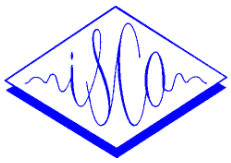

3rd International Conference on
Spoken Language Processing (ICSLP 94)
Yokohama, Japan
September 18-22, 1994

FUNCTIONAL MAPPING OF CEREBRAL MECHANISM OF READING IN THE JAPANESE LANGUAGE

Makoto Iwata, Yasuhisa Sakurai**, Toshimitsu Momose****

* Department of Neurology,
Tokyo Women's Medical College, Tokyo 162 Japan
Departments of **Neurology and ***Radiology,
University of Tokyo School of Medicine

ABSTRACT

Japanese patients with alexia without aphasia caused by focal left hemispheric damage show the dissociation between **Kanji** and **Kana.** Recently discovered was that the patient with left posterior inferior temporal (PIT) lesion developed alexia without aphasia selective for **Kanji**. We carried out activation studies using $H_2{}^{15}O$ PET scan and confirmed the role of PIT area in semantic reading process. Although the role of left angular gyrus (AG) in reading process could not be confirmed by PET scan studies, the adjacent left lateral occipital area was found to be significantly activated in phonological reading process.

I. INTRODUCTION

Japanese language uses two different and parallel systems of letters [1]. **Kanji**, morphograms, are mostly the original Chinese characters. Each Kanji letter has several phonetic values as well as remantic values, but **kanji** are usually used as strings of more than two letters to represent words. Once a word is formed by combination of kanji letters, the phonetic value of each letter becomes fixed and the entire string of letters should be read in a particular way. Cosequently, **Kanji** have not only meaning but also phonetic values when they are used to represent words, so they are not ideograms in the strict sense which have meanings only without definite phonetic value.

The phonogram system called **Kana**, was made by our Japanese ancestors from the imported Chinese characters. **Kana** is further devided into **Hiragana** and **Katakana**, which are entirely parallel system of phonogram. **Kana** are phonograms or more pecisely syllabograms which represent moras of the Japanese language.

II. STUDIES OF ALEXIAS

The first successful investigation of neuropsychology of letters was done by Dejerine, who reported successively two different types of alexia in 1891 [2] and in 1892 [3]. He proposed that the left AG is the center for reading and writing. Currently popular theory of cerebral mechanism of reading and writing is that the left AG serves for cross-modal association of sensory engrams [4]. According to this theory, reading is the process of visual to auditory engram transformation and writing the auditory to somesthetic or kinesthetic engram transformation, both of which are realized by the left AG.

However, the validity of this angular gyrus hypothesis has been criticized in Japan. At first, the AG lesion has been known to spare **kanji** reading, while **kana** reading is severely impaired [5,6]. Another argument came from the clinical observation of pure alexia in Japanese patients. The almost constantly associated agraphia of **kanji** in Japanese pure alexics has been one of the most intriguing problems in the studies of alexias [6,7].

The last challenge was given to the angular gyrus hypothesis also from the studies of Japanese alexics. One of the present authors found a non-aphasic patient with severe alexia and agraphia only for **kanji**. CT scan of the patient showed a

hemorrhagic lesion affecting the left PIT area [8,9].

In summary, there are three distinct types of alexia and agraphia without aphasia in the Japanese patients. The patients with left AG lesion show alexia and agraphia of **Kana,** but as to **Kanji**, only agraphia is observed. On the contrary, the left medial occipital lesion which causes alexia without agraphia in the westerners produces pure alexia of **Kana**, associated with alexia with agraphia of **Kanji**. The third condition caused by left PIT lesion causes alexia and agraphia specific for **Kanji** [7,8,9].

III. ALEXIA AND AGRAPHIA OF KANJI

The last type of alexia and agraphia specific for **Kanji** was first reported by one of the present authors [7,8,9] and found to be caused by focal damage of left PIT. Although the patient did not show any difficulty in reading and writing Kana, **Kanji** reading was very severely affected. There are several types of errors in **Kanji** reading. He often failed to recognize the whole character and read only a part of it. Figural confusion, and sematic paralexia were also noted. One of the most charactristic type of errors was the error in selecting appropriate phonetic value. Each Kanji letter has usually more than two phonetic values among which the appropriate one should be chosen according to the meaning of the word. The patient with left PIT lesion showed great difficulty in this ability.

