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CHAPTER

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Semantic Radicals in Phonetic Compounds: Implications for Visual Character Recognition in Chinese

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The Chinese writing system is generally considered to be logographic. Accordingly, the graphemes of written Chinese do not map onto individual phonemic units of the spoken language. Instead, each logogram corresponds to one morpheme. Moreover, the morphemes of the language are typically monosyllabic. Therefore, Chinese writing is sometimes described as a morphosyllabic or morphophonological system (DeFrancis, 1989; Perfetti & Zhang, 1995). The interweaving of component strokes within a character, together with spatial separation between characters, makes each Chinese character a salient and an integrated visual unit (Hoosain, 1991). Nevertheless, there is structure internal to the logographic character. One structural element of Chinese writing, the *semantic radical*, is evident only in the written language. Semantic radicals specify aspects of meaning, and they are not generally realized phonologically. A second structural element, the *phonetic component*, specifies aspects of a character's pronunciation, but does not reflect the meaning of the character. Because the semantic and phonetic components of Chinese compounds differ in function, the experimental study of reading in Chinese provides an approach to the study of reading that is inaccessible from the study of alphabetic writing systems. In an alphabetic orthography, letters combine to represent syllabic as well as morphological units. In contrast, in the logographic orthography of Chinese, components differ in function such that some components correspond to aspects of whole character phonology and others correspond to aspects of character meaning. In this chapter, we consider the functional differences between

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components and examine some of the implications for visual character recognition. We begin by describing this distinctive attribute of Chinese, that is, the differing contributions of the semantic and phonetic components to the phonological and semantic integrity of the phonetic compound.

SEMANTIC AND PHONETIC COMPONENTS CONTRASTED

Phonetic compounds constitute 90% of 4,574 characters in a 1,800,000-character corpus, according to the *Xiandai Hanyu Pinlu Cidian* [*Modern Chinese Frequency Dictionary*] (1986). This type of compound always includes both a phonetic component and a semantic radical. There are approximately 200 semantic radicals in modern Chinese, most of which cannot appear as characters and have no associated pronunciation. Therefore, on average, about 20 phonetic compounds are formed from each semantic radical. The *combinability* of a semantic radical reflects its tendency to enter into compounds. Although the combinability of semantic radicals in Chinese tends to be quite high, it is important to point out that there is substantial variability. Some semantic radicals appear in many compounds; others appear in only a very few. For example, the semantic radical 扌 (i.e., *hand*, or *the actions of hand*) appears in 328 phonetic compounds, whereas the semantic radical 身 (i.e., *body*) appears in only 6 phonetic compounds.

As when any language evolves, in Chinese there is a tendency for the semantic contribution of meaningful components to the meaning of the whole form to become progressively more opaque (Hoosain, 1991). The general consensus is that most Chinese semantic radicals still provide a useful cue to the meaning of whole characters. Jin (1985) observed that more than 90% of the phonetic compounds with the semantic radical 扌 have a meaning related to its semantic radical (i.e., *hand*, or *the actions of hand*). For example, 打 meaning *to hit* or *to beat*, 拉 meaning *to pull*, and 抱 meaning *to embrace*, all include the *hand* radical and have a meaning associated with the hand. In these characters, the semantic radical is semantically transparent.[1] Fan (1986) found that about 65% of phonetic compounds containing the semantic radical 纟 (meaning *silk* or *things related to silk fabric*) have at least aspects of their meaning that are consistent with the concept of silk. These studies indicate that the semantic contribution of

[1]Note that the definition of semantic radical transparency or opacity depends on the characters 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 defined as semantically transparent in these characters. However, it is defined as semantically opaque when it appears in 捌 (meaning "eight").

radicals is systematic with respect to the meaning of the compound. Although it is important to point out that the meaning of a compound itself may vary in its precision (Tan, Hoosain, & Peng, 1995), the meaning of a phonetic compound does tend to be at least partially transparent with respect to the meaning of its semantic radical. Nevertheless, there are exceptions. For example, 捌 meaning *eight* is also formed from the semantic radical 扌 (*hand*, or *the actions of hand*). In this example, the semantic radical is semantically opaque. In summary, somewhat like the morphemes of an alphabetic orthography, in written Chinese characters there exist meaningful orthographic components that tend to be related in a nonarbitrary manner to the meaning of the whole character.

