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Binding radicals in Chinese character recognition: Evidence from repetition blindness

Yi-Chuan Chen, Su-Ling Yeh *

Department of Psychology, National Taiwan University, Taipei, Taiwan

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ABSTRACT

Many Chinese characters consist of two radicals and it has long been debated whether characters are decomposed into radicals during the processing of character recognition. Here we examine this issue utilizing a novel repetition blindness (RB) paradigm that provides a sensitive measure of internal representations in the early stages of processing. We found a radical-RB effect (i.e., two characters are less likely to be correctly reported when they share a common radical) for both high- and low-frequency characters (Experiment 1). Experiment 2 was to exclude the possibility that radical-RB effect can be explained by character-level similarity. Finally, the radical-RB effect was found to be robust irrespective of how frequently a radical is presented in different characters (Experiment 3). All these results suggest that radicals are represented during the processing of characters, supporting the analytic (rather than holistic) hypothesis of Chinese character recognition. A model that highlights a dynamic process of binding radicals to construct character representations is proposed.

Introduction

How words are recognized is a critical issue in understanding the process of reading English (see Rastle & Davis, 2008, for a review). Take a word comprised of multiple morphemes (such as *teacher* consisting of *teach* and *er*) for example. These words are likely decomposed into morphemes at an early stage and serve as mediators to access the mental lexicon (e.g., Longtin & Meunier, 2005; Rastle, Davis, & New, 2004; Taft, 1994, 2003). On the other hand, a word may be recognized holistically and its decomposition into morphemes only occurs after lexical access (Marslen-Wilson, Tyler, Waksler, & Older, 1994; Plaut & Gonnerman, 2000; Rueckl & Raveh, 1999). The issues about Chinese character recognition have been undergoing a very similar debate although Chinese script is a completely different writing system from English. The primary goal of the present study is to investigate whether Chinese characters are necessarily decomposed into sub-character units in the orthographic processing.

Holistic vs. analytic hypothesis of Chinese character processing

About 70–80% of traditional Chinese characters are *phonograms* (形聲字 [síng sheng zìh]), consisting of two radicals. Take the phonogram 楓 ([fong], "maple") for example. It contains two radicals at different *positions*: 木 on the left and 風 on the right. In addition, the two radicals carry different *functions*: the radical 木 ([mù], "tree") conveys the semantic category, and the radical 風 ([fong], "wind") provides a phonological cue of the whole character. Accordingly, 木 is semantic radical (部首 [bù shǒu]) and 風 is the phonetic radical (聲旁 [sheng páng]) of the

* Corresponding author at: Department of Psychology, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 106, Taiwan. Fax: +886 2 23629909.

E-mail address: suling@ntu.edu.tw (S.-L. Yeh).

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character 楓 (see Liu, Su, & Chen, 2001; Zhou, Ye, Cheung, & Chen, 2009). In general, 75% of the phonograms consist of a semantic radical on the left and a phonetic radical on the right (Perfetti & Tan, 1999). That the meaning and the sound of a character are conveyed by different radicals in a phonogram is a unique property of Chinese characters, though the mappings between radicals and a character are not always as close as in the above example.

In a Chinese text, each character occupies a constant size irrespective of the visual complexity (i.e., the number of constituent strokes). In addition, each character usually corresponds to one syllable and one morpheme (e.g., Taft, 2006). These properties suggest a *holistic hypothesis* that each character itself is an orthographic processing unit (e.g., Chen & Liu, 2000). Radicals are then processed *after* the recognition of characters if the task requires the decomposition of characters into radicals; for example, when the participants were instructed to detect the occurrence of a particular radical embedded in characters (e.g., Chen, 1984; Cheng, 1981; Tao & Healy, 2002; Yu, Cao, Feng, & Li, 1990).[1]

Later studies propose an *analytic hypothesis* that radicals are processed first and then combined in order to access a character representation. This hypothesis is supported by studies demonstrating that character recognition is influenced by certain properties of radicals. These properties include position (or structure) of radicals (i.e., how radicals are arranged in a character, see Taft & Zhu, 1997; Taft, Zhu, & Peng, 1999 ; Yeh & Li, 2002; Yeh, Li, & Chen, 1997) and the function of radicals (i.e., whether a semantic or phonetic radical provides information to a character, see Fang, Horng, & Tzeng, 1986; Feldman & Siok, 1999a; Flores d'Arcais, Saito, & Kawakami, 1995; Leck, Weekes, & Chen, 1995; Liu, Chen, & Sue, 2003; Seidenberg, 1985).

