

WORD SUPERIORITY IN CHINESE

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In a line of research that began with Cattell (1886), it has been demonstrated that words play a special role in the recognition of text. A letter string that forms a word is recognized faster and more accurately than a nonword string; a letter is recognized faster and more accurately if it is presented as part of a word than if it is presented alone or as part of nonword (e.g., Reicher, 1969; for a review, see Henderson, 1982). This constellation of findings, often referred to as "word superiority", suggests that the reader does not simply process the text letter by letter, and that words are crucial. The letters in a word are processed so automatically that the reader is unaware of recognizing them, and when he is required to report a letter presented in a word, he finds it most efficient to infer the identity of the letter from that of the word.

Most of these experiments, however, have been carried out for writing systems like that of English, in which the "frame" units (W. S.-Y. Wang, 1981) explicitly correspond to linguistic words. However, some writing systems lack this property, notably that of Chinese. The frames of the Chinese system, the characters, correspond to monomorphemic syllables, rather than to words, even though it is true that because there are many monosyllabic words in Chinese, there are many characters that stand for words as well as for syllables. But most Chinese words are polymorphemic and are therefore written with strings of two or more characters, and these strings are not specially demarcated in text. Moreover, there are many bound morphemes in Chinese, and a character for such a morpheme occurs *only* as an element of a character string.

It is of some importance to establish whether word superiority is observable in writing systems in which the frames are not words. If word superiority is not found in these systems, we would have to view the word superiority found for word-frame systems as merely orthographic, to be attributed, perhaps, to the reader's long experience in dealing with this particular kind of frame. In the case of Chinese, we would then expect to find evidence for the superiority of morphemic syllables. On the other hand, if word-superiority is found even when the frames of the writing system do not correspond to words, we would have to say that the superiority of the word must depend essentially on its linguistic rather than its orthographic status.

At least two other investigators have investigated word superiority in Chinese. C.-M. Cheng (1981) compared the accuracy with which a briefly presented target character could be identified in real-word and in nonword two-character strings. (A nonword consisted of two valid characters that did not constitute a real word.) A string con-

taining the target character was presented either preceding or following a "distractor" string, and the subject had to report whether the target character was in the first or the second string. Performance was better for words than for nonwords, and better for high-frequency words than for low-frequency words.

Cheng also carried out a second experiment, parallel to the first, in which the targets were radicals presented as components of real characters, or of pseudocharacters, or of noncharacters. Pseudocharacters were created by interchanging radicals in two real characters, keeping their position within the character constant; noncharacters were created by interchanging radicals and locating them in orthographically impossible positions. The character containing the target was presented either preceding or following a distractor character, and subjects had to report whether the target was in the first or the second character. Performance was better for real characters than for pseudocharacters, and better for pseudocharacters than for noncharacters. This result is consistent with a word-superiority effect for monomorphemic words; however, as Hoo-sain (1991) suggests, it is not conclusive. Because the real characters stood for morphemic syllables as well as for words, the result is equally consistent with morphemic-syllable superiority. It would be desirable to repeat the experiment, comparing characters standing for bound morphemes with characters for free morphemes.

I.-M. Liu (1988) asked subjects to pronounce the character occurring in first, second, or third position in word strings, in pseudoword strings or in isolation, and measured reaction time. (The position of a character in isolation apparently refers to the position of the same character when presented in a word or pseudoword.) Characters in real words were pronounced faster than characters in pseudowords in some though not in all positions. However, characters in isolation were pronounced as fast as, and in some positions faster than, characters in words. Thus, if an advantage for the real-word context over isolation is considered essential for word superiority, Chinese may not properly be said to exhibit this phenomenon and Cheng's first experiment may, as Liu argues, merely demonstrate "compound-word superiority".

But perhaps it is not reasonable to expect the real-word context to be superior to isolation if the target characters may themselves be words. We would not be surprised to find the advantage of words over single letters for English breaking down if /l/ or /a/, which happen to be words as well as letters, were the targets. Analysis of Liu's results for target characters standing for bound morphemes might clarify the issue.

