Journal of Memory and Language 75 (2014) 93–103

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

Syllable articulation influences foveal and parafoveal processing of words during the silent reading of Chinese sentences

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ARTICLE INFO

Article history:
Received 26 June 2013
Received in revised form 9 May 2014
Available online 22 June 2014

Keywords:
Articulation duration
Neutral tone
Syllabic tone
Sentence reading
Chinese

ABSTRACT

The current study examined effects of syllable articulation on eye movements during the silent reading of Chinese sentences, which contained two types of two-character target words whose second characters were subject to dialect-specific variation. In one condition the second syllable was articulated with a neutral tone for northern-dialect Chinese speakers and with a full tone for southern-dialect Chinese speakers (neutral-tone target words) and in the other condition the second syllable was articulated with a full tone irrespective of readers' dialect type (full-tone target words). Native speakers of northern and southern Chinese dialects were recruited in Experiment 1 to examine the effect of dialect-specific articulation on silent reading. Recordings of their eye movements revealed shorter viewing durations for neutral- than for full-tone target words only for speakers of northern but not for southern dialects, indicating that dialect-specific articulation of syllabic tone influenced visual word recognition. Experiment 2 replicated the syllabic tone effect for speakers of northern dialects, and the use of gaze-contingent display changes further revealed that these readers processed an upcoming parafoveal word less effectively when a neutral- than when a full-tone target was fixated. Shorter viewing duration for neutral-tone words thus cannot be attributed to their easier lexical processing; instead, tonal effects appear to reflect Chinese readers' simulated articulation of to-be-recognized words during silent reading.

Introduction

Converging evidence from different visual word recognition paradigms indicates that orthographic, phonological, and lexical representations are automatically activated at different points in time during visual word recognition. Less time is spent looking at words with familiar letter sequences, regular phonology, and frequently encountered lexical forms than at words with unfamiliar orthography, irregular phonology, and rarely encountered forms (see Rayner, 2009, for a review). In alphabetic writing systems, activation of a word's represented phonological form occurs more quickly than activation of its semantic properties when the experimental task requires responding to individual words (see Perfetti & Bell, 1991; Tan & Perfetti, 1999, see also Frost, 1998, and Rastle & Brysbaert, 2006, for reviews), and also when it involves recognition of words during silent reading (Lee, Rayner, & Pollatsek, 1999, 2001).

In his comprehensive and influential review of phonological code use, Frost (1998) argued that the relatively early use of this code during visual word recognition suggests that it is relatively simple and abstract, i.e., that

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http://dx.doi.org/10.1016/j.jml.2014.05.007
0749-596X/

it consists of a sequence of sound-specific categories (phonemes) that map onto a corresponding sequence of visible letters. In the literature this has been referred to as the minimality hypothesis. The hypothesis implies that readers' use of phonological knowledge for visual word recognition has little in common with listeners' use of acoustic features during auditory word recognition, which does include use of articulation-specific sub- and supra-phonemic variation (e.g., Ranbom & Connine, 2007).

Contrary to the minimality hypothesis, the results of several recent studies on visual word recognition with alphabetic scripts revealed that visual word recognition may involve the use of articulation-specific word properties. In Abramson and Goldinger (1997; see also Lukatela, Eaton, Sabadini, & Turvey, 2004) lexical decisions were shorter for monosyllabic target words that were articulated with a short-duration vowel (e.g., "deaf") than for orthographically matched targets that were articulated with a long-duration vowel ("deal"). Similarly, less time is spent gazing at target words with a short- than with a long-articulation vowel during sentence reading, and this effect disappeared when a secondary articulatory suppression task was added to the reading task (Huestegge, 2010).

