Examining two extreme cases of kanji recognition by Japanese using magnetoencephalography

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Abstract

This paper reports two extreme cases of kanji recognition by Japanese participants using magnetoencephalography (MEG). MEG is a non-invasive technique to measure magnetic field activities generated by neural activities in the brain. MEG was used to investigate neural activities when participants saw visually presented kanji and other objects. In this study we will report two extreme cases; one, participant A was very good (100% accuracy rate) and the other, participant B was poor (25% accuracy rate) at recognizing Korean characters. In this study five types of stimuli were used. Those are real kanji 神, pseudo kanji  (graphically legal but non-existent), illegal kanji  (graphically illegal), Korean characters 마 and picture fonts  . Both participant A and B are native speakers of Japanese, female, 20-30s, and received college education in Japan. We compared the magnitudes of M100 components of magnetoencephalogram which are thought to be an indicator of very early visual recognition in the visual field. The magnitudes of M100 for real kanji, pseudo kanji, and illegal kanji did not differ between the two participants. However, the magnitudes of M100 for Korean characters and picture fonts were larger in participant A than participant B. Since both participants received college education at Japanese universities, they were supposed to have good kanji knowledge and operational skills in reading and writing Japanese. No difference in the magnitude of M100 for kanji might be an evidence for the participants' efficient kanji knowledge. Smaller magnitudes of M100 for Korean characters and picture fonts in participant B might suggest participant B's poor visual recognition skills in general and correspond to participant B's poor recognition of Korean characters. There seems to be discrepancy between Korean character/picture font recognition and kanji recognition. One possible explanation is that originally participant B's visual recognition was not good; however, participant B has obtained good kanji recognition skills through many years of practicing. Developmental research is necessary to answer the question raised by the results of the current study.

1. Introduction

1.1 Background

This paper reports preliminary results of the brain imaging experiment with magnetoencephalography (MEG) while participants engaged in visual Kanji (Chinese character in Japanese) and other character like visual object recognition tasks using two extreme Japanese subjects who was very good at recognizing Korean character (correct rate 100%) and who was poor at recognizing Korean character (correct rate 25%) . The purpose of the experiment was to explore the relationship between brain activities and Kanji or character recognition strategies by comparing two extreme cases of native speakers of Japanese. Hitherto, neurolinguistic studies using imaging techniques such as functional magnet resonance imaging (fMRI) have been focused on the locus of brain activities or the difference between right and left hemisphere based on task differences. More conventional neurolinguistic technique, event related potential (ERP) studies using electroencephalogram (EEG) have been focused on the behaviors of brain waves after linguistic stimuli were presented. Previous studies in neurolinguistic areas have been focused on the direct relationship between linguistic stimuli and brain activities. Little attention has been paid on the relationships between linguistic stimuli, brain activities and cognitive or affective factors such as visual discrimination abilities, learning strategies, motivation, etc. For example, knowing the locus of a linguistic activity in the brain does not directly contribute to the development of efficient and effective language teaching methods. It is necessary to examine the relationship among three factors, brain activities, linguistic process and cognitive activities to understand language learning process well.

1.2 Linguistic areas in the brain

Figure 1 shows linguistic areas in the dominant hemisphere. In case of right handed persons the left hemisphere is the linguistically dominant brain, and in 27% of left handed person the right hemisphere is the linguistically dominant brain（Knecht, Dräger, Deppe, Bobe, Lohmann, Flöel, Ringelstein, & Henningsen, 2000).

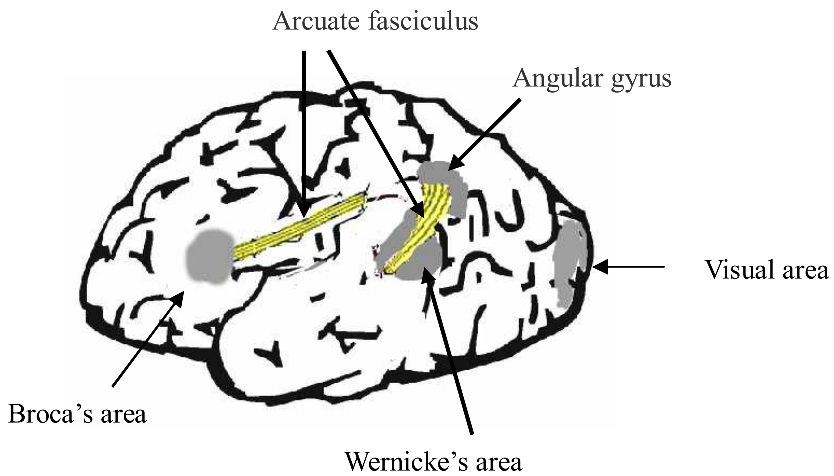

Figure 1. Linguistic areas in the left brain.