The experiment reported here explores further the phenomenon of word-superiority in Chinese. We asked whether a character is recognized faster when part of a two-character word than when part of a two-character pseudoword. Our experiment thus complements Cheng's (1981) first experiment, in which accuracy of identification was the dependent variable. The paradigm we used was adapted from Meyer, Schvaneveldt, and Ruddy (1974) and has already been used for Chinese by C.-M. Cheng and S.-I. Shih (1988). In each trial in our experiment, a Chinese subject saw a sequence of two characters on a monitor screen. This sequence might consist of two genuine Chinese characters, which might form either a real word or a pseudoword. In either case the subject was to respond, "Yes". Alternatively, the sequence might consist of a genuine character preceded or followed by a pseudocharacter, in which case the subject was to respond, "No". Reaction time was measured for all responses.

Methods

Design

To make possible the various critical comparisons in which we were interested, a rather complex design was used; see Table I. There were three main types of two-character sequences: Real bimorphemic Chinese words; pseudowords, each, like Cheng's (1981) nonwords, consisting of two real characters that did not form a real word; and pseudocharacter sequences, each consisting of a real character preceded or followed by a pseudocharacter. The real characters were drawn from the inventory used in the People's Republic of China, and thus included some "simplified" characters not used elsewhere. The pseudocharacters, like Cheng's, each consisted of a genuine, appropriately located semantic radical and a genuine, appropriately located phonetic radical that do not actually occur together in the Chinese character inventory.

Table I Experimental Design

Sequence Type:	Real Words (128)				Pseudowords (128)				Pseudocharacter sequences(256)							
Word F:	High F (64)				Low F (64)											
Char F:	HH	HL	LH	LL	HH	HL	LH	LL	HH	HL	LH	LL	HN	LN	NH	NL
	16	16	16	16	16	16	16	16	32	32	32	32	64	64	64	64
Subj. Group:	A	4	4	4	4	4	4	4	8	8	8	8	16	16	16	16
	B	4	4	4	4	4	4	4	8	8	8	8	16	16	16	16
	C	4	4	4	4	4	4	4	8	8	8	8	16	16	16	16
	D	4	4	4	4	4	4	4	8	8	8	8	16	16	16	16

There were 128 real words, half of which were of relatively high frequency and half, of relatively low frequency. Each of these two *word*-frequency sets was divided into four secondary sets with the four possible *character*-frequency patterns: high-high, high-low, low-high, low-low. We relied on H. Wang et al. (1986) for information about word frequencies and character frequencies. Finally, each of these eight secondary sets was divided arbitrarily into four tertiary four-word sets A, B, C, D. There were in all 32 such tertiary sets. The average number of strokes per character was kept approximately equal across these tertiary sets.

There were 128 pseudowords. For each of the tertiary sets, four pseudowords were formed by swapping initial characters within the set, discarding any resulting real words. Thus, pseudowords were perfectly matched with real words with respect to character frequency.

There were 256 pseudocharacter sequences, each consisting of a real character and a pseudocharacter. Four pseudocharacter sequences were derived by swapping the semantic radicals of the word-initial characters within each of the original tertiary sets, discarding any resulting real characters. Four more pseudocharacter sequences were formed by repeating this operation with word-final characters.

From these materials, four different but equivalent tests were compiled. Each test included 32 real words, 32 pseudowords, and 64 pseudocharacter sequences. In a particular test, the real words, the pseudowords, and the pseudocharacter sequences were composed of unrelated tertiary sets. For example, one test consisted of set A real words, set B pseudowords, pseudocharacter sequences with word-initial pseudocharacters based on set C, and pseudocharacter sequences with word-final pseudocharacters based on set B. None of the 256 characters occurred more than once within a test, and each test was balanced with respect to word frequency, character-frequency pattern within a sequence, ordinal position of pseudocharacters, and number of strokes per character. Across the four tests, each of the original 256 real characters occurred equally often in a real word and in a pseudoword, and equally often in a real character sequence and in a pseudocharacter sequence.

Subjects

There were 53 subjects. All were speakers of Mandarin and graduate students or spouses of graduate students at the University of Connecticut. All had been born and educated in the People's Republic of China, and were thus familiar with the simplified characters. Subjects were paid for their participation in the experiment.