The phonetic component, usually located in the right part of phonetic compounds, typically provides clues as to the pronunciation of the whole character. By one estimate, there are approximately 800 phonetic components (Taylor & Taylor, 1983). Relative to semantic radicals, the reliability with which phonetic components of characters specify the pronunciation of compounds is low. For example, Fan, Gao, and Ao (1984) found that 26.3% of 5,990 phonetic compounds are regular in that they have pronunciations identical to that of their phonetic component. This assessment is apparently based on a strict criterion, requiring both identical pronunciation and identical tone. Considering consistency and regularity of phonetics,[2] Zhou (1978) estimated that 38% of phonetic components have pronunciations that are consistent with that of their whole characters (see also Perfetti, Zhang, & Berent, 1992). Although assessments of the validity of phonetic components depend on researcher-defined criteria, the general consensus is that the phonetic cueing value of phonetic components is low (but see Mattingly & Ni, 1998), at least relative to the cueing value of semantic radicals. Extending the terminology of Perfetti and Tan (1998), one might claim that the mapping between written phonetic components and whole character phonology for compounds is less systematic than the mapping between written semantic radicals and whole character meaning.[3]

[2]A *consistent* phonetic has a pronunciation that is identical to the pronunciation of all characters that contain this phonetic. For an *inconsistent* phonetic, some whole characters containing this phonetic have pronunciation identical to that of its phonetic, but others do not. For example, all characters consisting of 家 (pronounced as /jia/, 稼 嫁 镓) are pronounced as /jia/, without exception. Therefore, 家 is a consistent phonetic. By contrast, some whole characters with the phonetic 加 (/jia/) are pronounced as /jia/ (e.g., 枷 驾 跏); some are pronounced as /qie/ (e.g., 茄 伽). As a result, 加 is an inconsistent phonetic. *Regularity* refers to whether a particular compound character has a pronunciation identical to that of its phonetic. If they have identical pronunciation, the character is considered *regular*. If they do not, it is *irregular*.

[3]This claim is based on the proportion of components that are related to the whole character. It assumes that similarity can be treated in an all-or-nothing fashion.

Much of the recent research in Chinese psycholinguistics focused on the issue of whether phonology contributes to character identification. Within the phonological domain, effects of sublexical phonology (i.e., the phonological correlate of the phonetic component) must be differentiated from the effects of whole character phonology. As for the role of phonetic components, the consensus is that there is no difference between regular and irregular phonetic components or between consistent and inconsistent phonetics in identifying frequently used compound characters in such tasks as naming and character decision. However, regular and consistent phonetic components do facilitate responses to low-frequency characters relative to irregular and inconsistent characters (Fang, Horng, & Tzeng, 1986; Hue, 1992; Seidenberg, 1985). These observations in Chinese parallel the word recognition research on phonological regularity and consistency in English (e.g., Baron & Strawson, 1976). It is also the case that with controls for surface frequency, character decision latencies to phonetic compounds with phonetics that are high in phonetic combinability (and therefore appear in many compounds) are faster than to compounds whose phonetics are low in combinability (Feldman & Siok, 1997). On the other hand, the time course of whole character phonological activation in Chinese character recognition remains less clear. One position is that phonological processing does not occur prior to lexical access for Chinese characters presented in isolation at relatively long exposure durations (e.g., Baron & Strawson, 1976; Chen, Yung, & Ng, 1988; Hoosain & Osgood, 1983; Leck, Weekes, & Chen, 1995). In contrast, studies with data-limited presentation conditions (e.g., backward masking) demonstrate an unequivocal role of whole character phonological information early in the course of character identification (Perfetti & Zhang, 1991, 1995; Tan et al., 1995; Tan, Hoosain, & Siok, 1996).

