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1042

The Role of Component Function in Visual Recognition of Chinese Characters

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M. Taft and X. Zhu (1997) reported that character decision latencies to real Chinese characters containing components that entered into many combinations were faster than decision latencies to characters with components that entered into only a small number of combinations. However, this effect was restricted to components that appeared on the right side of Chinese characters. In written Chinese, phonetic components tend to appear on the right, and semantic components tend to appear on the left. Therefore, in Taft and Zhu's study, there was the possibility of a confound between position (left vs. right) and function (semantic vs. phonetic). Results of the present experiment show combinability effects for components with semantic and with phonetic functions. Counter to the claim by Taft and Zhu that component frequency effects are constrained by position, when component function was considered, character decision latencies varied with component frequency but not reliably with position.

A recent study investigating component processing in written Chinese (Taft & Zhu, 1997) reported a position-sensitive effect of component frequency. That is, with surface frequency controlled, character decision latencies to real Chinese characters containing components that entered into many combinations were faster than decision latencies to characters with components that entered into only a few. This was true only for components that appeared on the right side of Chinese characters, however. Reminiscent of the left-to-right parsing account to specify access units in English (e.g., Taft & Forster, 1976), Taft and Zhu (1997) interpreted the position effect in written Chinese as evidence that the components of a character are activated in series from left to right. This finding, if valid, is potentially very important because the structure of Chinese differs from that in which most of the work on sublexical processing has been conducted. In particular, Chinese uses a logographic rather than an alphabetic writing system.

In written Chinese, each logogram corresponds to one morpheme, and the morphemes of the language are typically monosyllabic. Therefore, Chinese is sometimes described as a morphosyllabic or morphophonological system (DeFrancis, 1989; Perfetti & Zhang, 1995). The interweaving of component strokes within a character, together with the spatial separation between characters, makes each Chinese character a salient perceptual unit (Cheng, 1982; Hoosain, 1991; Tzeng, Hung, & Wang, 1977). Nevertheless, there is structure internal to Chinese characters. A majority of Chinese characters are compound characters, which consist of at least two components. To be more specific, in modern-day usage, only a small number of characters are not compounds and cannot be divided into components. More than 80% of characters are made up of a phonetic component and a semantic radical (Zhou, 1978; Zhu, 1988). We call these *phonetic compounds*, following standard terminology. (Note that there are other types of compound characters in Chinese—about 10% or fewer of all the Chinese characters.) In principle, the phonetic component of a phonetic compound (called "the phonetic" for short) reflects the pronunciation of the whole character, whereas the semantic radical ("the radical" for short) reflects its meaning. However, the validity of the two components differ. By some estimates, only 26.3% of phonetic compounds share a pronunciation identical with that of their phonetic (Fan, Gao, & Ao, 1984). Radicals tend to have semantic interpretations that are consistent with the semantics of whole characters (Fan, 1986). Nevertheless, there are exceptions. For example, 捌 meaning "eight" is formed from the semantic radical 扌 (meaning "hand" or "actions related to hand").

Semantic radicals tend to appear on the left side of phonetic compounds, whereas phonetic components tend to appear on the right side of phonetic compounds. In some cases, a component can appear only in a specific position. For example, the semantic radical 扌 (meaning "hand" or "actions related to hand") must appear on the left side of a character (e.g., 打, 折, 抄, 接, 托). However, in principle, it is possible for a component to appear in any position (left, right, top, bottom, or periphery) within a character. For example, the semantic radical, 山 (meaning "mountain"),

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can appear on the top (岗), at the bottom (峦), or on the left (峰). Moreover, it is possible for a component to function as a semantic radical in some characters and as a phonetic in others. For example, 火 (meaning "fire" and pronounced as /huo3/[1]) functions as a semantic radical in 灯 (the whole character means "light" and is pronounced as /deng1/) but functions as a phonetic component in 伙 (meaning "gang" and pronounced as /huo3/). Finally, although there are some differences in the positional flexibility of a component appearing in characters of the simplified script (used in mainland China and Singapore) as contrasted with the complex script (used in Hong Kong and Taiwan), this general characterization applies to both the simplified and complex scripts of written Chinese.