Evidence for analytic, holistic, or hybrid hypothesis from the character decision task

Character decision task (CDT, Taft, 2006) is the most frequently used paradigm that examines the orthographic processing of Chinese characters.[2] In this task, participants are instructed to discriminate whether the target is a character or non-character as soon and as accurately as possible. Participants' correct reaction times (RTs) in character trials are analyzed. A typical result of CDT demonstrates that participants' mean RT is faster for recognizing high-frequency (HF) characters than low-frequency (LF) characters (Liu, Wu, & Chou, 1996; Zhu & Taft, 1994).

The results utilizing CDT to examine the character decomposition process are, nevertheless, inconsistent. For example, *radical combinability* (the number of characters containing a given radical, see Feldman & Siok, 1997; or called *radical frequency* in Taft & Zhu, 1997) has been shown to influence CDT results. That is, participants' RT was shorter when the target character consisted of a high-combinability radical rather than a low-combinability one. However, such radical effects in CDT are often observed only in LF characters, but not necessarily in HF characters (e.g., Ding, Peng, & Taft, 2004; Li & Chen, 1999; Zhu & Taft, 1994). Evidence from CDT cannot be used to verify either the analytic or holistic hypothesis because each is supported by studies using only a subgroup of characters. One explanation is that LF characters are processed analytically, whereas HF characters are processed holistically due to familiarity (i.e., the unitization hypothesis, Healy, 1994; Tao & Healy, 2002). This third hypothesis suggests that the mechanism of Chinese character recognition is a *hybrid* of analytic and holistic processing.

An alternative explanation regarding the radical effects observed only in LF but not in HF characters is proposed by Ding et al. (2004, p. 532): HF characters reach their recognition threshold rapidly, and thus participants' RT to judge them is too short to reveal any facilitatory effect elicited by high-combinability radicals. This explanation, therefore, suggests a limitation that the CDT method is perhaps not sensitive enough to probe radical representations in HF character processing.

Another series of studies has examined the orthographic priming effect between two characters by presenting the target of CDT following a prime character that shares a radical (known as *primed-CDT*). Once again, contrary results have been reported, especially between those studies in which prime and target are presented at very similar stimulus onset asynchronies (SOAs). For example, Ding et al. (2004) and Feldman and Siok (1999a) reported a *facilitatory* effect when prime and target had a common radical (i.e., the RTs were shorter as compared to when they had no common radical) when the SOA was 43 ms. This facilitatory effect was only observed when the *target* was a LF character rather than a HF character, thus suggesting that the positive priming effect was elicited by the shared radical representation (Ding et al., 2004). On the other hand, Wu and colleagues (Wu & Chen, 2000, 2003; Wu & Chou, 2000) reported an *inhibitory* effect when prime and target shared a common radical (i.e., the RTs were longer as compared to when they had no common radical) when the SOA was 50 ms. Wu and Chen (2003) further demonstrated that the inhibition was only elicited by a *HF prime* rather than a LF or a pseudo-character prime. Wu and Chen suggested that this orthographic inhibitory effect is attributed to the fact that the quickly-activated character representation (i.e., the HF prime) inhibits representations of other orthographically-similar characters (including the target) during lexical access (i.e., a character-level inhibition), while radicals embedded in a character were not represented. These discrepant results, as well as the different mechanisms proposed regarding the priming at the radical or character level, are likely determined by the level at which the *prime* character was processed

[1] Utilizing a radical detection task that relies on participants' explicit report of the target radical may probe a conscious hierarchical processing which constitutes a reversed order of the unconscious hierarchical processing (e.g., Hochstein & Ahissar, 2002). That is, it is likely that radicals are processed before characters in the unconscious processing, whereas characters reach conscious level before radicals in the conscious processing (see Chen & Yeh, 2009). Therefore, discrepant results observed using explicit tasks (such as radical detection task) vs. implicit tasks (such as the character detection task) regarding radicals are very likely due to different mechanisms being probed.

[2] Naming task is another commonly-used paradigm to study Chinese character recognition. Nevertheless, naming task is often used to examine the function of phonetic radicals, and this is beyond the scope of the present study.