Table 1; Reading Test of a patient with left PIT lesion [10]

Kanji words*	Correct reading
Single letter	216 / 416 (51%)
Double letters	65 / 90 (72%)
Kana words*	408 / 416 (98%)

* 416 Kanji which must be learnt in Japanese primary school before age 8 and the corresponding words written in Kana

We reported another patient who developed an infarct which left her a right superior quadrantanopia and alexia with agraphia only for **Kanji** [10]. She had no aphasia and the infarcted area in this patient was located on the left fusiform gyrus involving its cortex as well as the underlying white matter. Part of the inferior temporal gyrus is also involved. Table 1 shows the results of reading aloud test of the patient. As the table shows, the dissociation between **Kana** and **Kanji** is striking.

From these neuropsychological findings, we proposed a dual pathway model of cerebral mechanism of reading letters. From the visual area which receives visual inputs of letters, two parallel and distinct association pathways convey the informations to the speech area; the one by way of the left AG and the other going through the left PIT. The former is assumed to be the phonological reading pathway and latter semantic pathway. Consequently, lesions of the left AG affect **Kana** reading, while that of the PIT chiefly affect **Kanji** reading.

III. PET SCAN STUDIES ON READING PROCESS

In order to confirm our dual pathway hypothesis on the cerebral mechanism of reading, we did $H_2{}^{15}O$ PET scan studies. The detailed descriptions of the method were reported elsewhere [11,12,13]. For the activation study, we use ^{15}O as a tracer in the form of intravenous bolus injection of $H_2{}^{15}O$ saline. Subjects are normal adult rirht-handed volunteer undergraduate university stidents, from each of whom an informed consent was obtained. The entire project of the experiments had been approved by the Ethical Committee for the Medical Research of the University of Tokyo School of Medicine.

In our experiments, two different tasks were given to the subjects [12,13]. Fixation task,in which the subject was asked to fixate his or her gaze upon the central white circle projected on the black screen 2 m

forward. Activation task was to read aloud vertically presented two-letter **Kanji** words, three-letter **Kana** words or three-letter non-sense strings of **Kana**. The rCBF were measured by 90 second scan six times in each subject, 3 times during fixation task and 3 times during reading aloud task. The obtained rCBF values were normalized so that the mean whole CBF was constant (40 ml/100g/min), and the mean rCBF during each task was calculated by intrasubject averaging of three measurements. Subtraction images were obtained in each subject by subtracting the mean activity of the fixataion task from that of the activation task.

For the anatomical identification of the activated areas, the subtraction PET images are superimposed on the MR images of each subject. In order to precisely analyze the activated areas, 40 circular ROIs (16 mm in diameter) from which rCBF changes were to be sampled were determined according to the superimposed PET-MR images of each cerebral area. The rCBF change of more than 5% of the whole CBF (2 ml/100g/min) was regarded as significant.

Figure 1 [14] shows the cortical areas which showed significant rCBF change by activation tasks. One of the most striking findings is the activation of the left PIT in all three activation tasks. The PIT of the right hemisphere was also activated by reading tasks of both **Kanji** and **Kana** words. But the activation rate of the left PIT was far more significant in reading either **Kana** or **Kanji** words as compared with non-sense **Kana** letter strings (Figure 2) [13]. On the other hand, the activation of the right PIT was always far less significant than that of the left PIT in every task. Consequently, the left PIT is thought to play a certain role in semantic reading process.

On the contrary, both left and right AGs showed significant decrease in rCBF during activation tasks. This may be either due to the real deactivation of AG by reading aloud task as compared with fixating task, or due to the artifactual apparent rCBF reduction by

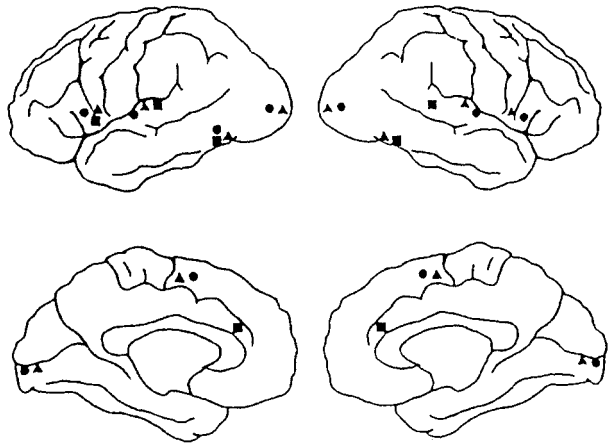

Figure 1: Cortical areas showing significant rCBF increase in reading **Kana** non-word (circle), **Kana** word (triangle), and **Kanji** word (square) [12]

the normalization of the whole CBF in the activation state. Anyhow, the role of the left AG in phonological reading was not confirmed by PET studies.