In Taft and Zhu's (1997) study, participants performed a character decision task that required judgments about whether compound characters which consisted of two (or more) components were legal Chinese characters. Components differed with respect to type frequency. In Experiment 1, components that appeared in more than 280 characters were classified as "high," whereas components that appeared in fewer than 69 characters were "low." A differential frequency effect (differences in character decision latencies for components with high and low frequencies) was examined for the right position as well as for the left. Results of that study indicated that for real characters, only the frequency of the component on the right affected positive decision latencies. The authors interpreted this outcome as evidence that the processing of the component that terminates last constrains decision latencies and that the components of a Chinese character are processed in a temporally overlapping series that proceeds from left to right (see Taft & Zhu, 1997, Figure 2).

Frequency of the right (or bottom), but not the left (or top), component was examined in Experiment 2, and the differential effect of component frequency was replicated. In particular, when character frequency and component frequency (computed over all positions) were matched and positional typicality of a component was manipulated, characters with components that frequently appeared on the right ($M = 69$) were responded to more accurately (and faster) than characters with components that rarely appeared on the right ($M = 14$). Taft and Zhu (1997) interpreted this outcome as evidence that decision latencies are constrained by a measure of frequency that is sensitive to the position in which a component typically occurs (p. 769).

Frequency counts for components in that study were based on the *Chinese Radical Position Frequency Dictionary* (1984), which considers 541 *bujian.* Bujian are components of a character, unconstrained with respect to either function or position. In essence, the count is based predominantly on graphic components of characters and only coincidentally includes semantic radicals and phonetic components. Because they based their statistics on this source, the frequency counts in Taft and Zhu's (1997) article reflect the tendency of both phonetic components and semantic radicals (as well as other units) to enter into compound characters.

As noted above, there is a potential problem because components on the right tend to have a phonetic function, and components on the left tend to have a semantic function. Taft and Zhu (1997) acknowledged the systematic relation between position and function and argued against the possibility that it compromised their results (pp. 772–773). They based their argument on the outcome of their Experiment 3. Materials were described as characters whose right unit was itself a character and was composed of two bujian. Results indicated that the frequency of the right unit did not affect response times, whereas the frequency of its internal bujian (which have no specific function analogous to that of phonetics) did affect response times. Because right units typically have a phonetic function and there was no frequency effect for those units, they argued that function was not important. It is worth nothing, however, that in Experiment 3, different frequency counts were used for the bujian (type frequency) and for the right unit formed from the two bujian (token frequency for the full unit in isolation as a character).

It is our claim that convincing assertions about the role of component position in the processing of written Chinese characters cannot be understood without also considering the function (semantic vs. phonetic) of a component. The results reported by Flores d'Arcais (1992) and summarized in Taft and Zhu's (1997, p. 764) article can be interpreted as support for this claim. That is, at some exposure durations, facilitation following exposure of a component was sensitive to the function of that component within the target character. Consequently, it is possible that the position-sensitive differential frequency effect observed by Taft and Zhu reflects the manner in which frequency was computed and the tendency, within a Chinese compound, for a systematic relation to exist between the position and the function of a component.

The present study was motivated by the finding (Taft & Zhu, 1997) that frequency of the right component influenced target decision time, whereas frequency of the left component did not, and the possible confound between position and function introduced by the way in which frequency was computed. To avoid confusion, we use the term *combinability* rather than *frequency,* Taft and Zhu's (1997) term. Semantic combinability reflects the tendency of a semantic radical to enter into few or many combinations to form phonetic and other types of compounds. It is defined primarily by function, not by form. Accordingly, complex and simplified versions were treated as the same component.

Stated generally, the present experiment looked for differential effects of component combinability and position in phonetic compounds with component function and whole character surface frequency held constant. By implication, it calls into question the evidence for left-to-right serial processing of Chinese compounds.

Method

Participants

Twenty students from the Beijing Business College in Beijing, China, all of whom were native speakers of Mandarin (Putonghua), participated in the study. They were paid for their participation.

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[1] The letters between the slashes indicate the *pinyin* (pronunciation) of the character, and the number indicates the tone.

Table 1
Experimental Materials Grouped by Attributes of Semantic Radicals

Attributes of phonetic compounds	Semantic radical on the left: High combinability radical	Semantic radical on the left: Low combinability radical	Semantic radical on the right: High combinability radical	Semantic radical on the right: Low combinability radical
Character	诲	躺	鸭	瓶
Character meaning	to teach	to lie (lay)	duck	vase
Character pronunciation	/hui4/	/tang3/	/ya1/	/ping2/
Semantic radical	讠	身	鸟	瓦
Semantic radical meaning	say, talk	body	bird	china
Phonetic component	每	尚	甲	并
Phonetic pronunciation	/mei3/	/shang4/	/jia3/	/bing4/
Average character frequency	171 (192)	173 (202)	161 (181)	169 (259)
Average combinability of semantic radicals	113 (49)	18 (8)	118 (45)	17 (11)
Average combinability of phonetic components	16 (6)	15 (7)	16 (5)	15 (4)
Average number of strokes	10.8	10.3	9.7	11.8

Note. Standard deviations are given in parentheses.

