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Implicit reading in Chinese pure alexia

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ABSTRACT

A number of recent studies have shown that some patients with pure alexia display evidence of implicit access to lexical and semantic information about words that they cannot read explicitly. This phenomenon has not been investigated systematically in Chinese patients. We report here a case study of a Chinese patient who met the criteria for pure alexia and had lesions in the left occipitotemporal region and the splenium of the corpus callosum. His explicit and implicit reading was evaluated with various stimuli in a number of tasks. We found that despite his severe impairment in overt reading and the definition of any characters, his performance was well above chance in various implicit tasks. His accuracy with respect to lexical decisions was so high that his performance was almost normal. These findings provide unequivocal evidence for the existence of implicit reading in Chinese patients with pure alexia and further support the involvement of the right hemisphere.

1. Introduction

Pure alexia is an acquired reading disorder, characterized by selective reading impairment in premorbidly literate individuals, with few or no writing problems (Dejerine, 1892; Warrington & Shallice, 1980). The classical account of pure alexia attributes this syndrome to a disconnection of the visual input to the left angular gyrus by damage to the visual cortex of the left occipital lobe and the splenium of the corpus callosum (Dejerine, 1892; Geschwind, 1965). However, in recent years, it has been found that a lesion limited to the left ventral occipitotemporal cortex can also result in pure alexia, indicating a key role for this region in this reading disorder (Beversdorf, Ratcliffe, Rhodes, & Reeves, 1997; Binder & Mohr, 1992; Cohen et al., 2003; Damasio & Damasio, 1983; Gaillard et al., 2006; Ino et al., 2008; Leff, Spitsyna, Plant, & Wise, 2006). This finding parallels recent functional magnetic resonance imaging (fMRI) studies of healthy subjects (e.g., Binder, Medler, Westbury, Liebenthal, & Buchanan, 2006; Cohen et al., 2002, 2003; Dehaene, Le Clec'H, Poline, Le Bihan, & Cohen, 2002; Jobard, Crivello, & Tzourio-Mazoyer, 2003), in which the left ventral occipitotemporal cortex was consistently shown to be selectively responsive to visual word stimuli in a variety of tasks.

Another recent insight is the recognition that patients with pure alexia can retain some implicit reading abilities, despite profound impairment of explicit reading processes such as reading aloud and word identification (Behrmann, Plaut, & Nelson, 1998; Bub & Arguin, 1995; Coslett & Monsul, 1994; Coslett & Saffran, 1989a, 1989b; Coslett, Saffran, Greenbaum, & Schwartz, 1993; Feinberg, Dyckes-Berke, Miner, & Roane, 1995). Indeed, a number of studies have demonstrated that alexic patients often show above-chance performances on some implicit tasks, such as lexical decision and semantic categorization tasks (Behrmann et al., 1998; Saffran & Coslett, 1998). This finding is consistent with the observation of the word superiority effect (Bowers, Bub, & Arguin, 1996) and the Stroop effect of words (McKeeff & Behrmann, 2004) in alexic subjects.

Not surprisingly, some researchers suggest that implicit reading in pure alexia is mediated by the right hemisphere (RH) because the primary lesion in these patients is on the left hemisphere (LH) (Coslett & Saffran, 1989a, 1989b; Feinberg et al., 1995; Larsen, Baynes, & Swick, 2004; Mayda et al., 2004; Saffran & Coslett, 1998). Consistent with this hypothesis, patients with pure alexia often perform better on concrete or highly imaginable words than on abstract words and functors (function words) and better on nouns than on verbs, which are thought to be typical characteristics of the orthographic processing in the RH (Larsen et al., 2004; Mayda et al., 2004; Saffran & Coslett, 1998). Furthermore, several fMRI studies of pure alexics have shown a strong activation to words

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in the right occipitotemporal area early after the onset of alexia (Cohen et al., 2004; Henry et al., 2005; Ma et al., 2004), providing further support for this hypothesis.

However, not all agree with the RH account of implicit reading in pure alexia (e.g., Baynes, 1990; Rapp & Caramazza, 1997). In many reported cases of implicit reading, the left ventral occipitotemporal cortex is not completely destroyed and the splenium of the corpus callosum is often intact. Therefore, it seems reasonable to assume that implicit reading can be subserved by the residual function of the LH. We report here a case study of pure alexia in a native Chinese speaker with extensive lesions in the left occipitotemporal cortex together with damage to the splenium of the corpus callosum. This allowed us to test the RH hypothesis without confounding the analysis with any residual reading function of the LH.

Equally importantly, because written Chinese is markedly different from alphabetic writing systems in several respects, this case also allowed us to examine whether alexia in native Chinese speakers manifests in different reading patterns, in both explicit and implicit reading tasks, compared with the alexia of alphabetic readers. Written Chinese, often called a "logographic" writing system, uses characters as the basic units. Visually, each character is composed of different strokes, which may or may not cross each other. The number of strokes in a character can vary considerably, ranging from one to more than 20. The strokes are combined to form simple characters or radicals, which in turn are further combined to form compound characters. There are two types of radicals: semantic and phonetic. Within a compound character, the semantic radical often occupies the left or top position, whereas the phonetic radical is on the right or at the bottom. The position of the radical is an important part of the orthographic rules of Chinese characters. If the positions of the radicals in a "character" are in the "correct" positions (thus orthographically legal), this "character" is regarded as a pseudocharacter, although it has no meaning or phonology. If any of the radicals is placed in a wrong position (and is therefore orthographically illegal), the "character" becomes a noncharacter (Ho, Ng, & Ng, 2003; Yin & Butterworth, 1998). Many radicals are also themselves simple characters, with their own meanings and pronunciations, whereas others are bound forms, which always act as components and must be combined with other radicals to form characters. There are about 1000 radicals, which form about 4500 characters in the modern Chinese writing system (Yin & John, 1994). These features make Chinese characters visually much more complex than alphabetic script.