Wernicke’s area is on the left posterior section of the superior temporal gyrus, near the auditory cortex. Karl Wernicke, a German neurologist and psychiatrist discovered that this area is related to understand spoken language in 1874. Wernicke’s area is thought to be relate between auditory input and meaning. Broca's area is on the the inferior frontal gyrus of the frontal lobe. Paul

Pierre Broca, a French pyhsician fount that this area is thought to be involved in language processing, speech production and comprehension in 1861 (Hagoort、2005). Wernicke's area and Broca's area are connected by a neural pathway, arcuate fasciculus. Angular gyrus has been known to be related to reading from studies in dyslexia. It is thought to be connect visual area and Wernicke's area (Horwitz, Rumsey, and Donohue, 1998).

1.3. MEG (Magnetoencephalography)

MEG is a brain imaging technique used to measure the magnetic fields produced by electrical activities in the brain through very sensitive sensors. As shown in Figure 2, electrical current originated from neural activities produces magnetic fields. MEG measures magnetic fields.

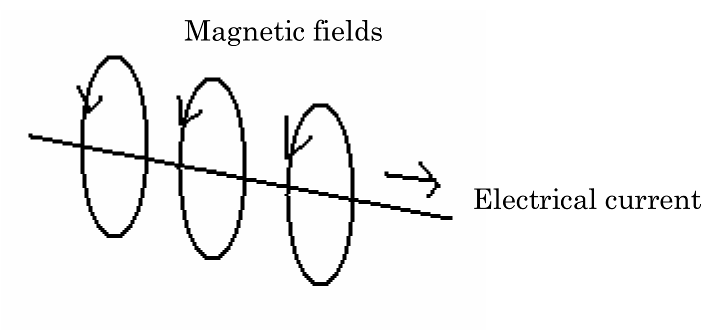

Figure 2. Electrical current and magnetic fields

The magnetic signals emitted by the brain are very small, 500-600 femtoteslas (fT, 1fT = 10^{-15} T) compared to the Earth's magnetic filed (10^{-5} T). Therefore, a shielding from is used to cut off external magnetic signals. A picture of shield room at Tokyo Medical and Dental University is shown in Figure3. MEG is primarily used to measure time courses of activity that cannot be measured by fMRI (Pylkkänen and Marantz , 2003 ; Stark and Squire, 2001).

Figure 3. Magnetic Shield Room at Tokyo Medical and Dental University

1.4. Brain and learning

The relationship between learning and brain activities is very complex. Haier, Siegel, MacLachlan, Soderling, Lottenberg, and Buchsbaum (1992) showed that the entire brain was activated while subjects were learning a computer game, whereas limited areas were activated once the subject mastered the computer game. Their study suggests that strong activation in the brain does not necessary reflect excellent performance.

1.5 Second language learning and neuroimaging studies

Bilingual or second language learning studies have paid more attention on the locus of language processing in the brain and critical period. However, language distance, age of acquisition, and competence in the two languages affect the locus and the number of language centers in the brain (Perani and Abutalebi, 2005). Bley-Vroman(1989) claims that the second language acquired after critical period should be different from the first language both qualitatively and quantitatively. Bruer(1999)argues that critical period exists for learning phonology, while not critical period exists for learning semantics. Bialystok and Hakuta (1994) claim that there is no critical period for learning grammar. According to Kim, Relkin, Lee, and Hirsch (1997), early bilinguals who acquired two languages simultaneously from early childhood have one language center, whereas late bilinguals who acquired two languages simultaneously from adolescence have two but adjacent language centers. One area was activated in early bilinguals in grammar judgment tasks in both first and second language, whereas more wide areas were activated in late bilinguals in the second language compared with the first language Perani and Abutaleb, 2005 ; Wartenburger, Heekeren, Abutalebi, Cappa, Villringer, and Perani, 2003).

