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ABSTRACT

A probe recall short-term retention task was used to test the applicability of the "phonological recoding" (Conrad, 1972) and "flexible decoding" (Smith, 1972) models to processing tactics used by readers of Chinese. Subjects were 45 adult speakers of Cantonese. Stimuli were lists of Chinese characters which varied in terms of phonological and visual similarity. The dependent variable was the proportion of correctly recalled target characters from "recent" positions. Significant primary memory interference effects were observed for phonologically similar lists but not for visually similar lists. Results were interpreted with reference to the two models of skilled reading. (Author)

Information Processing Models of Skilled Reading: The Relationship Between Chinese Orthography and Coding Tactics in Primary Memory[1]

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[1] This article is based on the author's unpublished doctoral dissertation (Indiana University, 1979).

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Information Processing Models of Skilled Reading: The Relationship Between Chinese Orthography and Coding Tactics in Primary Memory[1]

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Reading ability, or the lack of it is of major concern to educators, parents, politicians, and perhaps most of all, those individuals who experience reading difficulties (Carroll & Chall, 1975; Lubow, 1978). In an advanced technological society where factual knowledge is still conveyed primarily via the written medium, the inability to read proficiently will be a potentially severe handicap both to the individual and to the society as a whole. The definition of functional illiteracy is still being debated (Bermuth, 1975) but it is widely accepted that approximately 15% of the school age population in the United States has a marked reading problem (Carroll & Chall, 1975; Gibson & Levin, 1975). While estimates of reading disability in some European countries correspond with the data from the United States (Jansen, 1972; Ruthman, 1972), estimates from Japan are startlingly low. (Makita, 1968). Makita has reported that the rate of reading disability is less than 1% among the Japanese school age population.

An explanation for this wide discrepancy in the rate of reading disability between Japan and the United States is not immediately apparent. On the one hand, Makita (1968) and Gleitman and Rozin (1977) suggest that the cross-cultural variability in reading disability rates is due to the difference between the Japanese and English graphemic systems. On the other hand,

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Leong (1972) points out that these reading disability differences may be due to sociological variables such as family structure and attitudes toward education.

The aim of this study was to explore certain aspects of cognitive functioning during reading among skilled readers of a non-alphabetic and non-syllabic graphemic system, Chinese, with the aim of providing some preliminary information about the relationship of non-alphabetic graphemic systems to information processing tactics used by skilled readers of those systems. In addition, this study provides data concerning the generalizability of the existing models of information processing during reading which, until now, have been tested almost exclusively with readers of English.

Models of skilled reading can be classified into two groups on the basis of the role posited for phonological recoding during ongoing reading. According to advocates of the "phonological recoding" model (Baron, 1977; Conrad, 1972; Rubenstein, Lewis, & Rubenstein, 1973; and Shankweiler & Liberman, 1976), a crucial role is posited for the use of phonological knowledge during reading. Phonological knowledge includes a set of rules whereby an individual can derive an underlying systematic phonological representation from linguistic input. From their perspective, a skilled reader is one who is able to engage in the information processing tactic of transforming or recoding visually presented graphemic information into a phonological code. In turn, this phonologically coded information can then be utilized by the language processing system in the same manner as speech input is processed.

One of the assumptions underlying the phonological recoding model is that the language processing capabilities of humans are tied to the auditory and/or the articulatory cognitive processing systems. As a consequence of this neurological phenomenon, linguistic information presented visually via an orthographic system is most effectively processed when the visual input is first recoded into a phonologically based code before the language decoding process begins (Liberman, Shankweiler, Liberman, Fowler and Fischer, 1977). This claim for the close and relatively fixed relationship between the auditory/articulation system and human language processing capabilities can be te : the "phonological dependency hypothesis."

In rast to the phonological recoding model, Goodman (1967) LaBerge (1972), LaBerge and Samuels (1974) and Smith (1971) advocate a "flexible decoding" model. They claim that skilled readers have flexible decoding capabilities so that the stage of phonological recoding can be bypassed under certain conditions. In fact, Smith and Goodman suggest that the reading activity is most efficient when the reader can minimize reliance on phonological transformations and instead use a more direct tactic of going straight from graphemically coded information to meaning. Goodman (1967) also says that instead of simply storing accoustical information, the skilled reader holds meanings of lexical items or short phrases in primary memory.

Thus the phonological recoding model and the flexible decoding model differ clearly in terms of the role posited for phonological recoding during reading. The phonological recoding model assigns the process of phonological transformation a central role for fluent reading and assumes that primary memory is used most effectively as a repository for phonologically coded linguistic information. In contrast to the phonological recoding model, the flexible decoding model assigns phonological recoding a background role in fluent reading to be activated only when direct decoding from visual information fails and assumes that primary memory is most efficiently utilized by storing meanings rather than phonemes.

