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On the segmentation of Chinese words during reading

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ABSTRACT

Given that there are no spaces between words in Chinese, how words are segmented when reading is something of a mystery. Four Chinese characters, which either constituted one 4-character word or two 2-character words, were shown briefly to subjects. Subjects were quite accurate in reporting the 4-character word, but could usually only report the first 2-character word, demonstrating that word segmentation influences character recognition. The results suggest that even with these simple 4-character strings, there is an element of seriality in reading Chinese words: processing is initially focused at least to some extent on the first word. We also found that the processing of characters that are not consistent with the context is inhibited, suggesting inhibition from word representations to character representations. A simple model of Chinese word segmentation and word recognition is presented to account for the data.

1. Introduction

Words are generally regarded as the basic meaningful unit of language. In English, bottom-up information provided by the spaces between words can be used by readers to segment words. However, in Chinese, there are no spaces between the words. In fact, Chinese readers don't always agree on where the word boundaries are. Yet, it is clear that words are important in reading Chinese, because word frequency and word predictability effects for Chinese readers are comparable to those of readers of English (Rayner, Li, Juhasz, & Yan, 2005; Yan, Tian, Bai, & Rayner, 2006). Chinese sentences consist of characters that vary in complexity, but each character fits within the same sized square region;

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these characters are only separated by punctuation marks. How words are segmented in Chinese is an important question that we address in the present article.

In the last decade, a number of studies have examined the issue of Chinese word segmentation. Studies in which spaces were added between Chinese words have generally found no benefit for Chinese reading (Hsu & Huang, 2000a, 2000b; Inhoff, Liu, Wang, & Fu, 1997). However, Bai, Yan, Liversedge, Zang, and Rayner (2008) recently demonstrated that adding spaces between characters interfered with reading, while adding spaces between words yielded reading performance that did not differ from reading with normal non-spaced Chinese text. In many ways, it is remarkable that inserting spaces between words did not hinder reading (given that subjects in the study had a lifetime of experience reading without spaces). Bai et al. also found that inserting spaces between pseudo-randomly chosen character pairs interfered with reading to the same extent as inserting spaces between every pair of characters.

Chen (1999) argued that Chinese word segmentation is automatic and efficient. He asked subjects to search for a Chinese character among distractors, and found that search was faster when the character was embedded in a string of asterisks or a 2-character word than in a 2-character non-word or a string of scrambled characters. Inhoff and Wu (2005) embedded four characters constituting two 2-character words in sentences. In the ambiguous condition, the central two characters also constituted a 2-character word, while in the control condition the central two characters did not constitute a word. They found that gaze duration (the sum of all eye fixations on a word prior to moving to another word) and total viewing time (the sum of all fixations on a word, including regressions) were longer in the ambiguous condition than in the control condition. They argued that this result was inconsistent with what they called the *unidirectional parsing* hypothesis, which assumes that characters are assigned to words in a strictly serial left-to-right process. Rather, they argued that their results were consistent with what they called the *multiple activation* hypothesis, which assumes that all of the possible words that can be combined by the characters falling into the perceptual span are activated.

For Chinese reading, given that there is no bottom-up spacing information to aid in word segmentation, top-down information is likely to be a key factor in segmenting Chinese words. There are two possible hypotheses concerning the use of top-down information by Chinese readers to segment words. We will refer to these as the *feed-forward* hypothesis and the *holistic* hypothesis. The feed-forward hypothesis assumes that the visual information obtained from Chinese characters is initially fed into a character recognition system, and word segmentation follows after character recognition, leading to word recognition. Under this hypothesis, word segmentation does not feed back to the character recognition system. In other words, top-down information does not influence the process of character recognition. On the other hand, according to the holistic hypothesis, word segmentation influences character recognition through feedback. Thus, the various subsystems cooperate to influence word segmentation and word recognition.

In the present study, we further examined word segmentation in Chinese reading. In the crucial conditions of the five experiments, four Chinese characters, which either constituted a 4-character word or two 2-character words, were briefly presented to subjects. Three techniques were used to examine how the visual perception process and character recognition process differed in these two conditions. First, in Experiments 1, 2, 3, and 5, we used a naming paradigm in which subjects had to name the characters after a brief exposure of the characters. If the feed-forward hypothesis is correct, the number of characters that are recognized should not differ between the two conditions. Secondly, in Experiments 1 and 2, we presented a probe at one of the character locations. The response time to this probe should reflect attentional deployment (Cepeda, Cave, Bichot, & Kim, 1998; Hoffman, Nelson, & Houck, 1983; Kim & Cave, 1995; Kramer, Weber, & Watson, 1997; Laberge, 1983; Logan, 1994; Posner, 1980; Tsal & Lavie, 1988). This paradigm was mainly designed to examine whether word segmentation could influence attentional deployment. Object-based attention experiments have demonstrated that reaction times are faster when a probe is presented within the same object as the cue (Egly, Driver, & Rafal, 1994). Previous research has shown that words can be perceived as objects (Prinzmetal, Hoffman, & Vest, 1991; Robertson & Treisman, 2006). For example, Robertson and Treisman (2006) found that a patient with Balint's syndrome, who could only perceive single objects, could identify familiar words (ON and NO) but not the relative location of the two letters (O and N) in the