Procedure

Subjects were divided arbitrarily into four equal groups, and each group received a different test. Each subject was tested separately. A subject was told that on each trial in the test, he would see a sequence of two characters on the Macintosh computer monitor. If he was sure that both were genuine Chinese characters, he was to press the key designated as "Yes". Otherwise, he was to press the "No" key. The next trial began two seconds after the subject's response, or, if he failed to respond, two seconds after the sequence had appeared. Before the experiment began, the subject was given a 24-trial practice session with feedback.

Responses and reaction times were automatically recorded by the computer, using a program written by Leonard Katz and slightly modified by us. Reaction time for a trial was measured from the instant the two characters began to be written on the monitor screen. This measurement was subject to an error of ± 8.33 msec. because the write-time could not be known with any greater accuracy.

Results

The data for 13 subjects who responded with less than 90% accuracy were excluded from further analysis. For the remaining 40 subjects, the accuracy rates were 98.5% for real words, 92.2% for pseudowords, and 92.3% for pseudocharacter sequences.

Reaction-time data for the pseudocharacter sequences, for which the correct response was "No", are shown in Figure 1. Reaction times were shorter for pseudocharacter-initial than for pseudocharacter-final sequences. They were also shorter when the real character in the sequence was of high frequency than when it was of low frequency. However, real-character frequency had a much smaller effect for pseudocharacter-initial sequences than for pseudocharacter-final ones.

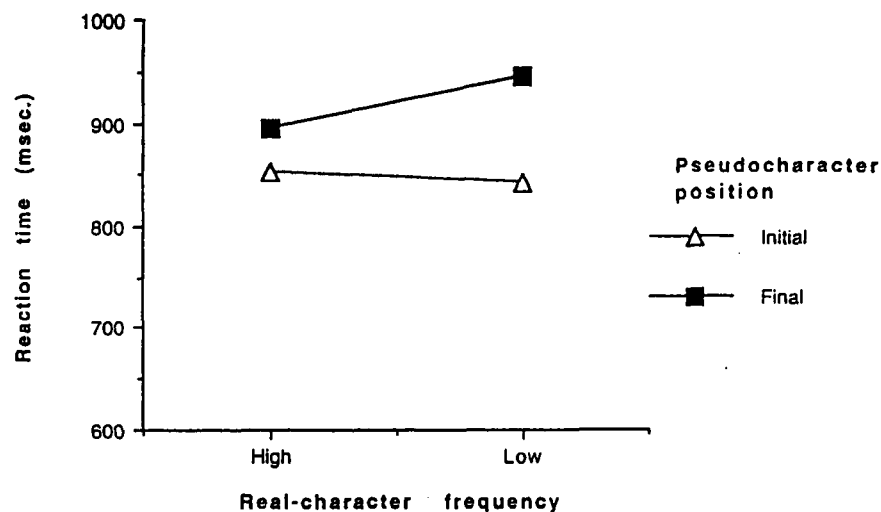


Figure 1. Reaction times for pseudocharacter sequences.

An analysis of variance was carried out on the pseudocharacter sequence data for which the factors were: Subject group (A/B/C/D), pseudocharacter position (initial/final), and real-character frequency (high/low). There was no effect of subject group: $F(3,36)=.729$. The effect of pseudocharacter position was highly significant: $F(1,36)=39.58$, $p \leq .0001$. The effect of real-character frequency was mildly significant: $F(1,36)=6.67$, $p < .05$. There was a highly significant interaction between pseudocharacter position and real-character frequency: $F(1,36)=14.40$, $p=.0005$.