Materials

Materials consisted of Chinese compound characters (in the simplified script), all of which were composed of a semantic radical and a phonetic component. Semantic radical combinability and position were manipulated. For high-combinability semantic radicals, their occurrence in the corpus of about 6,000 characters contained in the *Xiandai Hanyu Cidian* [Modern Chinese Dictionary] (1992) was no less than 65, with an average of 116 ($SD = 48$). For low-combinability semantic radicals, their occurrence was no more than 36, with an average of 17 ($SD = 9$). For example, 诲 has a semantic radical, 讠, that enters into many combinations (160) and appears on the left. By contrast, 躺 has a semantic radical, 身 that enters into relatively few combinations (6) and appears on the left. 鸭 has a semantic radical, 鸟, that enters into many combinations (98) and appears on the right. Finally, 瓶 has a semantic radical, 瓦 that enters into relatively few combinations (17) and appears on the right. To enter into the count, only components that functioned as semantic radicals within a compound were considered.

All characters had semantically transparent radicals[2] with high or medium frequencies (no less than six occurrences per million), according to the *Xiandai Hanyu Pinlu Cidian* [Modern Chinese Frequency Dictionary] (1986). All noncharacter targets were constructed either by taking real characters and changing one or more strokes, or by combining two components that did not co-occur. They looked like real characters but had no meaning or pronunciation.

Design and Procedure

Four sets of 10 characters, each set matched for surface frequency as well as for number of strokes, phonetic combinability, and phonological validity of the phonetic (Perfetti, Zhang, & Berent, 1992) were created (see Table 1). Combinability and position of the semantic radical were manipulated within subjects. As a result, all participants saw the same items, and the items represented all combinations of semantic radical combinability (high vs. low) and semantic radical position (left vs. right).

Participants were tested individually in a character decision task. Experimental materials were presented on an IBM 486/66 microcomputer in white 24-point characters against a black background. Each item was approximately 0.9 cm × 1.2 cm (Width × Height). Participants were seated approximately 50 cm from the screen. As each visual pattern appeared on the screen, they had to indicate whether it was a real character of Chinese. They indicated a positive response by pressing the key that corresponded to their dominant hand and a negative response by pressing the key that corresponded to their nondominant hand.

Each trial began with the presentation of a fixation cross at the center of the screen for 1,000 ms, followed immediately by a target. The target remained on the screen until participants responded or until 2,000 ms had elapsed. The computer automatically measured the interval between the presentation of the target and the onset of a response. The stimuli were presented to participants in an identical pseudorandom order.

Results and Discussion

Errors and extreme response times (more than three standard deviations from the grand mean) were eliminated from all reaction-time analyses. Outliers constituted fewer than 2% of all responses. The data of 1 participant were excluded because of a high error rate (greater than 50%). Table 2 summarizes the mean recognition times and accuracy rates over participants for real characters.

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[2] The definition of semantic radical transparency or opacity depends on the character in which it appears. A radical can be semantically transparent in some characters and opaque in others. For example, the semantic radical 扌 that appears in 打 (meaning "to hit" or "to beat"), 拉 (meaning "to pull"), and 抱 (meaning "to embrace") is semantically transparent in these characters. However, it is semantically opaque in the character 捌 (meaning "eight").

Analyses of variance (ANOVAs) were performed on target latencies and errors for real characters, with participants (F_1) and items (F_2) as random variables. For real characters, there was a significant effect of combinability on decision latencies, $F_1(1, 18) = 5.00$, $p < .04$, $MSE = 6{,}066.33$; $F_2(1, 36) = 14.09$, $p < .001$, $MSE = 10{,}444.78$. High radical combinability facilitated target decision latencies relative to low radical combinability. The effect of position was not significant by either participants or items (both $Fs < 1$). The interaction of Position × Radical Combinability was significant by participants, $F_1(1, 18) = 4.78$, $p < .05$, $MSE = 4{,}441.59$, but missed significance by items ($F_2 < 1$).[3] No significant effect of position was found in the error data, $F_1(1, 18) = 1.41$, $p = .25$, $MSE = 0.47$; $F_2(1, 36) = 1.30$, $p = .262$, $MSE = 0.90$. Finally, neither the effect of combinability nor the interaction between position and combinability approached significance with the error measure (all $Fs < 1$).