Short-term retention tasks have been used to examine the role of coding processes in reading related activities. Both the phonological recoding and flexible decoding models make claims regarding the code used to maintain information in primary memory during reading. The use of short-term retention experiments to test models of reading was predicated on the work of Conrad, Baddeley, and others (see Conrad, 1972). Their research demonstrated that linguistic material presented via either the auditory or visual channel was held in a phonologically coded form in primary memory. Based on the two store memory models developed by Waugh and Norman (1965), Kintsch and Buschke (1969) utilized a short-term retention task to assess the form of the code used to store visually presented linguistic information for short durations; i.e., less than 60 seconds. While current models of memory (Bjork, 1975; Craik & Jacoby, 1975; Shriffrin, 1975) have tended to blur the rigid notion of two separate and distinct storage systems, Craik and Levy (1976) say that the model or at least the equations derived from the model by Waugh and Norman would be applicable to short-term retention tasks which require serial rather than free recall.

In their study, Kintsch and Buschke (1969) found that probe recall performance was lower for a list of homonyms as compared to a list of unrelated words but only for those words occurring toward the end of the list; i.e., "recent" items. Kintsch and Buschke assumed that this finding was due to interference in primary memory and they concluded that the visually presented items were recoded into a phonological form for maintenance in the primary memory store.

In contrast to the findings reported by Conrad (1972) and Kintsch and Buschke (1969), some researchers report that graphemic input can be maintained in primary memory in a non-phonological form. Under certain conditions, experimenters have found that they can maximize the probability that subjects will utilize visual or semantic codes to maintain graphemic information in primary memory (Kroll, 1975; Shulman, 1970). Kroll's data indicate that under extreme conditions subjects can and do use visually based codes to maintain linguistic information. Along similar lines, Shulman (1970) found that if given explicit instructions and adequate time, subjects will code both semantic and phonological information in primary memory.

Bradshaw (1975) has criticized attempts by researchers to generalize from the results of short-term retention tasks to the behavior of fluent readers, but his critique is weakened by Kroll's and Shulman's findings. Only when the similarity between short-term retention tasks and ongoing reading are decreased even more than the task in the Kintsch and Buschke study will subjects attempt to use tactics which bypass the phonological coding of graphemic input. Taken as a whole, the short-term retention studies tend to support the phonological recoding model but the findings from Kroll and Shulman leave open the possibility that some readers may engage in flexible decoding tactics which bypass the stage of phonological recoding.

While Liberman et al. (1977) suggest that phonological recoding enables the reader to make use of existing efficient primary language processes and thus leads to fluent reading skills, there is an alternative explanation for the widespread occurrence of phonological recoding tactics among skilled readers (Carroll, 1972; Gleitman & Rozin, 1977). It may be that skilled readers use phonological based codes not so much because they are crucial for fluent reading but rather because the orthographic system of English makes phonological recoding a relatively efficient process once the basic recoding rules are learned. If this alternative explanation were supported, then the presence of phonological recoding among readers of English could be attributed to the properties of the English alphabet rather than to limitations inherent in the cognitive processing system's ability to handle linguistic information.

Gleitman and Rozin (1977; Rozin & Gleitman, 1977) have presented a detailed discussion of the manner in which various graphemic systems represent linguistic information and they concluded that in terms of readability, English orthography is a convenient system for the skilled reader in large part because representational forms in the graphemic system make contact with both the phonological and morphological levels of the spoken language. Their analysis of English as a multi-leveled graphemic system provides a possible explanation for some of the divergent results obtained in the reaction time and short-term retention studies reviewed above (e.g. Conrad, 1972; Kroll, 1975; Shulman, 1970). Depending on the nature of the experimental task and on the structure of the stimulus materials, the graphemic system can facilitate or impede phonological recoding or direct decoding. This can be called an "orthographic dependency" hypothesis. In contrast to the English alphabetic system, Gleitman and Rozin claim that for some non-alphabetic graphemic systems phonological recoding need not occur during reading. For example, they suggest, without offering any empirical evidence, that readers of Chinese do not typically engage in phonological recoding.

