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Research report

Longitudinal fMRI study of reading in a patient with letter-by-letter reading

Tadashi Ino[a,*], Kazuki Tokumoto[a], Kiyohide Usami[a], Toru Kimura[a], Yoichi Hashimoto[b] and Hidenao Fukuyama[c]

[a]Department of Neurology, Rakuwakai-Otowa Hospital, Otowachinjicho, Kyoto, Japan
[b]Neurosurgery, Rakuwakai-Otowa Hospital, Otowachinjicho, Kyoto, Japan
[c]Department of Functional Brain Imaging, Human Brain Research Center, Kyoto University Graduate School of Medicine, Sakyo-ku, Kyoto, Japan

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ABSTRACT

The present study provides a longitudinal fMRI study of reading 7 days after a hemorrhage in the left basal occipito-temporal region when the patient showed letter-by-letter (LBL) reading, and repeated again 50 days after onset, when his LBL reading had resolved. Direct comparison of the two sessions showed that right homologue of the so called visual word form area (VWFA), as well as a network related to language and verbal working memory, such as the bilateral premotor areas, Broca's area and its right homologue, and the left supplementary motor area were more strongly activated when his LBL reading persisted than when he recovered, whereas perilesional activity around the VWFA and the activity of superior part of the left superior parietal lobule were more strongly activated when he recovered than when his LBL reading persisted. These results suggest that dynamic functional reorganization of the brain was caused in the acute phase and that the increased activation of certain areas in the left superior parietal lobule in addition to the VWFA may be related to recovery from LBL reading.

1. Introduction

Pure alexia is defined as a reading disturbance with little or no writing impairment following left occipito-temporal lesions. Although in severe cases pure alexic patients cannot even read single letters, more frequently they preserve ability of single letter reading, albeit slowly, and read words by an effortful letter-by-letter (LBL) reading strategy. Normal people can read single words composed from three to eight letters as quickly as single letters since letters of word are perceived in parallel without saccadic eye movement within a word, even though a word is identified as a combination of individually recognized letters and is not recognized as an image (Pelli et al., 2003). When normal subjects read a text rapidly, they fixate to one word for about 250 msec before a saccade to the next word, and single-word perception takes approximately only 50 msec (Leff et al., 2000). Disturbance of the ability to map a percept of all the letters of a word on to the mental representation of the whole-word form (whole-word recognition) is considered to be related to LBL reading.

Although it has been hypothesized that pure alexia is caused by disconnection of the intact right visual cortex

* *Corresponding author*. Department of Neurology, Rakuwakai-Otowa Hospital, Otowachinjicho, 2 Yamashina-ku, Kyoto 607-8062, Japan. E-mail address: rakuwadr042@rakuwadr.com (T. Ino).
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from the left angular gyrus in a patient in whom the left visual cortex and the splenium of the corpus callosum were destroyed (Geschwind, 1965), a new interpretation for this symptom has emerged, benefited from the recent development of neural imaging techniques. Using fMRI, it has been proposed that there is a region specialized for reading of word named as visual word form area (VWFA) in the left mid fusiform gyrus or in the left occipito-temporal sulcus, just lateral to the fusiform gyrus, and that the lesion of this area will cause pure alexia or LBL reading (Cohen et al., 2000, 2002, 2004a, 2004b; Cohen and Dehaene, 2004; Dehaene et al., 2002, 2005). A recent meta-analysis of neuroimaging studies to clarify cultural effect on brain activities during reading indicate that the VWFA shows consistent localization across writing systems (Bolger et al., 2005). However, the concept of the VWFA has been challenged by other researchers (Price et al., 2003, Price and Devlin, 2003, 2004; McCrory et al., 2005) and the precise function of this area remains unclear, albeit several hypothesis have been proposed such as extracting and storing abstract patterns when processing visual input (Kronbichler et al., 2004), lexical processing that links modality-specific input and output representations (Hillis et al., 2005), binding of visual and verbal representations under the control of the left semantic areas (Vigneau et al., 2005), shared input system for both letters and objects (Joseph et al., 2006), and interface between visual form and its associated property such as phonological information and semantics (Devlin et al., 2006).