The results of planned comparisons on decision latencies revealed an effect of combinability (33 ms) for semantic radicals on the left, $F_1(1, 18) = 14.09$, $p < .001$; $F_2(1, 18) = 4.93$, $p < .04$, but not for radicals on the right (2 ms). Evidently, the tendency for a radical to enter into many combinations to form compounds benefited processing. However, the differential frequency effect was significant for characters that contain semantic radicals on the left, but it could not be demonstrated for semantic radicals on the right. Although the reliability of the interaction is equivocal, it is clear that the present finding does not replicate that of Taft and Zhu (1997) because they found a differential frequency effect on the right but not on the left.

By definition, our combinability measure is sensitive to function. We have demonstrated that for semantic radicals, recognition is facilitated with increases in the number of characters in which a component appears. To buttress our claim that function must be considered in any investigation of combinability, we also conducted a post hoc analysis of the effect of phonetic combinability. By analogy with our counts for semantic radicals, we defined phonetic combinability in terms of the tendency for a phonetic to enter into many or few phonetic compounds. Counts were based on the *Xiandai Hanyu Duogongneng Zidian* [Modern Chinese Lexicon] (1995). Characters were classified according to position of the phonetic component (left vs. right) and phonetic combinability. High-combinability phonetic components had a mean of 19 and a range of 16 to 26. Low-combinability phonetics had a mean of 9 and a range of 2 to 14. Surface frequency, number of strokes, and semantic combinability were matched across conditions by including a subset of 32 characters (see Table 3). Table 4 summarizes the mean recognition times and error rates.

Table 2
Character Decision Latencies (in Milliseconds) and Error Rates (in Percentages)

Semantic radical combinability	Position of the semantic radical	
	Left	Right
High		
M	649	668
Error rate	2.1	3.7
Low		
M	682	670
Error rate	1.6	3.2

Results of an ANOVA indicated that the effect of phonetic combinability on decision latencies was significant by participants, $F_1(1, 18) = 21.39$, $p < .0005$, $MSE = 16{,}241.07$, and was marginal by items, $F_2(1, 28) = 3.76$, $p = .06$, $MSE = 9{,}316.13$. High phonetic combinability facilitated target decision latencies relative to low phonetic combinability. Neither the effect of position nor the interaction of Position × Phonetic Combinability was significant in analyses of either participants or items (all $Fs < 1$). No significant effects were found in the error data (all $Fs < 1$).

The results of planned comparisons on decision latencies revealed an effect of combinability for phonetic components on the left (24 ms) and on the right (33 ms) that was significant by participants, $F_1(1, 18) = 4.02$, $p < .05$, and $F_1(1, 18) = 8.66$, $p < .009$, respectively, though not by items, $F_2(1, 14) = 1.42$, $p = .25$, and $F_2(1, 14) = 2.37$, $p = .15$, respectively.

In summary, we have demonstrated an effect of component combinability for semantic radicals and for phonetics. For semantics, the interaction of Position × Combinability was significant by participants (although it did not even approach significance by items), and therefore it is possible that position of the semantic also plays a role in character recognition. For phonetics, there was no interaction with position. When semantics and phonetics are counted separately, combinability effects in character recognition are robust. Position effects, if they exist, are function dependent.

More reliable effects of combinability for left components than for right components are not consistent with Taft and Zhu's (1997) left-to-right serial account of character processing in Chinese (see Taft & Zhu, 1997, Figure 2). However, the present results are not inconsistent with an interactive-activation model of character processing such as theirs that incorporates subcharacter-level (e.g., strokes, phonetic, semantic) as well as character-level processing. Of course, a multilevel interactive-activation model need not predict effects that are position sensitive.

A critical difference between the present study and that of Taft and Zhu (1997) is the role of component function and, therefore, the way in which frequency or combinability was computed. On the basis of a sample of 4,516 Chinese characters from the *Xiandai Hanyu Cidian* [Modern Chinese Dictionary] (1992), we have estimated that approximately 75% of Chinese phonetic compounds have their semantic radical on the left. Of the remaining compounds, approximately 5% have the semantic on the right, 15% have the semantic on top, 4% have the semantic at the bottom, and fewer than 1% have the semantic on the periphery (see also Hoosain, 1991). Therefore, it is possible that the differential

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[3] Taft and Zhu (1997) did not explicitly report the results of the analysis of the interaction effect between position and combinability, nor did they report the main effects of these two variables.