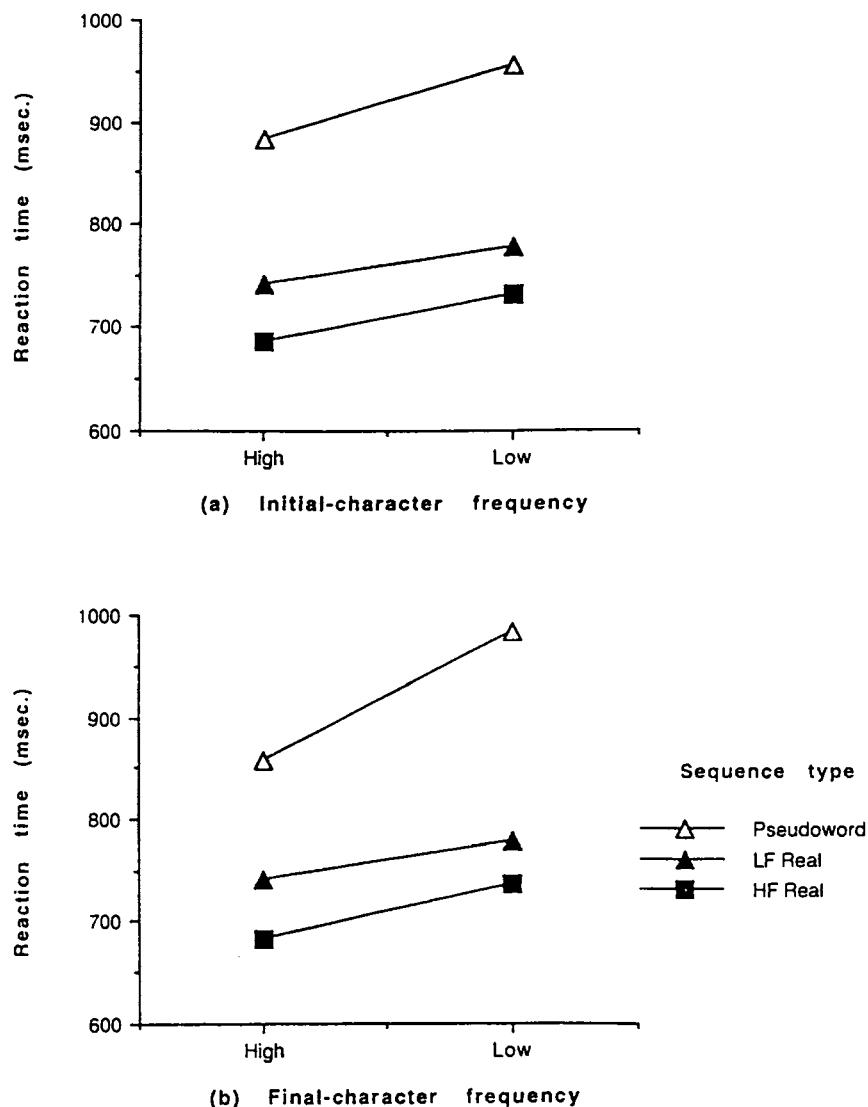


Figure 2. Reaction times for real word and pseudoword sequences as a function of initial- and final-character frequency.

The data for the real words and the pseudowords, for which the correct response was "Yes", are plotted in Figures 2a and 2b. Figure 2a shows the effect of varying initial character frequency; Figure 2b, the effect of varying final-character frequency. From both figures, it is apparent that reaction times are shorter for real words than for pseudowords, and shorter for high-frequency words than for low-frequency words. For both real words and pseudowords, reaction times are shorter for initial high-frequency characters than for initial low-frequency characters (Figure 2a) and similarly, shorter for final high-frequency characters than for final low-frequency characters (Figure 2b). However, reaction times for pseudowords are more affected by character frequency than are reaction times for real words.

An analysis of variance was carried out on the real and pseudoword data. The factors were: Subject group, sequence type (real word/pseudoword), initial-character frequency (high/low), and final-character frequency (high/low). There was no effect of subject group: $F(3,36) = .17$. The effect of sequence type was highly significant: $F(1,36) = 438.61$, $p < .0001$. The effects of both character-frequency factors were highly significant: Initial, $F(1,36) = 41.47$, $p \leq .0001$; final, $F(1,36) = 66.22$, $p \leq .0001$. There were significant interactions between sequence type and each of the character-frequency factors: Initial: $F(1,36) = 7.29$, $p < .05$; final: $F(1,36) = 19.31$, $p < .0001$.