Research on the role of semantic radicals in character recognition is sparse relative to the work on the phonetic. Nevertheless, the results of two studies that examined the time course of orthographic and phonological information can be interpreted as suggesting an influence of semantic radicals in character recognition. One study (Leck et al., 1995) used a semantic categorization procedure that required subjects to decide whether or not a particular target character (e.g., 狐 meaning *fox* whose radical is 犭 meaning *beast* or *wild animal*) belongs to a particular semantic category (e.g., animal). For phonetic compounds, the false positive response rate to foils that shared the same semantic radical as the target (e.g., 猜 meaning *guess* whose semantic radical is 犭) was higher than that to control foils. However, the false positive response rate to foils that shared identical phonetic components with the target (e.g., 呱 /gua/ meaning *noisy* whose phonetic is 瓜 /gua/) was not different from that of controls. Because repetition of the semantic radical and of the phonetic component both introduce partial graphic similarity, it is unlikely that the effect is orthographic in origin.

In a backward-masking perceptual paradigm (Ju & Jackson, 1995), a target and a linguistic mask were presented in succession, and each target–linguistic mask pair was preceded and followed immediately by a pattern mask. The masks were presented for 30 ms. The exposure duration of the target was adjusted individually to maintain a 40% to 60% target identification rate. In the orthographic mask condition, more than 90% of the targets had a semantic radical identical to that of the mask, and the mask facilitated target recognition relative to controls. Ju and Jackson explained their finding as revealing the role of orthographic information in target recognition. Alternatively, this outcome, in conjunction with that of Leck et al. (1995), could be interpreted as evidence that the semantic characteristics of semantic radicals influence target recognition. That semantic radicals play a part in character categorization is compatible with the finding from compound Japanese kanji (Flores d'Arcais, Saito, & Kawakami, 1995), whereby the meaning of the component radicals was retrieved in a naming task, even when the radicals were not semantically related to the meaning of the whole character.

In summary, Chinese phonetic compounds are composed of two types of components that differ with respect to their function. We argue that an appreciation of the different nature of the components is essential to any investigation of how the visual units of Chinese are processed (Feldman & Siok, 1997; cf. Taft & Zhu, 1997). In the remainder of the chapter, we first describe descriptive and experimental variables that may influence the identification of components of compound characters. Then we present some evidence of our own for the processing of the semantic radical by skilled readers of Mandarin (Putonghua).

CHINESE CHARACTER RECOGNITION: DESCRIPTIVE AND EXPERIMENTAL VARIABLES

In written Chinese, there is little consensus about the psychologically relevant units for character recognition. Because characters are distinguished by fixed spaces in text and occupy a square area, irrespective of the number of strokes they possess, some researchers have assumed that characters are the basic units of visual recognition and mental representation (e.g., Hoosain, 1991; Morton, Sasanuma, Patterson, & Sakuma, 1992). Similarly, because the number of strokes in a character affects naming (Leong, Cheng, & Mulcahy, 1987) and character decision latencies (Tan & Peng, 1990), others have posited analysis of features such that the number of strokes in a character is an important factor in printed character identification (Flores d'Arcais, 1992; Huang, 1986; Leong et al., 1987; Tan et al., 1995). Finally, it is suggested that combinations of strokes constrained with respect to position (i.e., stroke patterns) are the relevant units of analysis (Chen, Allport, & Marshall, 1996)

Strokes combine to form components, and some researchers (e.g., Taft & Zhu, 1997) claimed that the components[4] of compound characters are decomposed in the course of recognizing a character. In a character decision task (Taft & Zhu, 1997), subjects made judgments about whether or not compound characters that consisted of two components were legal Chinese characters. Components differed with respect to type frequency. Components that appeared in more than 280 characters were classified as high in frequency, whereas components that appeared in fewer than 69 were low in frequency (Taft & Zhu, 1997, Experiment 1). They examined differences in character decision latencies for targets composed of high- and low-frequency components (i.e., a differential frequency effect). Because compound characters contained two components, the differential frequency effects were examined for the right position as well as for the left. Results indicated that the type frequency (the number of characters containing a particular component) of the right component affected decision times, whereas the type frequency of the left component did not. Taft and Zhu explained this outcome as suggesting that all components of a compound are activated sequentially in the process of character recognition. Their view is reminiscent of the left-to-right processing account for visually presented words in alphabetic orthographies (Taft & Forster, 1976) in that components of a character are activated in series. As originally described, this account is neutral with respect to the role of lexical variables (e.g., character frequency) in processing and focuses instead on sublexical events.