Linguistically, the orthography of Chinese characters is much more opaque than that of alphabetic words. The visual form of a character only provides very limited information about the sound form of this character. Simple characters with similar shapes have very different sounds. For instance, 田/tian 2/, 由/you 2/, 甲/jia 3/, and 申/shen 1/ have similar appearances but have completely different pronunciations. Although about 80% of modern Chinese characters are phonetic compound characters, only about one-third are "regular", in that the phonetic radical has the same pronunciation as that of the whole character, so exceptions are more frequent than regular forms. Furthermore, unlike alphabetic words, in which the letters or letter combinations systematically map to phonemes, thus displaying grapheme-to-phoneme conversion (GPC), Chinese characters map onto the syllable level. A phonetic radical may (for a regular character) or may not (for an irregular character) have the same pronunciation as the whole character that contains the radical, but the pronunciation of a radical can never be a segment of the whole character's sound. This means that the pronunciation of a character is never made up of the combination of its radicals. For example, 里/Li 3/ is pronounced the same as 理/Li 3/ but is completely different from 埋/mai 2/, and 里 does not map to any segment of the pronunciations of 理 or 埋. It should also be noted that the homophone density of Chinese characters is much higher than that of alphabetic scripts. There are about 400 syllables (regardless of their tones), whereas there are more than 4500 characters (Language and Teaching Institute of Beijing Linguistic College, 1986). This means that, on average, more than 10 characters share one sound (syllable).

As a result of these visual and linguistic features, reading and learning to read Chinese characters place very high demands on visuospatial processing and rely on memorizing the obligatory relationships between the lexical entries and their pronunciations/meanings (Frith, 1985; Lyman, Kwan, & Chao, 1938; Peng, Shu, & Chen, 1997; Tan, Spinks, Eden, Perfetti, & Siok, 2005; Tzeng, Hung, Cotton, & Wang, 1979; Zhou & Marslen-Wilson, 1999). These findings have led to the reasonable assumption that processing Chinese characters involves more of the RH than does the processing of alphabetic scripts, and this has been repeatedly demonstrated by psycholinguistic studies (April & Tse, 1977; Chen, Cheung, & Flores d'Arcais, 1995; van Orden, 1987). In addition to the behavioral data, fMRI studies of healthy Chinese subjects have shown the activation of the bilateral ventral occipitotemporal cortices during reading tasks (Liu et al., 2008; Peng et al., 2003), whereas only weak or no activation was observed in the right occipitotemporal cortices during alphabetic word-reading tasks (Binder et al., 2006; Cohen et al., 2000, 2002, 2003; Dehaene, Le Clec'H, Poline, Le Bihan, & Cohen, 2002; Fiebach, Friederici, Muller, & von Cramon, 2002; Jobard et al., 2003).

The uniqueness of Chinese characters may also cause Chinese alexic patients to show different reading patterns. For example, a letter-by-letter strategy is commonly and effectively used by alphabetic alexic patients to assist them in the recognition of a single word. However, this strategy can have little benefit for Chinese patients, because the phonetic radical cannot provide reliable phonological information for reading characters. It is also possible that implicit reading is more easily manifested in Chinese alexia. First, as discussed above, Chinese reading places more reliance on the whole character, and Coslett et al. (1993) observed that their subject appeared to use a "whole-word" strategy when he was performing lexical decision and semantic judgment tasks. Second, the greater requirement to memorize the associations between lexical entries and their pronunciations/meanings may make it easier to access phonological and semantic information, although not necessarily at the explicit level.

There are relatively fewer cases of Chinese pure alexia reported in the literature compared with the large number of cases of alphabetic pure alexia (Gao, 2006). The first such case was reported by Lyman et al. (1938). This patient was a Chinese–English bilingual speaker. Of particular relevance is that he could postmorbidly read English much better than Chinese, at least partly because of his successful use of the letter-by-letter reading method. In contrast, although he repeatedly traced the strokes of the presented Chinese character with his finger, this seldom worked. This patient was not a typical case of pure alexia (Yin & Butterworth, 1998) because he showed profound impairment in writing. Wang and Tang (1959) subsequently reported a more typical Chinese alexic patient with no writing deficit. He had a lesion in the left occipitotemporal area and had right homonymous hemianopia and amnesia. Although his spoken language, auditory comprehension, and writing ability were well preserved, his reading ability was severely damaged. He could sometimes read out a few simple and high-frequency characters and some radicals, often by kinesthetic facilitation and context assistance. He also had greater difficulty in reading handwriting than the printed word. Ever since the 1990s, increasing numbers of cases of pure alexia have been reported among Chinese people (e.g., Gao, 2006; Wang, Wang, Feng, & Li, 1998; Yin & Butterworth, 1992, 1998; Zhao, Chen, & Gao, 1998). The association of pure alexia with a lesion in the left occipitotemporal area was