Several neuroimaging studies of pure alexic patients have suggested close relation between pure alexia and the VWFA. In a study of six patients who had a lesion in the left basal occipito-temporal region, the VWFA was injured in three cases with pure alexia but was not injured in three cases without pure alexia (Cohen et al., 2003). Similar results were obtained in a more recent study (Leff et al., 2006). A case study of a patient who developed LBL reading after a focal corticectomy for treatment of intractable seizure provided strong evidence for the existence of the VWFA (Gaillard et al., 2006). In this study, a mosaic of selectivity for words, faces, houses, and tools in the ventral occcipito-temporal region was revealed by fMRI in the patient. After removal of the region just to the posterior of the word-sensitive area, the patient developed severe reading difficulty while the performance of picture naming and face recognition was completely normal. The post-surgery fMRI showed that word-specific activations disappeared although activations for other categories were observed. In another case study, a patient who presented with LBL reading following the surgical removal of the left occipito-temporal regions was investigated by fMRI (Cohen et al., 2004a, 2004b; Henry et al., 2005). The VWFA in this patient, which appeared to be anatomically spared but deafferented from lower level visual cortex, was weakly activated only during reading task. On the other hand, the right homologue of the VWFA and the areas related to language and verbal working memory were more strongly activated than normal control.

The present investigation provides a longitudinal fMRI study of reading in a patient who developed LBL reading following a traumatic cerebral hemorrhage, and recovered almost completely within approximately 35 days after onset. Results were compatible with the concept of the VWFA and also with the recent hypothesis regarding the dynamic brain reorganization during language recovery.

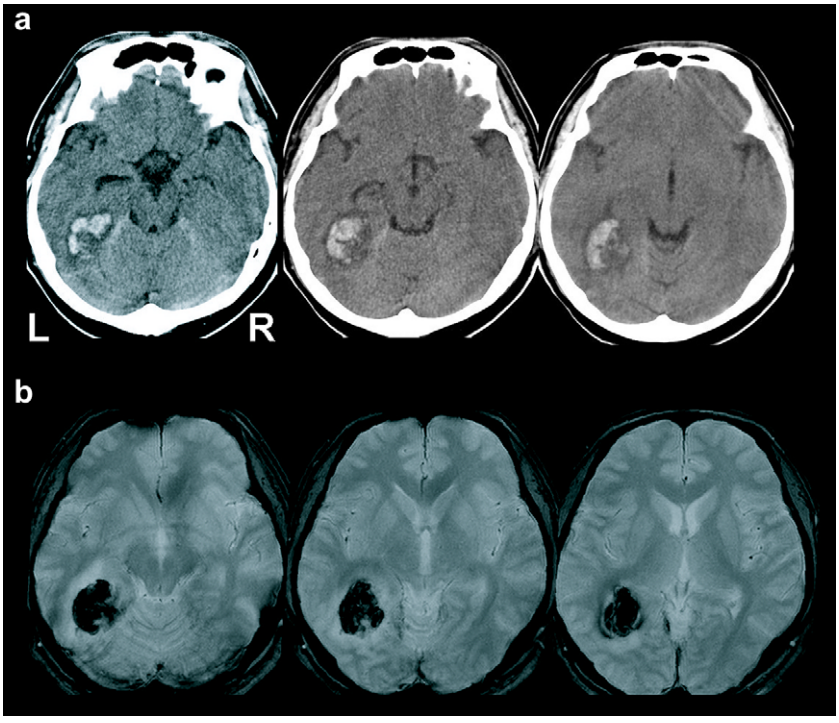

Fig. 1 – (a) CT scan on admission. (b) T 2* MRI 4 days after onset showing a hemorrhage in the left basal occipito-temporal region.