According to Taft and Zhu's view, the sublexical components that comprise a character must be analyzed position by position in order to recognize a character. Within this serial framework, some positions exert a greater influence on character identification latencies than do others. Our view, also analytic in nature, focuses on the function of components. A simple survey conducted in our lab, based on a sample of 4,516 phonetic compounds from *Xiandai Hanyu Cidian* [*Modern Chinese Dictionary*] (1992), estimates 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 on the bottom, and 1% have the semantic in the periphery (see also Hoosain, 1991, for another simple survey). In other words, semantic radicals tend to be on the left, and it is atypical for semantics to appear on the right. Serial accounts of how compounds are processed must consider the function (viz., semantic or phonetic) of the component.

In the Taft and Zhu study, frequency or combinability of components was based on the *Chinese Radical Position Frequency Dictionary* (1984). Listed in

[4]Taft and Zhu referred to all components as *radicals* irrespective of function.

that source are 541 *bujian*. Bujian are components of a character, unconstrained with respect to both function and 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 (1997) reflect the tendency of both phonetic components and semantic radicals (as well as other units) to enter into compound characters. It is possible, therefore, that the position-sensitive differential frequency effect they observed reflects the way in which frequency was computed.

EXPERIMENTAL EVIDENCE FOR THE PROCESSING OF RADICALS

As previously noted, there is little direct experimental evidence to date for the role of the semantic radical in recognition of Chinese characters, and the available evidence is generally tenuous (see also Zhou & Marslen-Wilson, chapter 3, this volume). Some experimental work of our own looks at the role of semantic radicals in the recognition of Chinese compound characters. Most of it is based on variants of the primed character decision task. Because radicals are written units that map onto meaning, the research entails comparing effects of semantic and graphic similarity among compound characters with the effects of a shared radical. The basic strategy in the second, third, and fourth experiments described later is to compare patterns of facilitation (and inhibition) for targets following primes that share various dimensions of similarity with the target, and to manipulate the temporal relationship between prime and target. The first experiment, however, looks at identification latencies for isolated compounds where properties of the radical are manipulated. In particular, the semantic radicals of characters differed with respect to the number of combinations they entered into to form characters (i.e., combinability). Effects significant by both subjects and by items are reported unless otherwise indicated.

Experiment 1: Radicals Influence Isolated Character Recognition: Effects of Combinability

One experiment conducted in our laboratory was motivated by the outcome of an experiment (Taft & Zhu, 1997) in which combinability of the right component influenced target decision time, whereas combinability of the left component did not. An effect of combinability for components on the right but not for components on the left is intriguing. While it is possible that the effect of combinability on target decision latencies is position sensitive, as Taft and Zhu claimed, it is also possible that the confound between position and function inherent in their frequency count contaminated the effect of combinability. Experiment 1 attempted to differentiate effects of position and function by using a combinability measure that is sensitive to function (see Feldman & Siok, 1997, for a more complete account).

We presented compound characters, all of which were composed of a radical and a phonetic, to subjects from the Beijing Business College in a character decision task. Semantic radical combinability and position were manipulated. For example, 诲 has a radical, 讠, that enters into many combinations (160) and appears on the left. By contrast, 躺 has a radical, 身, that enters into relatively few combinations (6) and appears on the left. 鸭 has a radical, 鸟, that enters into many combinations (98), but it appears on the right. Finally, 瓶 has a radical, 瓦, that enters into relatively few combinations (17) and appears on the right. All target characters had semantically transparent radicals with high or medium frequencies (no fewer than 6 occurrences per million), according to *Xiandai Hanyu Pinlu Cidian* [*Modern Chinese Frequency Dictionary*] (1986). Four sets of 10 characters, each set matched for surface frequency (171, 173, 161, 169, respectively) as well as number of strokes, combinability of the phonetic, and phonological regularity of the phonetic, were created. Combinability and position of the semantic radical were manipulated within subjects.