In part, Gleitman and Rozin base their analysis on work done with readers of Japanese (Sasanuma and Fujimura, 1971, and Sasanuma, 1975). The Japanese writing system is a non-alphabetic system which combines syllabic systems (Katakana and Hiragana) with a morphemographic, or character, system (Kanji). Studies by Sasanuma and Fujimura (1971) with Japanese patients who have suffered brain damage, suggest that the storage and access of the Kana and Kanji systems differ. According to Sasanuma and Fujimura, Japanese readers use phonological recoding for the syllabic system, Kana, but not for the morphemographic system, Kanji. As a result of the work of Erickson, Mattingly, and Turvey (1977), Sasanuma and Fujimura's interpretation has been called into question. Using Kintsch and Buschke's (1969) short-term retention task, Erickson et al. found that neurologically unimpaired readers of Japanese recoded morphemographs (Kanji) into a phonological form. Their findings paralleled the results obtained by Kintsch and Buschke and thus support the claim that phonological recoding plays a crucial role in fluent reading which is not limited to alphabetic graphemic systems.

While the subjects in the Erickson et al. study were using phonological recoding tactics, the leap from their study to all readers of morphemographic systems is unwarranted. Gleitman and Rozin (1977) point out that the intermingling of the kana and kanji scripts results in a graphemic system which bears a surprisingly close resemblance to the multi-leveled English orthographic system. In this case, one would expect to find very similar patterns of cognitive processing tactics among neurologically unimpaired skilled readers of both languages. The crucial test of the role of phonological recoding in primary memory will come from subjects who use an exclusively morphemographic writing system such as Chinese.

In a pair of experiments which closely parallels the experiment to be reported on below, Tzeng, Hung, and Wang (1977) examined the role of phonological recoding for readers of Chinese. One of their experiments incorporated Wicklegren's (1965) retroactive interference paradigm and the other experiment was a sentence verification task. On both tasks, they found evidence of phonological interference. These results support the hypothesis that even readers of a pure morphemographic writing system use phonological recoding tactics during reading.

While the findings of Tzeng et al. are in accord with other studies which demonstrate that readers engage in phonological recoding of written material, they have also used subjects who were skilled readers of English. Thus we cannot rule out the possibility that these subjects responded to the experimental task demands by using cognitive processing tactics which they were using in their daily lives as students in the United States. Another limitation of the Tzeng et al. study is that they did not examine the possibility that similar interference effects would have been found along a dimension of visual similarity. Perhaps characters are maintained in primary memory in some multiply coded form and then similarity along any of the coded dimensions would affect processing efficiency. The goal of the research to be described below was to deal with the two issues which limit the generalizability of the Tzeng et al. findings, i.e. their failure to examine the possibility that interference effects would also be found for stimulus materials which were visually similar.

To provide more data concerning the predictions derived from the phonological recoding model and the flexible decoding model, the probe recall methodology used by Kintsch and Buschke (1969) and Erickson et al. (1977) was adapted for readers of Chinese.

The following hypotheses were tested in this study.

(1) On a probed recall task, the presence of phonological similarity among Chinese characters in a list of otherwise unrelated characters will

lead to a decrement in primary memory estimates of recall probability (Phonological Dependency Hypothesis).

(2) On a probed recall task, the presence of orthographic similarity among Chinese characters in a list of otherwise unrelated characters will lead to a decrement in primary memory estimates of recall probability (Orthographic Dependency Hypothesis).

Design

This study was a two by three factorial design. Factor one was the degree of alphabetic knowledge, high or low, and factor two was the character list type, orthographically similar, phonologically similar, or control. An alphabetic knowledge questionnaire was used to identify those subjects who had only a limited knowledge of the alphabetic principle, i.e. the ability to represent words by means of symbols which correspond to auditorily non-isolatable, phonemic segments. Groups of subjects were randomly assigned to one of the levels of the character list type factor. Statistical analyses were based on a fixed-effects model (Kirk, 1969).

Subjects

The High Alphabetic Knowledge group (HAK-group) subjects came from the introductory psychology course subject pool at the Chinese University of Hong Kong. Students received course credit but no payment for their participation in this study. All 30 subjects were native speakers of Cantonese who were proficient at reading both English and Chinese. Subjects in the Low Alphabetic Knowledge group (LAK-group) were all workers, only one of whom had more than a primary school level of formal education. The LAK subjects were also native speakers of Cantonese. A total of 61 workers from two sites participated in the testing sessions but the data to be reported came from only 15 subjects.