Of interest is the significant increase of the rCBF on bilateral lateral occipital areas, especially on the left side, in reading **Kana** presented either as words or as non-sense letter strings, without any significant activation during Kanji-word reading task. It implies that the lateral occipital area especially on the left side, which is located just behind the AG might play a certain role in phonological reading process.

Classical clinical studies based upon the neuropsychologaical deficits caused by brain damage and PET scan studies of the normally functioning brain have positive-negative relationship. Both shows us a true image of the brain, but there may be contradictions between them. We do hope to make a good link between these two aspects of neuropsychology and to found a solid base for Neurogrammatology.

REFERENCES

[1]M.Iwata et al, "The Japanese writing system and functional hemispheric specialization," Proceedings of 12th World

Congress of Neurology, Excerpta Medica, 53-62, 1982.
[2]J.Dejerine, "Sur un cas de cécité verbale avec agraphie," C.R.Soc.Biol.,3: 197-200, 1891.
[3]J.Dejerine, "Contribution à l'étude anatomo-pathologique, et clinique des différentes variétés de cécité verbale," C.R.Soc.Biol.,4:61-90,1892.
[4]N.Geschwind, "Disconnexion syndromes in animals and man," Brain,88:237-294, 585-644, 1965.
[5]A.Yamadori, "Ideogram reading in alexia," Brain, 98:231-238,1975.
[6]M.Iwata, "Kanji versus kana. Neuro-psychological correlates of the Japanese writing system," TINS,7:290-293,1984.
[7]M.Iwata, "Neural mechanism of reading and writing in the Japanese language," Functional Neurology,1:43-52,1986.
[8]M.Iwata,"Neural mechanism of reading and writing; Neurogrammatological approach," in Y.Tsukada(Ed) "Perspectives on Neuro-sciences: From Molecule to Mind," Univ.Tokyo Press,299-312,1985.
[9]T.Momose et al, "Functional studies with $H_2{}^{15}O$ PET," Biomed.Res., 13 (suppl.1):77-82, 1992.
[10]Y.Sakurai et al, "Kanji word reading process analysed by positron emission tomography," Neuroreport,3:445-448,1992.
[11]Y.Sakurai et al, "Semantic process in kana word reading: activation studies with positron enission tomography," Neuroreport, 4:327-330,1993.
[12]Y.Sakurai,"Mechanism of reading analysed by PET scan," Brain Medical 6:63-69,1994.

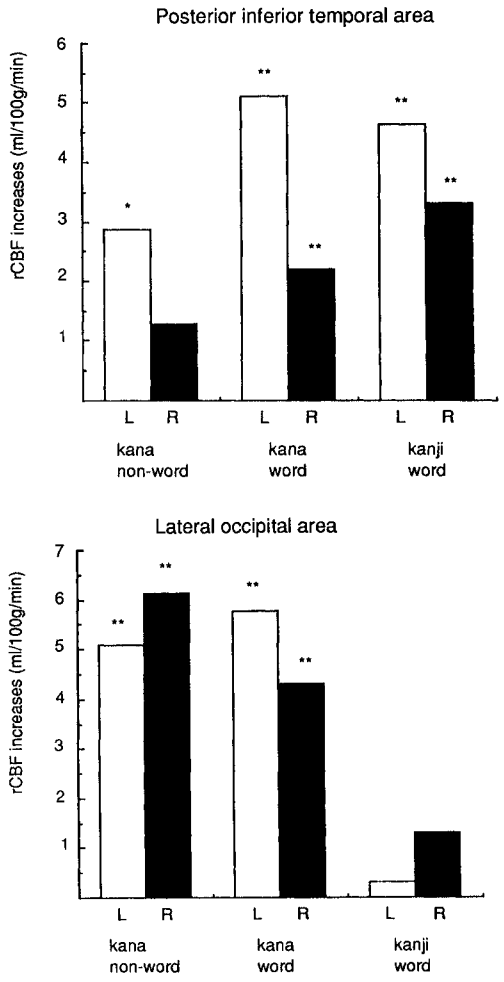

Figure 2: Mean rCBF increases in the PIT (above) and the lateral occipital area (below) in reading **Kana** non-word, **Kana** word and **Kanji** word tasks [11]