Character decision latencies revealed a main effect of combinability (33 ms) for radicals on the left, but not for radicals on the right (2 ms). High radical combinability benefited processing. However, the interaction of position by 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.[5] Analogously, in a post hoc analysis, when combinability of the phonetic was manipulated, there was an effect of combinability but no interaction with position. In summary, when combinability of semantic radicals and phonetic components are counted separately, combinability effects in character recognition are robust. Position effects, if they exist, are function dependent.

Experiment 2: Radicals Influence Primed Character Decision Latencies: Effects of Semantic Transparency

A second experiment was directed at semantic processing of the radical. Participants were native speakers of Mandarin (Putonghua) attending South China (Guangzhou) Normal University. Sixty-four targets, half with high-combinability semantic radicals and half with low-combinability semantic radicals, were presented in a character decision task. Targets followed primes at an SOA (stimulus onset asynchrony) of 243 ms. Across experimental lists, each target (e.g., 论 meaning *to say* or *to talk* and formed from the

[5]Taft and Zhu (1997) did not report the F values for the interaction effect between position and combinability (frequency), nor the main effects of these two variables.

radical 讠 meaning *say* or *related to the action of saying*) was preceded by four types of primes: (a) R+S+ primes (e.g., 评 meaning *to comment*) shared an identical semantic radical and were semantically related to the target. In this condition, the meaning of semantic radical was consistent with the meaning of both the target and the prime. That is, the radicals were semantically transparent; (b) R+S– primes (e.g., 诸 meaning *some* or *various*) shared an identical semantic radical with the target but were semantically unrelated to the target. In this condition, the semantic radical of the prime did not provide any clue as to the prime's meaning, thus it was semantically opaque; (c) R–S+ primes (e.g., 述 meaning *to speak*) were semantically related to the target but did not share a radical; and (d) R–S– control primes (e.g., 竿 meaning *stick*) were neither semantically related nor shared any component with the target (for further experimental details, consult Feldman & Siok, in press; Siok, 1996).

All targets were compounds composed of a phonetic component and a semantic radical. For high-combinability radicals, their occurrence in a corpus of about 6,000 characters contained in *Xiandai Hanyu Cidian* [*Modern Chinese Dictionary*] (1992) was no fewer than 56, with an average of 197 (SD = 215). For low-combinability radicals, their occurrence was no more than 41, with an average of 22 (SD = 9). All target characters had semantically transparent radicals with high or medium frequencies (no less than 10 occurrences per million), according to *Xiandai Hanyu Pinlu Cidian* [*Modern Chinese Frequency Dictionary*] (1986). The average surface frequency of the targets was 246 (SD = 294) for the high-combinability radical characters, and 254 (SD = 273) for the low-combinability radical characters. All primes had frequencies of no fewer than 4 occurrences per million. The average frequency among the four prime types did not differ significantly, and the average frequency of each prime type was lower than the average target frequency. Each radical appeared in only one prime-target pair.

For primes that shared a radical with the target, semantic transparencies ratings were obtained from 10 informants who were native Mandarin (Putonghua) speakers. They indicated their judgment by position on a 7-point scale where 1 indicated very low and 7 indicated very high. For primes in the R+S+ conditions, the average semantic cueing value was 5.7 (SD = .46). For primes in the R–S+ conditions, the average semantic cueing value was 1.8 (SD = .19). Finally, another 10 informants were asked to assess the semantic similarity of each prime-target pair in the R+S+ and R–S+ conditions, on a 7-point rating scale. The mean semantic relatedness value for the 64 targets and their R+S+ primes was 5.8 (SD = .51). For the same targets and their corresponding R–S+ primes, the mean semantic relatedness value was 5.9 (SD = .51). Based on semantic cueing ratings, semantically related primes with and without a shared radical were matched for semantic similarity to the target.