Data were discarded for the following reasons: (1) non-native speakers of Cantonese -- 13 workers; (2) knowledge of an alphabetic writing system -- 17 workers; (3) test instructions misunderstood -- 4 workers; (4) equipment failure -- 3 workers; (5) suspected cheating -- 2 workers; (6) failure to get any correct responses -- 3 workers; and (7) test list characters unknown -- 1 worker. To create equal cell sizes, data from three workers in the orthographically similar character list condition were randomly discarded. All 61 workers were paid for their participation in the study. It is assumed that the 15 LAK-group subjects could read Chinese since none of the subjects reported any difficulty filling out the alphabetic knowledge questionnaire. However, given the limited extent of their formal education, it is questionable if these subjects could be considered to be fluent readers of Chinese. No formal assessment of reading ability was done. Table 1 gives a breakdown of the subjects by age, sex, and educational background.

INSERT TABLE 1 ABOUT HERE

Materials

Three different stimulus lists, each containing 16 individual Chinese characters, were developed. The lists differed along two dimensions, surface phonetic stimilarity and orthographic similarity. The High Phonological Similarity List contained eight pairs of single character nouns which were homonyms with only minimal orthographic similarity among the characters. The High Ortographic Similarity List contained eight pairs of single character nouns which were geometrically similar with only minimal phonological similarity among the characters. The third list was a Control list in which both phonological and orthographic similarity were minimized. Appendix A contains the three list of test characters along with their phonetic transcriptions, and English equivalents. In addition, to the three test lists,

Table 1

Demographic Data for Alphabetic Knowledge Groups by Character List Type Conditions

Alphabetic Knowledge Group	Character List Type	Sex: Male	Sex: Female	Age	Level of Formal Education: Primary School	Middle School	University
High	Orthographically Similar	4	6	20.6[a] (19-21)[b]	0	0	10
	Phonologically Similar	7	3	19.7 (18-21)	0	0	10
	Control	3	7	19.6 (18-22)	0	0	10
Low	Orthographically Similar	3	2	40.2 (21-59)	5	0	0
	Phonologically Similar	3	2	20.6 (17-22)	5	0	0
	Control	1	4	27.8 (18-49)	4	1	0

[a]Mean

[b]Range in parentheses.

three practice lists were created. Commonly appearing characters were selected and phonological and orthographic similarity were minimized in each practice list.

Phonological similarity was operationalized by matching pairs of characters in terms of their phonological representations including tone. Only pairs of homonyms were chosen, consequently the phonologically similar characters were in fact phonemically identical.

Orthographic similarity was operationalized by separating the characters into two components, the radical which is often on the left hand side or top of the character, and the phonetic which is often on the right hand side or bottom. Selected characters (1) were identical in terms of the radical and (2) differed by three or less in the total number of strokes in the phonetic component. Within these constraints, the experimenter then subjectively chose those pairs of characters which were felt to be the most visually confusable. For example, given three characters which met the first two requirements for orthographic similarity, such as 陸, 陽, and 限, 陸 was rejected while 陽 and 限 were selected as potential stimulus items. No studies have been done to determine empirically the visual confusability among sets of Chinese characters, therefore it is impossible to determine the degree to which this relatively mechanistic selection procedure resulted in the creation of a list of orthographically similar pairs of characters.

The 48 test characters were selected from a group of approximately 175 characters on the basis of familiarity ratings made by students at the Chinese University of Hong Kong. Ratings on the final set of 48 test items were obtained from an additional group of 10 university students. A repeated measures analysis of variance indicated that there was no significant difference between character list type on the basis of the familiarity ratings, $F(18,2) = .103, p > .05$. Familiarity ratings were also obtained from the LAK-group subjects after they completed the short-term retension task. Once again, there was no significant difference in familiarity rating among character list types, $F(2,28) = .435, p > .05$.

For each character list type, 20 lists, one for each trial, were created. On the basis of restrictions derived from Erickson et al. (1977), each trial list contained 16 randomly ordered characters. The restrictions on character order were as follows:

(1) Similar characters could never directly follow one another within a list.

(2) A character could serve as the probe or the target item no more than twice but each character was used in each role at least once.

(3) The target characters appeared in certain specific positions within the test lists, i.e. in position #3, #5, and #7 twice each, in positions #4 and #6 once each, and in positions #11, #13, and #15 four times each.

(4) The distance between the similar character and the target character were also controlled by locating the similar item either 6 or 7, or 2 or 3 positions away from the target items with ¼ of the trials at each separation distance.

(5) The relative locations of the target character and the similar character were varied between trials such that for ½ of the trials one would come before the other and on the other ½ of the trials the order was reversed.

The test characters were printed on boldface type (老體2級) and then 35 mm transparencies were made of each individual character. The test lists were originally presented via a Kodak slide projector with each character appearing for 1.5 seconds and a 1.5 second inter-stimulus interval. One and a half seconds after the last character appeared, an undlerlined probe character appeared. To ensure standardization of the presentation between groups, the trials were pre-recorded on a reel-to-reel videotape system.