An analysis of variance was carried out on the real word data alone to determine the effects of word frequency. The factors were: Subject group, word frequency (high/low), initial-character frequency, and final-character frequency. There was no effect of subject group: $F(3,36) = 32$. The effect of word frequency was highly significant: $F(1,36) = 19.79$, $p \leq .0001$. The effects of both character-frequency factors were highly significant: Initial, $F(1,36) = 15.03$, $p < .0005$; final, $F(1,36) = 18.31$, $p \leq .0001$. There was no interaction between word frequency and either of the character-frequency factors: Initial, $F(1,36) = .24$; final, $F(1,36) = .65$. There was a significant interaction among subject group, word frequency, initial character-frequency, final-character frequency: $F(3,36) = 6.56$, $p < .005$. We believe this interaction to be artifactual, reflecting an unfortunate choice of items in one of the tertiary subsets.

The pseudoword function in Figure 2b is steeper than the pseudoword function in Figure 2a, suggesting that character frequency has more of an effect in final position than in initial position. To explore further the effect of character-frequency order, reaction time data for high-low and low-high character-frequency patterns are plotted in Figure 3. For pseudowords, reaction times for the low-high pattern are shorter than for the high-low pattern. For real words, there is no comparable effect of character-frequency pattern.

An analysis of variance was carried out on the real and pseudoword data for the high-low and low-high patterns alone. The factors were: Subject group, sequence type, and character-frequency pattern (high-low/low-high). There was no effect of subject group: $F(3,36) = .23$. The effect of sequence type was significant: $F(1,36) = 209.35$. The effect of character-frequency pattern fell just short of significance: $F(1,36) = 3.86$, $p = .0571$. There was a significant interaction between sequence type and character-frequency pattern: $F(1,36) = 4.39$, $p < .05$.

An analysis of variance was also carried out for the high-low and low-high patterns in the real word data alone. The factors were: Subject group, word frequency, and character-frequency pattern. There was no effect of subject group: $F(3,36) = .24$. The effect of word frequency was significant: $F(1,36) = 21.45$, $p \leq .0001$. There was no effect of character-frequency pattern: $F(1,36) = .15$. There was no interaction between word-frequency and character-frequency pattern: $F(1,36) = .06$. There was a significant interaction between word frequency and subject group: $F(3,36) = 6.06$, $p < .005$. We believe this interaction has the same source as the artifactual interaction mentioned above.

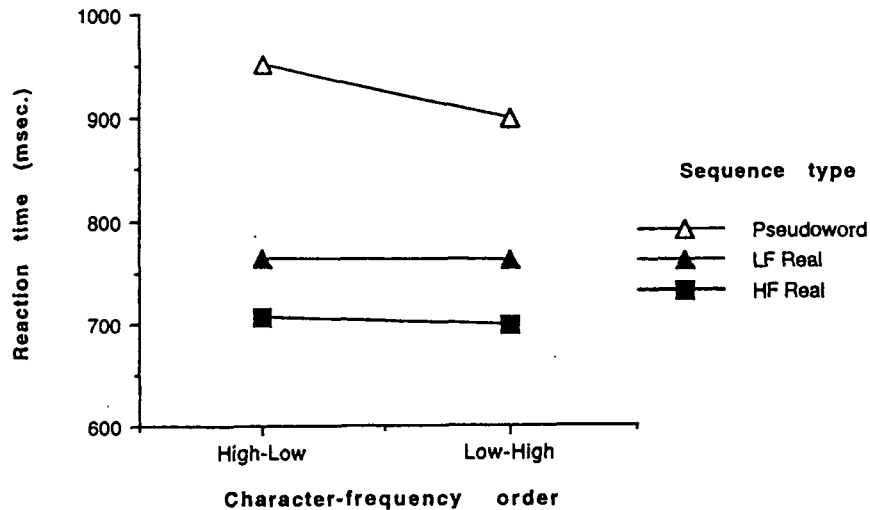


Figure 3. Reaction times to real and pseudoword sequences as a function of character-frequency order.