Furthermore, Ashby's work (Ashby & Clifton, 2005; Ashby & Martin, 2008; Ashby & Rayner, 2004; Ashby, Sanders, & Kingston, 2009; Ashby, Treiman, Kessler, & Rayner, 2006) provided evidence for the early use of articulation-specific sub- and supra-phonemic features during visual word recognition. Using the eye-movement-contingent display change technique (Rayner, 1975) to manipulate the parafoveally visible preview of a target word *before* the actual target was subsequently fixated, Ashby et al. (2006) showed that readers spent less time gazing at a target when its previously available parafoveal preview contained a vowel with a matching rather than a mismatching articulation duration. Using the same technique, Ashby and Rayner (2004; see also Ashby & Martin, 2008) further showed that readers spent less time viewing target words when the parafoveal preview revealed the intact beginning syllable than when it revealed a shorter or longer beginning letter sequence (preview of "pi###" or pil##, respectively, prior to the fixation of the target "pilot"). Syllabic stress also influenced word viewing durations, as stressed words and words with two syllables received more fixations than unstressed and monosyllabic words (Ashby & Clifton, 2005; Breen & Clifton, 2011). Using the masked priming technique with ERP recordings and prime target sequences with matching or mismatching voicing for final consonants, Ashby et al. (2009) showed that mismatching consonants elicited more negative amplitudes than matching consonants as early as 80 ms after target onset. Together, these findings with English text indicate that articulation-specific features influence visual word identification.

Logographic scripts, such as Chinese, differ fundamentally from alphabetic scripts, as they are not designed to represent sound-specific properties of words. The basic units of Chinese script, characters, are designed to represent syllables and morphemes, and graphemically similar characters can have radically different pronunciations. Nevertheless, there is strong evidence for the use of sound codes during visual word recognition. Effective prime durations are shorter for homophone primes than for matched semantic primes (Tan, Hoosain, & Peng, 1995; Tan, Hoosain, & Siok, 1996; see Perfetti, Liu, & Tan, 2005, for a review), and Chinese readers use parafoveally available phonological information during the subsequent fixation on a previewed target character (Liu, Inhoff, Ye, & Wu, 2002; Tsai, Lee, Tzeng, Hung, & Yen, 2004; Yan, Richter, Shu, & Kliegl, 2009).

Nevertheless, Frost (2012) argued that orthographic transparency has a profound effect on the use of phonological information, and some language-specific features of Chinese script may prevent its readers from early and fast access to phonological information. Chinese characters are formed according to a variety of principles (Feng, Miller, Shu, & Zhang, 2001). The most ancient characters are so-called *pictographs* and *ideograms*, which originated from drawings by ancient cave dwellers or formed through analogy or association. Obviously, these characters were designed to represent meaning rather than pronunciation. The majority of modern Chinese characters are *phonograms* typically consisting of two independent components/radicals, one of which represents the meaning category of the whole character, and the other provides a rough clue regarding pronunciation. However, the articulation of the phonetic radical and of the full character often differ, as only about 30% of phonetic compound characters have the same pronunciation as their phonetic radical (Zhou & Marslen-Wilson, 1999). Frost (2012) pointed out that the use of semantic information could thus precede use of phonological information in phonograms because of their orthographic structure: the semantic radical is generally to the left of the phonetic radical and Chinese sentences are read from left to right.

In agreement with script-specific effects of word recognition, there is considerable experimental evidence according to which Chinese script is optimized for foveal and parafoveal semantic information extraction. For example, direct access from orthography to semantics in Chinese, with phonological mediation bypassed, has been reported with character/word recognition tasks under some circumstances (Chen & Shu, 2001; Zhou & Marslen-Wilson, 2000). Using the error disruption paradigm, Feng et al. (2001) obtained evidence for very early phonological activation for English readers, but not for Chinese readers. Furthermore, a direct comparison of phonological and semantic parafoveal preview effects with Chinese text revealed more robust semantic than phonological preview effects (Yan et al., 2009). Multi-level regression models that included the time line of a parafoveal word preview as predictor showed that preview benefits accrued earlier for useful semantic but not for useful phonological information (Tsai, Kliegl, & Yan, 2012; Yan, Risse, Zhou, & Kliegl, 2012; Zhou, Kliegl, & Yan, 2013).

For Chinese text, the current default assumption regarding a word's represented phonological form appears to be that it is impoverished and relatively abstract, as maintained by the minimality hypothesis. In fact, the somewhat later use of phonological codes during the reading of Chinese could well be associated with the use of abstract phonological knowledge. While word recognition with alphabetic scripts uses articulation-specific sub- and supra-phonemic