Decision latencies are summarized in Table 2.1. Results indicated that the effect of prime type was significant (see Table 2.1). At an SOA of 243 ms, semantically related primes with (R+S+) and without (R–S+) a shared radical produced equivalent (14 ms) and statistically significant facilitation relative to the unrelated control condition. By contrast, primes formed from the same radical where the meaning of the radical was semantically opaque (R+S–) produced significant inhibition (15 ms) relative to the unrelated control condition.

In addition to matching primes on dimensions of similarity to the target, combinability, a variable more directly reflective of properties of the radical, was explored. This variable is reminiscent of a measure on base morpheme productivity (in alphabetic studies of morphology) in that it reflects the size of the set of words in which a particular morpheme (more specifically, the set of characters in which a particular radical) can appear (Feldman, Frost, & Pnini, 1995).

The experimental manipulation of combinability entailed contrasting decision latencies for (different) isolated phonetic compounds formed from high- and low-combinability radicals. As previously discussed, a similar variable, radical frequency, was studied by Taft and Zhu (1997), although it is important to point out that the present definition differs from that of Taft and Zhu in that only semantic radicals entered into the count. In Experiment 1, there was evidence that radical combinability influenced character identification such that recognition latencies varied as a function of the number of compound character combinations a radical can enter into (see also Feldman & Siok, 1997). Analogous to a reciprocal activation perspective (see Andrews, 1989), characters with radicals that enter into many combinations would receive more reciprocal activation, or feedback, from their character "neighbors" and hence would be identified earlier. From an alternative perspective, density of representations for characters formed from the same

TABLE 2.1
Mean Response Latencies (ms) and Error Rates (%) for Targets as a Function of Radical Combinability and Prime Type in Siok (1996)

	Prime Type			
	R+S+	*R+S–*	*R–S+*	*Control*
High Combinability				
Mean	530	555	527	542
Facilitation	12*	–13*	15*	
Low Combinability				
Mean	537	569	540	552
Facilitation	15*	–17*	12*	

*$p < .05$.

semantic radical may be important such that characters that are members of large clusters benefit relative to those from clusters that are more sparse. In a priming task, processing of compound targets could be constrained by prior identification of the same radical in the prime, so that magnitude of facilitation varies with the combinability of the radical.

In Experiment 2, at an SOA of 243 ms, there was a main effect of combinability indicating that decision latencies for targets were sensitive to the number of combinations in which its radical could appear. With controls for character frequency, across all prime conditions, high-combinability targets were recognized significantly faster than targets in the low-combinability conditions. Importantly, combinability and prime type did not interact. That is, radicals influence how compounds are processed, but similar effects are observed across all prime types.

Finally, semantic transparency scores (from semantic cueing values) were correlated with the difference in response times between R+S+ and controls and between R+S– and controls. The correlation (based on item means) was significant ($r = .43$, $p < .001$). That is, semantic transparency of the radical is associated with the direction of priming, either facilitation or inhibition.

In summary, effects of the radical of the prime on target decision latencies were demonstrated. Varying dimensions of similarity were assessed relative to the same target, and only prime characteristics varied across conditions. Target latencies were significantly faster following semantically related primes (R–S+) relative to controls. This outcome demonstrates whole character semantic relatedness at an SOA of 243 ms. More relevant to our program of research on processing of the semantic radical, the effect on the target of repeating the semantic radical in prime and target varied as a function of semantic transparency. When the meaning of the radical was transparent in both the prime and the target, significant facilitation was observed. When the meaning of the radical was transparent in the target but opaque in the prime, inhibition was observed. This outcome is critical in that it reveals that it is the semantic dimension of the radical that is detected when primes and targets are offset by an SOA of 243 ms. In Experiment 2, it is important to note that we cannot exclude the possibility that the orthographic form of the radical also plays a role. In particular, facilitation due to whole character semantic relatedness and inhibition due to orthographic similarity based on a shared semantic can account for much of the data.[6] Experiment 3 was designed to differentiate more directly the