Procedures

All testing was done by two native speakers of Cantonese who were trained by the experimenter. The testing session lasted approximately one hour but testing conditions varied slightly between testing sites. the HAK-Group and 3 LAK-Group subjects were tested at the University while the remaining 12 LAK-Group subjects were tested in an office at a local factory. The variability between testing sites had no obvious effect on task performance.

Instructions, printed in Chinese, were handed out and read aloud in Cantonese to the subjects. The testing session consisted of three practice trials followed by 20 test trials. For each trial, 16 single characters were presented at the rate of one every 3 seconds. Following the last character, a "probe" character was presented. Subjects were instructed to write down the character which had followed the "probe" character in the test list. Thus, if the "probe" character had appeared in position 11, subjects were to write down the character which had appeared in position 12.

All scoring was done by the experimenter. Alternative forms of a character were scored as correct but incorrectly written characters were scored as errors. The only incorrectly written characters were from the LAK-groups (approximately 5% of their responses).

Preliminary Data Analysis

The data from this study were analyzed to provide information about primary memory coding tactics used by readers of Chinese. Specifically, the data were analyzed for evidence of performance deficiencies in terms of the number of correctly recalled characters from each of the character list treatment groups, i.e. High Phonological Similarity Character List group and High Orthographic Similarity Character List group, relative to the Control Character List group. Lower recall rates for items appearing toward the end of the test lists, i.e. "recent" items, for either of the treatment lists as compared to the control list would be interpreted as evidence of capacity overload or interference effects in primary memory. It is assumed that these effects would be due to the similarity among the coded stimulus items being maintained in primary memory during the retention interval.

INSERT TABLE 2 ABOUT HERE

Given the confounding of alphabetic knowledge with educational level such that the High Alphabetic Knowledge group (HAK-group) was also more highly educated than the Low Alphabetic group (LAK-group), the data were initially analyzed to determine if overall performance was equivalent between the two alphabetic knowledge groups. Total correct by alphabetic knowledge group and character list type are shown in Table 2. A two by three analysis of variance indicated that there were significant differences for alphabetic knowledge group, $\underline{F}(1,39) = 4.26$, $\underline{p} > .05$, and character list type, $\underline{F}(2,39) = 7.11$, $\underline{p} > .01$, but no significant alphabetic knowledge by list type interaction,

Table 2

Means and Standard Deviations of Total Correct for the Two Alphabetic Knowledge Groups by the Three Character List Type Conditions

	Alphabetic Knowledge Group	
Character List Type	High[a]	Low[b]
Orthographically Similar	7.80 (2.09)[c]	3.80 (2.16)
Phonologically Similar	4.70 (2.31)	3.40 (2.19)
Control	8.40 (3.34)	8.00 (5.09)

[a]N= 10 per cell

[b]N= 5 per cell

[c]Standard Deviations in parentheses

$F(2,39) = 1.38$, $p > .05$. As a consequence of this significant difference in recall performance between alphabetic knowledge groups such that HAK subjects recalled significantly more characters than LAK subjects, the character list type effects were analyzed separately for each alphabetic knowledge group. A breakdown of total correct by recall at "recent" positions, i.e. target positions 11, 13, and 15 and average recall at "early" positions, i.e. tartet positions 3, 4, 5, 6, and 7, is given in Table 3 for each alphabetic knowledge group and character list type.

INSERT TABLE 3 ABOUT HERE

Following the procedures used by Kintsch and Buschke (1969), a one-way analysis of variance was done for the secondary memory estimate by character list type to ensure that the secondary memory contribution to recall for "recent" items was equivalent between character list type groups. The secondary memory estimate is taken to be the proportion correct averaged over the "early" positions in the test list. For the HAK subjects, there was no significant differences in secondary memory estimates among the character list groups, $F(2,27) = 1.67$, $p > .05$. However, for the LAK subjects the differences among secondary memory estimates approached statistical significance, $F(2,12) = 3.66$, $p = > .057$. On the basis of this finding, the data from the LAK-groups were also analyzed using Waugh and Norman's (1965) unbiased primary memory estimate which partials out the effects of secondary memory on recall probability for the LAK-groups. Table 4 contains the unbiased primary memory estimates for the LAK-groups.

