-interval between characters (See Table 5). In these two tasks, writing should be done by means of the information of memory. This suggests that the writing-speed of the Kanji characters dependent on the memory would be relatively invariable; about 0.3 sec per stroke. And the increase of the writing-time in the Transcription suggests that the visual feedback process in writing would take about 0.12-0.14 sec/stroke in average. Seeing the difference of the time-interval between the Writing and the Transliteration, the time required to utilize Kanji from the information of Hiragana should be about 0.3 sec in average. In a like manner, the comparison of the time-interval between the Writing and the Transcription shows that the processing of visual information for writing takes about 0.5 sec longer than the retrieval of the memory representation.

There is still a problem about the interpretation of the time-interval between characters. The variance of the time-interval within a task is not small on each subject. If the interval would be independent of the number of strokes of the following character, the interval should be invariable. It is considered that the reason of this discordance is as follows. In the Writing task, there was a tendency that subjects had segmented their address into their prefectures, districts, cities or towns, and names. In the Transliteration, the familiarity of the material had not be controlled exactly. And in the Transcription, subjects reported that they had to elaborate inevitably the writing-order of strokes, even if they had not seen the character before. These factors are considered to have influenced the time for preparing next writing.

Conclusion

Table 6 represents the rough view of the relation between the tasks of the two experiments and the information processing of the visual language. If the process of writing a character would be a serial process, the informatin might be decoded by phonetic or semantic information first, and the retrieval process of appropriate graphic information in the second place, and the motor process for the last time.

It is suggested from the results of the experiment I that the time required to utilize the phonetic representation for output should be less than 0.2 sec. Weber and

Table 6. The relation between the experimental tasks and the supposed type of information.

Experimental task	Input	Memory representation	Output
Speaking (silently)	semantic	phonetic	phonetic-motor
Imaging	semantic	graphic	graphic
Writing address	semantic	graphic	graphic-motor
Transliteration	visual	phonetic semantic grahic	graphic-motor
Transcription	visual	graphic	graphic-motor

Castleman (1970) also reported that the rate of speaking alphabets was 0.16 sec/character, for the native speakers of English. There may be a dispute whether the process of imaging characters should need phonetic information or not. The rate of imaging characters was about 1 sec/character in the experiment I, regardless of the type of the characters. But, the correspondence of characters to the phonetic representation is different between English alphabet and Kanji. This suggests that the imaging a character would be independent with the phonetic representation. With the same material, the time to prepare writing following character took about 0.7 sec in experiment II. The procedure adopted in experiment I was a projection or generation of graphic image of characters, in a exact manner. It is considered that the processing of graphic representation for writing would not be the same as that of imaging. And the results of the experiment II suggests that the handwriting based on the information of the long-term memory is more stable than that demanding some visual information processing.

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