[6]Without facilitation following R+S+ primes (see Zhou & Marslen-Wilson, chapter 3, this volume), there would be no compelling evidence for semantic processing of the radical. A null effect following R+S+ primes in conjunction with R–S+ facilitation and R+S– inhibition can be interpreted as evidence of whole character semantic facilitation (S+) combined with orthographic inhibition due to repetition of the radical (R+). We suspect that multiple presentations of the same radical within the same session may have attenuated R+S+ facilitation in the Zhou and Marslen-Wilson study (chapter 3, this volume).

contribution of orthographic similarity from semantic transparency of the radical in the character recognition task.

Experiment 3: Radicals Influence Character Decision Latencies: Temporally Constrained Orthographic Facilitation

Further support for the claim that radicals are processed semantically comes from another study (Siok & Feldman, 1998) that included visually similar primes in addition to R+S+, R+S–, and R–S+ primes. Visually similar primes were generally formed from a radical that differed from the radical of the target by only one or two strokes. For example, the radical 礻 (meaning *god, ceremony,* or *sacred*) differs from the radical 衤 (meaning *clothes*) by the addition of only one stroke. Construction of experimental materials was based on judgments of visual similarity by 10 informants from Beijing Business College. Surface frequency and number of strokes were matched across conditions. Materials were presented to 145 subjects from Beijing Business College at SOAs of 243 ms and 43 ms. SOA was manipulated between subjects.

As summarized in Table 2.2, results indicated that at a 243 ms SOA, visually similar primes had no significant effect (5 ms), whereas, in replication of the previous experiment, R+S+ primes facilitated (22 ms) and R+S– primes inhibited (–22 ms). Because R+S+ and R+S– primes were equated for visual similarity to the target, and because visually similar primes had no effect on target decision latencies, it is unlikely that the inhibition in the R+S– condition can be attributed to graphic similarity. Nevertheless, when the same primes and targets were presented with an SOA of 43 ms, visually similar primes and R+S– primes both produced statistically equivalent facilitation. Evidently, orthographic similarity between characters can provide a source of facilitation at very short SOAs. Moreover, this outcome suggests that the visually similar primes were in fact comparable to R+S– primes in their similarity to targets. In summary, whereas R+S– primes produced facilitation at 43 ms, they produced inhibition at 243 ms. The comparison across SOAs suggests that the effect of semantic inconsistency of the radical is evident by 243 ms. Before that, only its orthographic similarity with the target has an effect.

A fuller interpretation of the effect of semantic inconsistency in R+S– compounds rests on further investigation. In particular, it is not yet clear whether inhibition reflects complexities of recognizing the prime itself or the effect of recognizing the prime on subsequent recognition of the target.

In summary, Experiment 3 provides further evidence for the semantic radical as a psychologically relevant unit of processing in the visual recognition of Chinese compounds. Primes that were visually similar to the target

TABLE 2.2
Mean Response Latencies (ms) and Error Rates (%) for Targets as a Function of Prime Type in Siok and Feldman (1998)

	Prime type				
	R+S+	*R+S–*	*Visually Similar*	*R–S+*	*Control*
SOA = 43 ms					
Mean	700	723	726	723	760
Facilitation	+60*	+37*	+34*	+37*	
SOA = 243 ms					
Mean	682	726	699	683	704
Facilitation	+22*	–22*	+5	+21*	

*$p < .05$.

had a facilitatory effect on target recognition latencies at 43 ms and had no effect at 243 ms, whereas R+S– primes had a facilitatory effect at 43 ms and an inhibitory effect at 243 ms. Facilitation following semantically related primes (R–S+) was evident even at an SOA of 43 ms.[7] Finally, target latencies following semantically related primes with (R+S+) and without (R–S+) a shared radical differed, but only at the 43 ms SOA. Collectively, these findings suggest that, although the orthographic information of semantic radicals is available in the 43 ms SOA condition, by 243 ms, the orthographic characteristics of the prime and target radical do not dominate processing. With the longer SOA, the semantic aspects of the radical play a critical role in character decision.