INSERT TABLE 4 ABOUT HERE

Table 3

Means and Standard Deviations of Raw Score Proportion Correct at "Early" and "Recent" Target Positions for Alphabetic Knowledge by Character List Type

Alphabetic Knowledge Group	Character List Type	"Early" Positions Average[a]	11	13	15	"Recent" Positions Average[b]
		Correct Recall by Target Position				
High						
	Orthographically Similar	.350 (.251)[c]	.267 (.158)	.425 (.265)	.625 (.177)	.439 (.120)
	Phonologically Similar	.190 (.120)	.200 (.158)	.225 (.219)	.400 (.337)	.275 (.142)
	Control	.310 (.223)	.325 (.237)	.475 (.275)	.675 (.265)	.492 (.224)
Low						
	Orthographically Similar	.100 (.173)	.350 (.285)	.150 (.224)	.300 (.274)	.267 (.160)
	Phonologically Similar	.100 (.071)	.100 (.137)	.200 (.209)	.300 (.274)	.200 (.126)
	Control	.380 (.268)	.350 (.285)	.500 (.395)	.450 (.326)	.443 (.273)

[a]"Early" Positions Average = Proportion correctly recalled averaged over target positions 3, 4, 5, 6 and 7.

[b]"Recent" Positions Average = Proportion correctly recalled averaged over target positions 11, 13, and 15.

[c]Standard Deviations in parentheses.

Table 4

Means and Standard Deviations of Unbiased Primary Memory Estimates at Three Target Positions by Character List Type for Low Alphabetic Knowledge Groups

Character List Type	Unbiased Estimates of Recall Probability: Target Positions 11	13	15	Average Primary Memory Unbiased Estimate[a]
Orthographically Similar	.278 (.317)[b]	.056 (.248)	.222 (.304)	.185 (.178)
Phonologically Similar	.000 (.151)	.111 (.232)	.222 (.304)	.111 (.140)
Control	-.048 (.460)	.194 (.638)	.113 (.526)	.086 (.440)

[a]Average Primary Memory Unbiased Estimate = average of unbiased estimates at target positions 11, 13, and 15.

[b]Standard Deviations are in parentheses.

Results

Evidence of phonological interference effects (Hypothesis 1) was found using Dunnett's test for planned non-orthogonal comparisons. Among the HAK-groups raw score primary memory estimates were significantly lower for the High Phonological Similarity Character List as compared to the Control Character List, $|\underline{tD}|(2,27) = 3.60$, $\underline{p} < .01$. Primary memory recall probability among the LAK subjects did not differ significantly between the High Phonological Similarity Character List and the Control List for either the raw score estimate, $|\underline{tD}|(2,12) = 1.79$, $\underline{p} > .05$, or the unbiased estimate, $|\underline{tD}|(2,12) = 0.14$, $\underline{p} > .05$. Thus evidence of phonological interference in primary memory was observed among highly educated readers of Chinese, the HAK subjects, but not among the minimally educated readers, the LAK subjects.

The comparison between the High Orthographic Similarity Character List and the Control Character List using Dunnett's test for evidence regarding visual interference effects (Hypothesis 2) revealed that there were no significant differences in terms of raw score primary memory estimates for either the HAK-groups, $|\underline{tD}|(2,27) = 0.87$, $\underline{p} > .05$, or for LAK-groups, $|\underline{tD}|(2,12) = 1.34$, $\underline{p} > .05$. Similarly, the use of unbiased estimates of primary memory recall probability for the LAK subjects did not reveal any significant differences between the High Orthographic Similarity List and the Control List, $|\underline{tD}|(2,12) = 0.54$, $\underline{p} > .05$. These results indicate that there was no evidence for visual interference effects among either of the alphabetic knowledge groups.

Discussion

Hypothesis one, which predicted interference effects on the probe recall task for the phonologically similar character list, was supported by the performance of the High Alphabetic Knowledge subjects. This result is one which would have been expected on the basis of phonological recoding models of reading (Conrad, 1972; Rubenstein et al., 1973; Shankweiler & Liberman, 1976). The performance of the HAK-groups also paralleled the findings of other researchers who have used non-alphabetic stimuls materials (Erickson et al., 1977; Tzeng et al., 1977). Evidence of phonological recoding tactics among readers of Chinese provides cross-cultural support for the phonological recoding model and indirect support for the "phonological dependency" hypothesis of language processing capacity.

Hypothesis two predicted interference effects on the probe recall task for the list of orthographically similar characters relative to the control list. The data provide no support for this hypothesis since there were no significant differences among the HAK-groups in terms of recall performance on the High Orthographic Similarity List as compared to the Control List. Without evidence of interference effects due to orthographic similarity, the data from this study provide no support for the flexible decoding model (Goodman, 1967; LaBerge, 1972; Smith, 1971).