Discussion

These results complement those of Cheng (1981) and provide further evidence of a word superiority effect for Chinese. The key finding is that a character is evaluated more rapidly when part of a real-word sequence than when part of a pseudoword sequence (Figure 2a,b). The advantage for real words is consistent across differences in character-frequency pattern. The magnitude of the advantage, around 200 msec., is very large.

The results also reveal something about the basis of word superiority. Let us compare the way subjects deal with sequences that are real words and sequences that are not: the pseudocharacter sequences and the pseudowords. Common to all three

sequence types is the effect of character frequency (Figures 1,2a,b). We can conclude from this simply that word superiority is not magical: Word recognition in Chinese, whatever its other properties, is mediated by character identification. The recognition of a word is evidently facilitated by previous encounters with its characters in other words. On the other hand, the fact that we found a word-frequency effect (Figure 2 a,b), independent of the character-frequency effect, for a task ostensibly requiring only character recognition, suggests that word recognition cannot be simply a matter of recognizing one character at a time, then deciding that a character string is a word.

This proposal is supported by the fact that evidence of serial processing is found for pseudocharacter sequences and pseudowords, but not for words. In the case of the pseudocharacter sequences, it was found that sequences beginning with a pseudocharacter were rejected faster than those beginning with a real character, and that real-character frequency affected the latter but not the former (Figure 1). The obvious interpretation is that if the first character was genuine, the subject evaluated it, the amount of time required depending on the frequency of the character. Then he had to evaluate the pseudocharacter, which required more time, before he could reject the sequence. On the other hand, if the first character was a pseudocharacter, he could reject the sequence as soon as he could evaluate this character; there was no need to consider the second character at all. What is of interest here is simply that the subject is processing the characters serially.

As for the pseudowords, there was an effect of character-frequency order (Figure 3): The effect of character frequency was greater for the initial character than for the final character. Thus, a low-frequency character in initial position inhibited the response more than a high-frequency character in final position facilitated it; conversely, a high-frequency character in initial position facilitated the response more than a low-frequency character in final position inhibited it. We are not able to offer a conclusive explanation for this phenomenon without further experimentation, but it is plausible that when there was a low-frequency character in final position, the subject was apt to delay his evaluation, whereas he was less apt to do so when there was a low-frequency character in initial position because he had to hurry on to evaluate the final character. What is clear, however, is that the phenomenon is an order effect. It suggests that the characters in pseudowords, like those in pseudocharacter sequences, are being processed serially.

This is not the case for real words. There is no effect of character-frequency order (Figure 3). Given the order effects observed for the other two sequence types, this finding has two implications. It suggests first that the characters in real words are processed in parallel. Assume that the "logogens" (Morton, 1969) for Chinese are strings of characters corresponding to words. When a string matching a particular logogen appears in text, all of its constituent characters will be activated at the same or nearly the same time, just like the letters of an English word (Sperling, 1969). This means that in the case of a real word, a subject in our experiment would have had only one decision to make instead of two. Having recognized the word, he would have known immediately that both characters must be genuine. Much of the advantage of real words over pseudowords may be due to this fact.

The second implication is that if logogens for two or more character strings of unequal length are activated, the logogen for the longest string is preferred. For the present experiment, this means that a subject was not free to choose whether to treat a sequence as two separate monomorphemic characters or as a single bimorphemic word. Rather, bimorphemic logogens automatically took precedence if activated. Without this "Longest String Principle", the subject would have been free to waste time by processing the real words serially, just as if they were pseudowords. This principle also explains why readers of Chinese can read rapidly despite the absence of explicit word boundary markers in the text.

Conclusion

Word superiority has been demonstrated for Chinese, and it has been argued that it depends in great part on the reader's ability to process the characters of a word in parallel. Of course, it may be that Liu (1988) is right to insist that experiments like this one and the first experiment in Cheng (1981) demonstrate merely "Compound-word superiority"; the superiority of monomorphemic words remains in question. But even compound-word superiority is of great theoretical importance. Because there are no word boundaries in Chinese writing, our results are evidence that word superiority generally depends not on orthographic experience, but on linguistic experience.

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