Experiment 4: Effects of Repeating a Radical at Long Lags

The temporal relation between prime and target in Experiment 3 was manipulated in order to track the time courses of the orthographic, semantic, and shared radical dimensions of similarity between prime and target. In contrast, in Experiment 4, the temporal relationship between prime and target was defined so as to minimize the independent contributions of orthographic and semantic similarity.

From the study of morphological processing in alphabetically transcribed languages, we know that when many (viz., 7 to 13) items intervene between prime and target, the prior presentation of a word that is similar in form but morphologically unrelated has no effect on target recognition (e.g.,

[7]Perfetti and Tan (1998) report that the effect of semantic relatedness in the naming task becomes evident after 85 ms. This value must be contingent on attributes of the experimental materials (e.g., frequency, semantic vagueness, homophony) as well as on the task. In no way does our finding conflict with their claim.

Feldman & Andjelković, 1992; Feldman & Moskovljević, 1987; Grainger, Colé, & Segui, 1991; Hanson & Wilkenfeld, 1985; Laudanna, Badecker, & Caramazza, 1992; Murrell & Morton, 1974; Napps & Fowler, 1987; Segui & Grainger, 1990; Stolz & Feldman, 1995). Similarly, effects of semantic relatedness between prime and target are also absent at intervals of 7 to 13 items (Bentin & Feldman, 1990). By analogy with the work on morphological processing, increasing the interval between presentation of prime and target should eliminate effects of orthographic similarity and whole form semantic relatedness.

In Experiment 4, participants responded to every character they saw, and the designations of "prime" and "target" simply reflected earlier or later presentations of a character formed from a particular radical within the experimental list. Related pairs were separated by an average of 10 intervening items. The materials and the task were the same as in Experiment 2.

Results of Experiment 4 revealed a main effect of prime type (R+S+, R+S–, R–S+, and unrelated), but no effect of radical combinability and no interaction of prime type by radical combinability when several items separated prime and target. Post hoc multiple comparisons indicated that R+S+ primes produced significant facilitation (16 ms). R+S– primes produced no significant effect (7 ms), nor did R–S+ primes (3 ms). That is, at long lags, only semantically transparent radicals in primes facilitated target decision latencies.

The outcome of Experiment 4 provided further evidence for the radical as a unit of processing in written Chinese compounds. Facilitation was evident under temporal conditions that do not reveal effects of orthographic similarity due to a shared radical or semantic relatedness between full forms that do not share a radical. Nevertheless, in the semantically transparent (R+S+) condition, orthographic similarity occurred in conjunction with semantic similarity. Under these conditions, long-term facilitation due to repetition of a radical with multiple intervening items was observed.

CONCLUDING REMARKS

Across four experiments, we demonstrated that the semantic radical is a unit of processing in the character recognition task in Chinese. An effect of radical combinability was demonstrated for compounds both in a character decision task for single characters and in a primed character decision task. The comparison of target latencies following various types of primes and at various SOAs provides insight into when particular dimensions of the semantic radical are psychologically salient.

When the prime is processed for only a very short period (43 ms) before onset of the target, the visual attributes of the radical seem to predominate.

When processing of the prime proceeds for 243 ms before presentation of the target, semantic transparency of the radical plays a salient role in target identification. Semantic transparency in both the prime and target (or the consistency of the semantic contribution of the radical to the meaning of the prime and the target) facilitates recognition, whereas semantic opacity (or the inconsistency of the semantic contribution of the radical to the prime relative to the target) typically hurts. Finally, after several intervening items, effects of a radical shared by prime and target are evident only when orthographic similarity and semantic relatedness co-occur. This condition arises with semantically transparent radicals.

In summary, we demonstrated that combinability, a function-specific attribute of components (e.g., semantic radicals), influences latencies in the character decision task, and that the semantic attributes of semantic radicals are activated in the course of character recognition in Chinese.

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