The findings regarding Hypothesis two are also relevant to questions about the validity of the "orthographic dependency" hypothesis. Graphemic recoding tactics were not observed among the subjects who participated in this experiment; consequently the prediction that users of a morphemographic system would use non-phonological recoding tactics was not supported. While the inability to reject the null version of Hypothesis two cannot be used to infer that there is no causal relationship between graphemic structure and information processing tactics, nevertheless, there is a convergence of non-significant graphemic interference effects among studies of readers of alphabetic and non-alphabetic orthographies (Conrad, 1972; Kintsch & Buschke, 1969; Erickson et al., 1977). This convergence of non-significant results casts doubt on the validity of the "orthographic dependency" hypothesis.

While the performance of the HAK-group conformed to the predictions derived from the phonological decoding model, the performance of the LAK-group did not correspond to the predictions from either the phonological recoding or flexible decoding model. Even after controlling for differences in estimates of secondary memory recall probability, there was still no evidence of treatment related interference effects in primary memory among the LAK-groups.

The absence of significant treatment effects among the LAK-groups may be explained with reference to a potential confounding variable, the reading ability of the subjects in the LAK-groups, since the information processing models described in the study only claim to account for the performance of <u>skilled</u> readers. It is assumed that tactics used by beginning readers may vary considerably from the tactics which have been acquired by the skilled reader. If the LAK subjects were not skilled readers of Chinese, then there is no reason to expect that either the phonological recoding or the flexible decoding model could be used to predict the performance of the LAK-groups on this probe recall task. While there was no independent assessment of reading ability, the overall lower recall performance of the LAK-group relative to the HAK-group could be interpreted as evidence of reading deficiencies among some of the LAK subjects. In this case, the absence of significant treatment effects has no direct bearing on the predictions derived from either model.

In general, the data from this probe recall experiment uphold the claim derived from the phonological recoding model that skilled readers of Chinese will use phonological recoding tactics to maintain information in primary memory during reading related activities. However, the strength of this conclusion is somewhat moderated by certain methodological difficulties.

The major factors limiting the interpretability and generalizability of the findings from this study were the size and composition of the LAK-group. Contrary to the intended goal of creating two groups of skilled readers of Chinese who differed only in terms of their relative degree of alphabetic knowledge, the members of the LAK-group differed considerably from members of the HAK-group in terms of educational background, occupation, and probably reading ability. The sample size of the LAK-group can be corrected easily in future studies. In contrast to problems of sample size, the failure to locate a highly educated group of skilled readers of Chinese who knew no English may not have been due to sampling error and thus not so easily rectified. In a modern urbanized environment like Hong Kong, know-ledge of English or some other foreign language may be a prerequisite for securing an advanced level of education. Future studies should search for the appropriate HAK and LAK groups among less urbanized speakers of Chinese.

A weakness related to differences in educational background was that reading ability was not assessed. As a result, there was no way to determine if the absence of primary memory interference effects among the LAK-groups was due to reading deficiencies or to the use of novel decoding tactics among the LAK subjects. This problem can be overcome in future studies by incorporating tests of reading ability to screen out poor readers.

The nature of the stimulus materials also limited some of the conclusions which could be drawn from this study. In a probe recall task, information processing tactics are inferred from recall differences between the control list and the treatment lists. If observed, lower recall on the treatment list is assumed to be due to interference in primary memory caused by the similarity among the coded forms of the items in the treatment list which overloads the subject's primary memory maintenance capacity. The yoked characters on the High Phonological Similarity list were homophonic but the yoked characters on the High Orthographic Similarity Character list were not homographic. Perhaps the absence of significant interference effects for the High Orthographic Similarity Character list was due to the use of characters which were not sufficiently similar along a visual dimension to overload primary memory maintenance capacity. In terms of visual similarity, this study suffers from a shortcoming which is also evident in the Erickson et al. study, i.e. the degree of visual similarity among the orthographically similar characters was not adequately assessed. In future studies, characters should be selected on the basis of visual and phonological confusability estimates which have been empirically determined by methods such as those used by Thomasson (1971) or Conrad (1972).

Implications for Further Research

The evidence of phonological interference effects in primary memory obtained in this study and the similar findings obtained by Tzeng et al. (1977) leads one to conclude that linguistic information from Chinese characters is maintained in primary memory at least in part by means of phonologically based codes. However, it has been claimed that the Chinese graphemic system does provide some degree of regular phonological information in as many as 90% of the characters (French, 1976). Of the graphemic systems in current use, Chinese may be the least analytic in terms of the phonological information represented in the characters, but nevertheless the characters may provide enough phonological information so that phonological recoding is an efficient tactic to use during reading. Thus, the question still remains: Do skilled readers of Chinese engage in phonological recoding because the system provides that information or is it that phonological information is incorporated into the orthographic system because readers are neurologically predisposed to phonologically based processing of linguistic information? Perhaps the best way to investigate this question, for readers of Chinese, would be to look for evidence of phonological, visual, or semantic coding tactics among beginning readers. In addition, reading research with Chinese children may provide important information concerning the relationship between graphemic structure and the information processing demands faced by the beginning reader.