1.6 M170

MEG recordings of visual word processing show five prominent components, M100 at about 90-110 ms, M170 at 150-200ms, M250 at 200-300 ms, M350 at 300-200 ms and M420 at 400-500ms with alphabetic scripts (Kutas and Hillyard, 1980; Pylkkänen and Marantz , 2003; Pylkkänen, Llinas, and Murphy, 2006). M100 is associated with primal visual processing. M170 is associated with spelling processing or character recognition. Functional meaning of activities between 200-300 ms has not been well understood. It is supposed that MEG components between 200-500 ms are associated with morphological and word level semantic processing. Although the function of M170 in visual processing is still under discussion, M170 is also associated with face recognition. (Liu, Harris, and Kanwisher, 2002). It seems that M170 reflects some specific process in human visual recognition.

In this study we attempt to compare two extreme case of kanji recognition by Japanese focusing on M170. We expect to obtain some insights into the mechanism of kanji recognition process by comparing the M170 amplitudes of different stimulus condition and cognitive behaviors

2. Method

2.1 Subject

Subjects are two Japanese female graduate students. Their ages were 26 and 30 at the time of the experiment. Both were right handed, normal vision, and voluntary participated in the experiment. Subject 1 responded Korean characters with 100% accuracy rates, whereas subject 2 responded with 25% accuracy rate.

2.2 Procedure

There were five types of stimuli, real kanji 神, pseudo kanji 礻刂 (graphically legal but non-existent), illegal kanji 車礻 (graphically illegal), Korean characters 마 and picture fonts. Eighty items for each group, total 400 items were used. There were 20 sessions. Each session had randomly arranged 20 items. There were 2 second intermissions between sessions. The stimuli were presented a character by a character around for 100 milliseconds and participants were asked to sound a castanet when they saw a Korean character. MEG data were collected using BTi Magnes 2500WH (USA) at Tokyo Medical and Dental University. Data were sampled at 254.31 Hz with hand width 50 Hz and High Pass Filter 1.0 Hz.

2.3 Psychological and Cognitive tests

To determine subjects' visual and verbal preferences, Paivio's (1986) "Visual and verbal preference inventory" which was translated into Japanese by the author were used. To examine subject's visual discrimination abilities, "Picture Identical Test" (ETS, USA) was used.

2.4 Analysis

MEG data with more than 4000fT noises were excluded from the data. The selected scanned data were averaged by stimulus groups. The averaged data were converted into text files and root mean square (RMS) were calculated and used for determine the maximum amplitude and latency of M170.

3. Result

Figure 4 showed averaged waves of MEG recordings after 900 ms post stimulus onset by stimulus groups for subject 1 and subject2.