Table 3
Experimental Materials Grouped by Attributes of Phonetic Components

Attributes of phonetic compounds	Phonetic component on the left: High combinability phonetic	Phonetic component on the left: Low combinability phonetic	Phonetic component on the right: High combinability phonetic	Phonetic component on the right: Low combinability phonetic
Character	郊	鸭	躺	诲
Character meaning	countryside	duck	to lie (lay)	to teach
Character pronunciation	/jiao1/	/ya1/	/tang3/	/hui4/
Semantic radical	阝	鸟	身	讠
Semantic radical meaning	country, area	bird	body	say, talk
Phonetic component	交	甲	尚	每
Phonetic pronunciation	/jiaol1/	/jia3/	/shang4/	/mei3/
Average character frequency	144 (197)	133 (192)	133 (108)	139 (220)
Average combinability of semantic radicals	75 (75)	73 (46)	78 (68)	70 (56)
Average combinability of phonetic components	19 (3)	10 (3)	19 (2)	8 (4)
Average number of strokes	12.1	10.1	11.5	10.3

Note. Standard deviations are given in parentheses.

frequency effect on the right reported by Taft and Zhu was based, at least in part, on attributes of the phonetic component. Our analysis of phonetic combinability is consistent with this interpretation.

It appears that combinability effects persist and position effects are tenuous at best when counts differentiate between components with a semantic as contrasted with a phonetic function. Taft (personal communication, January 25, 1997) has argued that the very fact that function and position are correlated in Chinese makes it unlikely that the method of calculation should affect the estimate of (relative) component frequency. This could be the case for the semantic combinability measure, but for the phonetic combinability measure, it is our intuition that it is not. We offer two reasons, both of which focus on counts of phonetic combinability. First, in our study at least, because the phonetic counts have an average of about 16 and range from 2 to 26 and the semantic counts have an average of about 60 and range from 2 to 235, the presence of a high-combinability semantic component in the phonetic count would have an exaggerated effect. Similarly, components that can function both as a phonetic and as a semantic radical would pose special problems. For example, the component 山 (bujian in the terminology of Taft & Zhu, 1997) has a count of 168 according to Taft and Zhu (1997). By our count, it has a value of 121 as a semantic radical and a value of 8 as a phonetic. A second problem is that most of the phonetic components (those that can stand alone as characters) are not listed in the *Chinese Radical Position Frequency Dictionary* (1984) used by Taft and Zhu.

Our results are consistent with the view that the structural properties of Chinese characters discourage left-to-right processing. Characters, as basic written units, are square shaped and occupy a uniform area in texts. Some characters possess a left–right construction (e.g., 课), whereas others have a top–bottom construction (e.g., 基). Still others have a circular (e.g., 国) or semicircular (e.g., 句) structure. If the components of complex characters were processed in a (directionally) serial way, the recognition of characters with circular or semicircular structure, as well as those with more complex structures, would be impossible. Indeed, a distinctive feature of many Chinese characters is the graphic complexity of their components. For example, the phonetic component (e.g., 𢦏, /zail/) of the character 栽 (/zail/) occupies three quadrants, whereas the semantic radical (e.g., 木) occupies one. Variation in graphic structure inherent to written Chinese contrasts sharply with the linear structure of most alphabetically transcribed languages and has been offered as an account of why character processing cannot proceed from left to right (Tan, Hoosain, & Siok, 1996).

In summary, like Taft and Zhu's (1997) results, our results indicate that character components are analyzed in character identification. What is less certain is whether there exist effects of position to be interpreted as evidence of left-to-right serial processing or whether a directionally serial account could meaningfully be applied to a nonalphabetic script such as Chinese. What we have demonstrated is that the frequency with which a component (semantic or pho-

Table 4
Mean Character Decision Latencies (in Milliseconds) for the Post Hoc Analysis

Phonetic component combinability	Position of the phonetic component: Left	Position of the phonetic component: Right
High		
M	661	651
Error rate	2.1	1.6
Low		
M	685	684
Error rate	3.2	2.1

netic) enters into combinations to form phonetic compounds in Chinese (combinability) influences character decision latencies and that when function of the component is considered, effects of position are inconsistent.

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