Conclusions

In general the results from this probe recall experiment contribute to the growing body of cross-cultural research which demonstrates that skilled readers will use phonological recoding tactics in reading related activities. At the same time, this study offers no evidence that the Chinese subjects were engaging in visual recoding tactics. Thus, the cross-cultural applicability of the phonological recoding model has been supported by this study.

The evidence of phonological interference in primary memory among skilled readers of Chinese suggests that phonological recoding is a reading tactic which is closely tied to the human capacity to process speech input. The similarity among readers of Chinese, Japanese and English in terms of the information processing tactics used to maintain information during the probe recall task suggests that graphemic structure plays little if any role in the reading tactics used by skilled readers. Thus the existing data tend to offer support for the "phonological dependency" hypothesis rather than for the "orthographic dependency" hypothesis as an explanation for the prevalence of phonological recoding among skilled readers.

The results from this study indicate that cross-cultural research using non-alphabetic graphemic systems can provide a useful means for testing predictions derived from information processing models of reading. From a methodological perspective cross-cultural research poses both conceptual and logistic, difficulties but carefully designed studies can add a useful dimension to psychological and educational research. It is hoped that basic research with readers of non-alphabetic graphemic systems will lead to the development of effective reading program for users of all types of graphemic systems.

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Appendix A

Chinese Character Test Lists

High Phonological Similarity List Characters

		Cantonese Pronunciation	Equivalent English Noun(s)			Cantonese Pronunciation	Equivalent English Noun(s)
1(a)	油	jɐu^4	oil	5(a)	粥	dzuk^7	gruel; congee
1(b)	郵	jɐu^4	post office	5(b)	燭	dzuk^7	candle
2(a)	話	wa^6	language	6(a)	匠	dzoeŋ^6	worker; mechanic
2(b)	畫	wa^6	picture	6(b)	象	dzoeŋ^6	elephant
3(a)	科	fɔ^1	series; rank	7(a)	形	jiŋ^4	appearance
3(b)	窠	fɔ^1	hole; nest	7(b)	營	jiŋ^4	military post; camp
4(a)	式	sik^7	form; pattern	8(a)	圖	tou^4	plan; chart; map
4(b)	色	sik^7	color	8(b)	桃	tou^4	peach

High Orthographic Similarity List Characters

		Cantonese Pronunciation	Equivalent English Noun(s)			Cantonese Pronunciation	Equivalent English Noun(s)
1(a)	珠	dzy^{1}	pearls	5(a)	旅	loey^{5}	travelers
1(b)	球	kɐu^{4}	ball; sphere round; gem	5(b)	族	dzuk^{9}	class; tribe
2(a)	陽	joeŋ^{4}	male; sun	6(a)	銅	tuŋ^{4}	copper
2(b)	限	han^{6}	limit; boundary	6(b)	鍋	wɔ^{1}	pot
3(a)	終	dzun^{1}	end; death	7(a)	棉	min^{4}	cotton
3(b)	紙	dzi^{2}	paper	7(b)	棍	gwɐn^{3}	stick
4(a)	菓	gwɔ^{2}	fruit	8(a)	客	hak^{8}	visitor
4(b)	墓	mɔk^{9}	grave	8(b)	官	gun^{1}	officer

Control List Characters

		Cantonese Pronunciation	Equivalent English Noun(s)			Cantonese Pronunciation	Equivalent English Noun(s)
1(a)	袋	dɔi6	bag	5(a)	雲	wɐn4	clouds
1(b)	糧	loeŋ4	provisions; taxes	5(b)	秋	tsɐu1	autumn
2(a)	匪	fei2	vagabond	6(a)	湖	wu4	lake
2(b)	椅	ji1	chair	6(b)	盒	hɐp9	covered box
3(a)	熊	huŋ4	bear	7(a)	位	wɐi6	seat, throne
3(b)	餅	biŋ2	cake	7(b)	暇	ha6	leisure
4(a)	磚	dzyn1	brick	8(a)	階	gai1	steps
4(b)	琴	kɐm4	lute; organ	8(b)	舟	dzɐu1	ark; boat