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Research Report

Foveal splitting causes differential processing of Chinese orthography in the male and female brain

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Abstract

Chinese characters contain separate phonetic and semantic radicals. A dominant character type exists in which the semantic radical is on the left and the phonetic radical on the right; an opposite, minority structure also exists, with the semantic radical on the right and the phonetic radical on the left. We show that, when asked to pronounce isolated tokens of these two character types, males responded significantly faster when the phonetic information was on the right, whereas females showed a non-significant tendency in the opposite direction. Recent research on foveal structure and reading suggests that the two halves of a centrally fixated character are initially processed in different hemispheres. The male brain typically relies more on the left hemisphere for phonological processing compared with the female brain, causing this gender difference to emerge. This interaction is predicted by an implemented computational model. This study supports the existence of a gender difference in phonological processing, and shows that the effects of foveal splitting in reading extend far enough into word recognition to interact with the gender of the reader in a naturalistic reading task.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Chinese character pronunciation; Foveal splitting; Gender difference; Connectionist modeling; Phonological processing

1. Introduction

Male and female brains have been shown to differ in many aspects of language development and impairment, in imaging studies of normal language processing, and in behaviors elicited by non-naturalistic language processing tasks (e.g., divided visual field studies [35]), but reliable gender differences have previously not been visible in naturalistic studies of the normal orthographic processing of skilled adult readers. Chinese orthography contains different elements that relate to the phonological and semantic aspects of the individual characters. The recent appreciation of the role of the anatomy of the fovea, and subsequent cortical projections, in visual word recognition suggests that the spatial arrangement of information in major character types may lead to differential processing in the male and female brain. Here, we show, for the first time, a robust effect of the gender of the reader in a naturalistic reading task.[1]

Chinese phonetic compound characters comprise about 81% of the 7000 frequent characters in Chinese orthography [25]. A majority of these characters have a distinct structure that provides a unique opportunity, as we will show, for differential hemispheric processing to arise in reading: they consist of two radicals, a semantic radical and a phonetic radical, standing side by side (Fig. 1). Some 90% of them have the semantic radical on the left and the phonetic radical on the right (SP characters); the remainder have the

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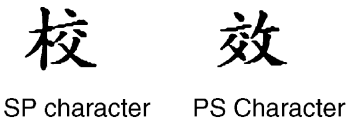

Fig. 1. Examples of phonetic compounds. The SP and PS characters, meaning "school" and "effect", respectively, share the same phonetic radical. Both characters are pronounced as 'xiao4' in Pinyin, a spelling system based on the Latin alphabet.

semantic radical on the right and the phonetic radical on the left (PS characters). In other words, the ratio between the number of SP and PS character types is about 9 to 1. In the usage of characters, as reflected in the token frequency of the characters, the ratio between the number of SP characters and PS characters is about 5.5 to 1. Thus, on average, the minority PS characters tend to have higher token frequency than SP characters. The semantic radical usually carries information about the meaning of the character, and the phonetic radical typically provides partial information about the pronunciation of the character. Among both SP and PS characters, the phonetic radical types outnumber the semantic radical types; the ratio is about 10 to 1 [13]. Hence, given that SP characters also hugely outnumber PS characters, the overall information distribution of Chinese phonetic compounds is skewed to the right.

Recent understanding about how the structure of the retina, in particular the fovea, interacts with visual word recognition suggests that SP and PS characters might present the brain with different processing problems. The fovea is the part of the retina across which a fixated word is projected. It is responsible for fine-grained, focal visual processing. From anatomical and behavioral studies, it has become increasingly clear that the human fovea is precisely vertically split [10,11,24]. This fact has fundamental implications for visual word recognition [4,32]: when a word is fixated, the left part of the word is initially projected to the right hemisphere (RH) and the right part to the left hemisphere (LH). Thus, visual word recognition can be reconceptualized in terms of coordinating the information in the two hemispheres. If foveal splitting was sufficiently precise, a single Chinese character might have its semantic and phonetic radicals contralaterally projected initially to different hemispheres, under normal reading conditions (Fig. 2).

If the two hemispheres are receiving qualitatively different input, we might expect such a processing task to be carried out differently in male and female readers. There are longstanding observations about gender differences in language, from the social use of language [6,14] to cognitive processing abilities [8,12,35] and language development [2] and impairment [9,23]. Observed gender differences have been claimed to reflect anatomical differences in the brain [1,22,36] and functional differences in hemispheric lateralization, particularly with respect to phonological processing, as revealed by functional magnetic resonance imaging (fMRI) [20,28,30,34]. There is converging evidence showing more left-lateralization of phonological processing in the male brain than in the female brain. Nevertheless, the implications of this difference for the naturalistic study of normal reading behavior are still unclear, in that laterality studies standardly employ visual hemifield presentations, in which the word is not directly fixated but is initially projected to one or other hemispheres [35]. Chinese SP and PS characters offer a unique opportunity to examine this issue in a task as simple as pronouncing a centrally presented character. Naming has been shown to produce robust laterality effects [35]. Providing our assumptions about the precision of foveal splitting are correct, we may expect differential processing of the semantic and phonetic radicals in the two halves of the brain in male and female readers. Hence, in the current study, we conducted a behavioral experiment examining gender differences in the time taken to generate the pronunciation of single, centrally presented characters; we tested the hypothesis that there would be significantly different processing in male and female readers of Chinese.

This hypothesis also arose from a computational simulation of Chinese character pronunciation, which contrasted differences between a split cognitive architecture, which had two interacting processing domains (i.e., two connected sets of hidden units), and an otherwise comparable non-split architecture, which had a single processing domain (i.e., a single group of hidden units) [16]. The two models behaved differently and the split model was identified with the female brain, in that it allowed a mapping between orthography and phonology to be carried out in two partially

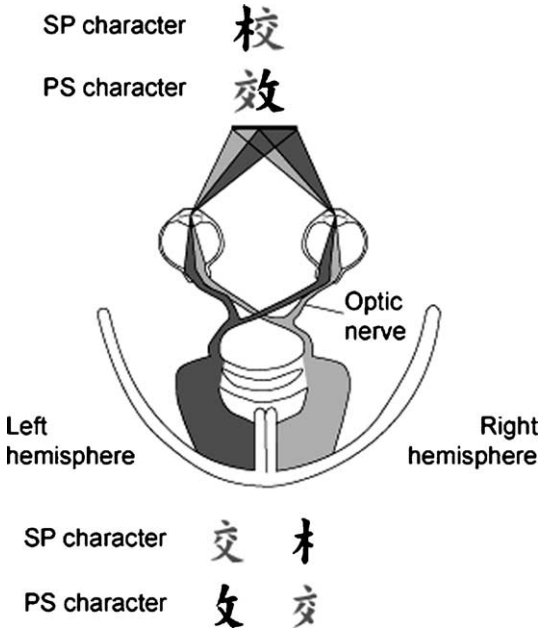

Fig. 2. Illustration of foveal splitting and contralateral projection of the two radicals of an SP character and a PS character. The phonetic and semantic radicals are shown in grey and black, respectively.