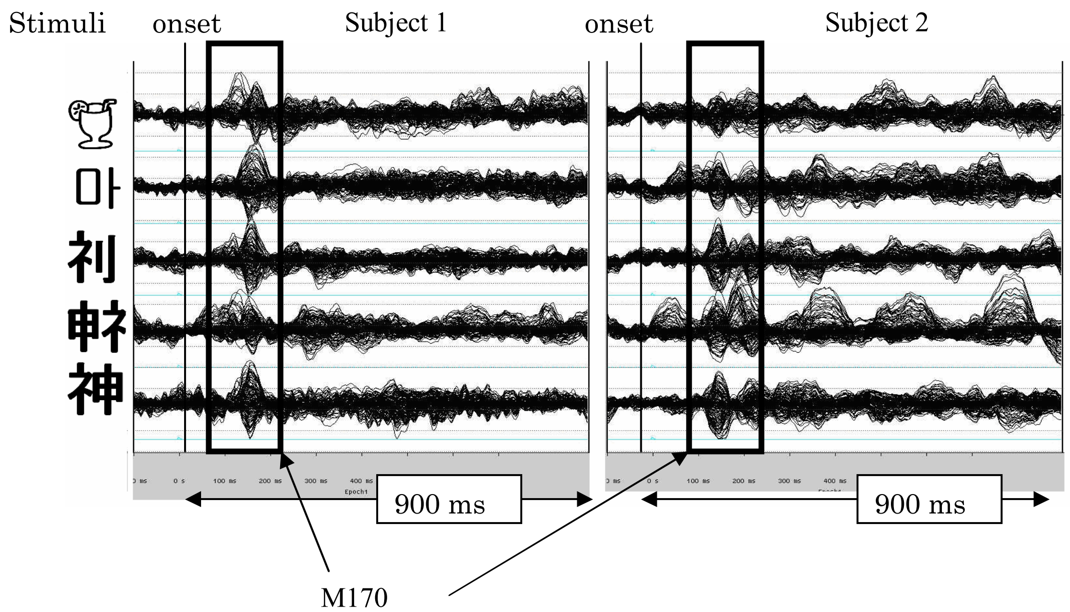

Figure 4. Averaged MEG waves by stimulus groups. En-squared MEG peaks indicates M170.

Figure 5 and Figure 6 show RMS graph of subject 1 and subject 2 based on the averaged MEG data for the five stimulus group during the entire MEG recording from -0.1 seconds before onset to 0.9 seconds after onset. Figure 7 shows RMS graphs of M170 for each subject.

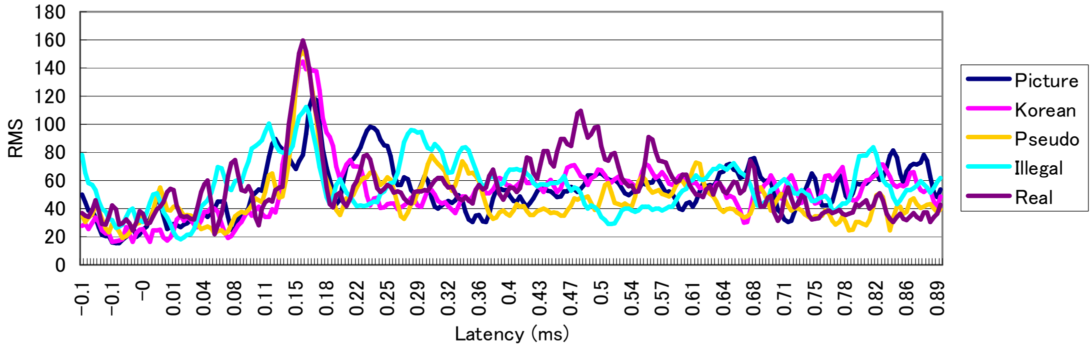

Figure 5. RMS graph of Subject 1

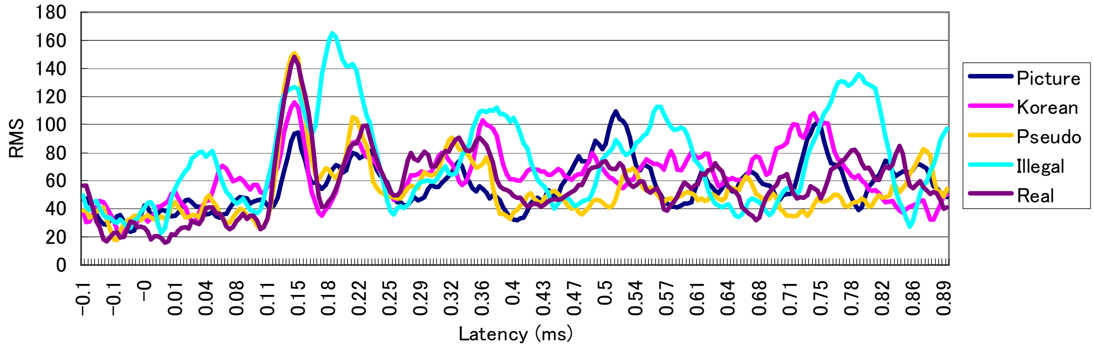

Figure 6. RMS graph of Subject 1

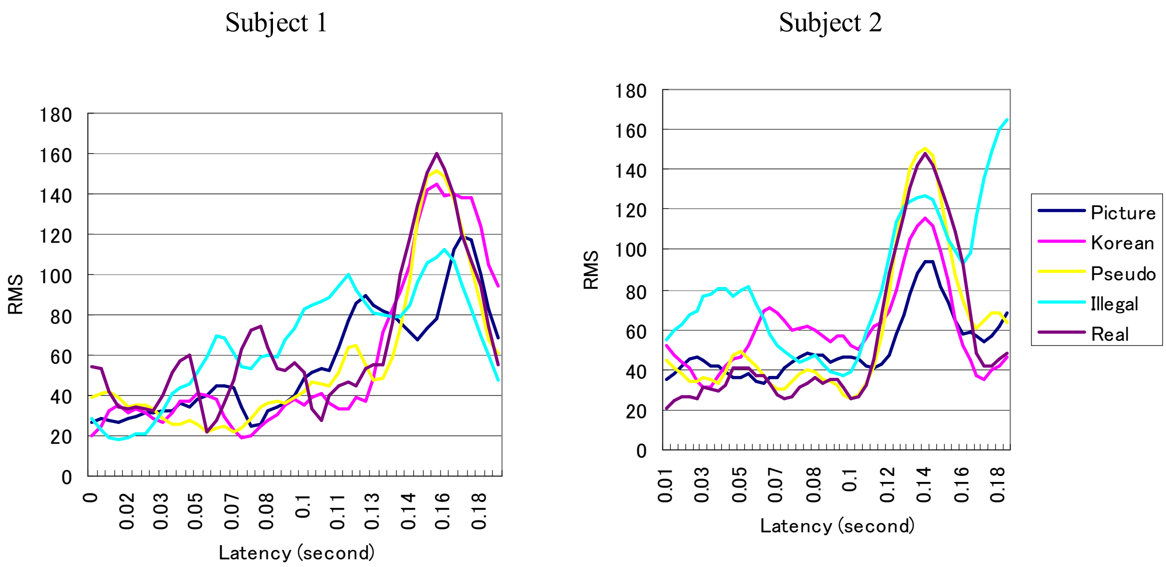

Figure 7. RMS graphs of M170 of subject 1 and subject 2

Table 1 shows lateness in milliseconds at the highest RMS, the amplitudes of the highest RMS, and the highest RMS ratios to the real kanji.

Table 1 Latencies of the highest RMS, the amplitudes of the highest RMS, and the highest RMS ratios to real kanji

Stimulus	Subject 1			Subject 2		
	Latency (ms)	Highest RMS	RMS Raito to Real K	Latency (ms)	Highest RMS	RMS Raito to Real K
Picture	167	119	0.74	147	94	0.63
Korean	155	145	0.90	143	116	0.78
Pseudo Kanji	155	151	0.94	143	151	1.02
Illegal Kanji	159	112	0.70	143	127	0.85
Real Kanji	155	160	1.00	143	148	1.00

Table 2 Cognitive test scores

	Subject 1	Subject 2
Korean character identification rate	100%	25%
Verbal preference (full score 10)	7	6
Visual preference (full score 10)	4	9
Identical Matching Test	96.9%	92.8%

Table 2 shows cognitive test scores. The mean score of verbal preference for Japanese was 5.26 (n=82 SD=2.1) and that of visual preference for Japanese was 7.75(n=82 SD=1.3). Visual preference score was significantly higher than verbal preference score for Japanese, t(81)=-10.50, p<0.001 (two-tailed), d=1.0. The mean score of Identical Matching Test (IMT) for Japanese was 96.2% (n=30 SD=2.7). The scores of IMT for subject 1 was about the same with the mean scores for Japanese, whereas that for subject 2 was a little below the mean score.

4. Discussion

In terms of latencies of over all stimulus groups, subject 2 was faster than subject 1. In subject 1, latency of illegal kanji (159 ms) was slightly slower than those of Korean character, pseudo kanji and real kanji (155 ms respectively). And latency of picture font (167 ms) was slowest among the five stimulus group. In contrast, in subject 2, latencies of the five stimulus groups were almost the same, 143ms. The slowest latency was picture font, 147 ms, however, the difference in latency between picture font and others were only 4 ms. In subject 1, the difference in latency between picture and others was 12 ms. It seems that both subject 1 and subject 2 processed picture fonts differently from other character based visual objects. However, subject 1 seemed to distinguish picture fonts from character based objects in more different manner than subject 2.

In terms of RMS ratios to real kanji, there were two notable groups in subject 1. The higher group consisted of real kanji (RMS ratio =1.0), pseudo kanji (RMS ratio = 0.94), and Korean character (RMS ratio = 0.90). The lower group consisted of picture fonts (RMS ratio = 0.74) and illegal kanji (RMS ratio = 0.70). In subject 2, the higher group consisted of pseudo kanji (RMS ratio = 1.02) and real kanji (RMS ratio = 1.0). The remaining three stimuli did not seem to be processed differently depending on their specific characteristics. The RMS ratios were illegal kanji (RMS ratio = 0.85), Korean character, (RMS ratio = 0.78), and picture fonts (RMS ratio = 0.63) in the order of higher to lower. The common phenomenon for both subject 1 and 2 was that the RMS ratio of picture font was the lowest.

In terms of verbal and visual preferences, in subject 1 the verbal score, 7, was higher than the average for Japanese, 5.26, and the visual score, 4 was lower than the average for Japanese, 7.75. In subject 2, the verbal score, 7, and the visual score, 9, were higher than the averages. Subject 1 seems to be slightly verbal oriented and subject 2 seems to be slightly visual oriented. Interestingly, the IMT score of subject 1 (96.9%) were higher than that of subject 2 (96.2%). The IMT score of subject 1 that was the approximately same the average. The IMT score of subject 2 was lower than the average.

What made difference the correct rates of Korean character between subject 1 (correct rate =100%) and subject 2 (correct rate =25%)? The RMS ratio of Korean character in subject 1 (0.90) was larger than that of subject 2 (0.78). It seems that subject 1 processed Korean characters as linguistic visual object, where as subject 2 processed Korean characters more likely as picture fonts, non-linguistic visual object. Subject 1 seems to be verbal oriented with high visual identification performance, whereas subject 2 seems to be visual oriented with lower visual identification performance. These cognitive style differences might be responsible for the two subjects' behavior and neurological differences.

An interesting difference between the two subjects seems that subject 1 divided the five stimuli into clear two groups in terms of both latency and RMS ratios, where as subject 2 did not. Subject 1 divided the five stimuli into two groups, real kanji, pseudo kanji, and Korean character versus illegal kanji and picture font. It seems that subject 1 divided the stimuli based on more linguistic basis, whether a visual object belongs to real character or not solidly. In contrast subject 2 processed realistic kanji (real kanji and pseudo kanji) and picture fonts differently from illegal kanji and Korean characters in terms of RMS ratios, however, illegal kanji and Korean characters did not belong to any group. Further, there was no difference in latencies of the four character based stimuli. More unfamiliar objects, illegal kanji and Korean characters, were distinguished based on

RMS ratios, not on latency. It seems that subject 1 had more clear criteria and strategies to distinguish character like visual objects that subject 2.

The common phenomenon between subject 1 and 2 was that the latency of picture fonts was slowest and the RMS ratio of picture font was lower in the five stimuli in both subject 1 and subject 2. This result agreed with Shirahama,Ohta, Takashima, Matsuhima, and Okubo (2004)`s previous MEG study with Japanese native speakers. Although, kanji is logograph and it has been thought that kanji is processed like picture for a long time (e.g., Takebe, 1993), it seems that Japanese processed kanji differently from picture fonts.

Comparing latencies and the amplitudes of M170 from MEG data based on linguistic stimuli with cognitive data, such as visual and verbal preference and IMT seems to be useful to understand the relationship between neurological process and linguistic behavior. The current study did not examine the locus of visual character recognition. Comparing the differences activated areas in the brain during visual character recognition by employing experts and non-experts will give us more neurological information about the difference between good and poor linguistic performance. The current study compared only two extreme cases. It is necessary to examine neurological behaviors of many subjects to obtain more generalized insights on how Japanese process kanji or kanji like characters.

5. Conclusion

It seems that subject 1 with good Korean character recognition processed Korean character as character, a linguistic visual object, whereas subject 2 with poor Korean character recognition. Subject 1 might have more clear criteria and strategies to distinguish linguistic visual objects than subject 2. Although, kanji has been thought to be logograph, kanji and picture fonts were processed differently. MEG recoding data seems to be a good tool to examine whether a visual object is processed linguistically or not.

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