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Brain Activity When Reading Sentences and Emoticons: An fMRI Study of Verbal and Nonverbal Communication

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SUMMARY

In this paper, we describe a person's brain activity when he or she sees an emoticon at the end of a sentence. An emoticon consists of some characters that resemble the human face and expresses the sender's emotions. With the help of a computer network, we use e-mail, messaging, avatars, and so on, in order to communicate with a recipient. Moreover, we send an emotional expression by using an emoticon at the end of a sentence. In this research, we investigate the effect of an emoticon as nonverbal information, using an fMRI study. The experimental results show that the right and left inferior frontal gyrus were activated and we detect a sentence with an emoticon as the verbal and nonverbal information. © 2011 Wiley Periodicals, Inc. Electron Comm Jpn, 94(5): 17–24, 2011; Published online in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/ecj.10311

Key words: face; fMRI; emoticon; nonverbal communication; human computer interaction.

1. Introduction

In order to appropriately share emotions and feelings with others, humans have developed methods for abstraction and display of facial features and expressions. For example, caricatures and portraits in a newspaper or comics entertain readers by using specific facial expressions [1, 2]. In addition to newspapers, comic books, and other paper media, the recent progress in digital media has given rise to new abstract facial expressions. For example, the emoticons and face icons used in e-mails and chats are very abstract and have only a limited means of expression but yet can convey emotions such as joy or sadness to many people [3]. In addition, avatars are employed by Internet users to represent themselves, and skillful handling of the avatars makes communications more enjoyable [4, 5].

Thus, faces are now expressed in various ways. Coda, McCloud, Yuasa, and other investigators have systematized the facial images used in e-mails, chats, and other electronic communications, by the level of abstraction [6, 7], and Yuasa and colleagues have investigated brain activities related to emoticons, which offer the highest level of abstraction [8–11].

On the other hand, humans can convey emotions such as joy or sadness not only through facial expressions but also by using appropriate words. By combining words with facial expressions, emotions are expressed more effectively thus contributing to communications with others. For example, in comics and caricatures, the characters' images are merged with their words, and video game characters combine movements, prosody, facial expressions, gestures, etc.

However, combinations of abstract facial expressions with words, that is, combinations of verbal and nonverbal information, have not been studied in detail. In addition, benchmarks are needed in order to evaluate numerous abstracted faces in comics, caricatures, and computer graphics.

In this context, we examine brain activity while reading "emoticon-enriched sentences," that is, texts mixed with the most highly abstract facial images. Emoticon-enriched sentences (e.g., "I had fun (≥∇≤)") are composed of words to be interpreted semantically, along with simple emoticons denoting facial expressions, and thus are a basic combination of verbal and nonverbal information. The investigation of brain activities related to emoticon-enriched sentences is likely to clarify the fundamental structure of verbal and nonverbal communication. An understanding of such a fundamental structure may, for example, contribute

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to the design of robots or computer characters that make efficient use of both verbal and nonverbal communications.

Below, after a survey of previous research in Section 2, we explain the experimental method and the results obtained by fMRI in Section 3. These results are then discussed in Section 4, and a summary is given in Section 5.

2. Previous Research

Extensive research in brain imaging using PET and fMRI, as well as observations of patients with specific pathologies, have shown that language utterance and comprehension are related to particular areas, called Broca's area and Wernicke's area [12]. Broca's area is located near the inferior frontal gyrus in the left hemisphere; since patients with damaged Broca's area have language output disorders, this area is assumed to be responsible for language utterance. In addition, Broca's area is probably related to word order, because some patients with a damaged Broca's area have problems with the comprehension of word order [13]. Wernicke's area is located near the superior temporal gyrus in the left hemisphere; this area is assumed to be responsible for language comprehension [12, 14].

In addition, Sakai and colleagues performed a detailed study of brain regions related to language comprehension [15–18]. Using judgment tasks involving verb subjects and pronouns, and decision tasks involving word order, they ascertained that regions related to syntax processing are located from the left inferior frontal gyrus to the left lateral premotor cortex. They also reported that experiments with the visual representation of symbols and the auditory representation of speech indicated that text comprehension is concentrated near the ventral portion of the left inferior frontal gyrus. This is illustrated in Fig. 1 [15].

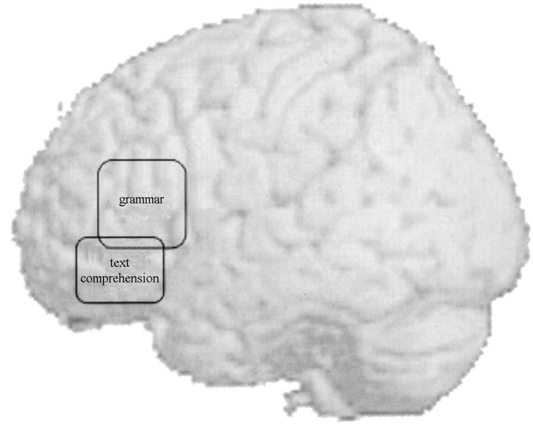

Fig. 1. Grammar processing and semantic processing [15].

Kawashima and colleagues and Nakamura and colleagues measured brain activation by nonverbal stimuli. In particular, Kawashima and colleagues measured brain activity when experimental subjects were asked to discriminate between emotions (joy, sadness, etc.) in presented speech. In addition, various facial expressions were presented to the same experimental subjects for the same purpose. They report activation of the right inferior frontal gyrus in both cases [20]. Nakamura et al. measured brain activity in facial evaluation tasks, and reported activation of the right inferior frontal gyrus [21].

As regards facial expressions, Kanwisher and colleagues reported that the right fusiform gyrus activates when facial images are presented to experimental subjects [22, 23]. In addition, prosopagnosic patients, who cannot recognize human faces, are reported to have pathologies in the fusiform gyrus, lingual gyrus, and other areas of the right hemisphere [20].

Yuasa and colleagues examined brain activity related to emoticons and face icons. In emoticon discrimination tasks they ascertained that the right fusiform gyrus is not activated, but the left inferior frontal gyrus is activated [8–11, 19]; examples of facial icons are given in Fig. 2 [19].

Nomura and Takehara studied ambiguous information presentation. In particular, they examined brain activity in the discrimination of ambiguous and clear facial expressions, and reported that the anterior cingulate gyrus and certain other areas become more active when ambiguous facial expressions are presented [24].

Maddock and colleagues investigated brain activity when facial expressions were combined with emotional words. In particular, they presented emotional nouns and adjectives to experimental subjects, and observed their brain activity by fMRI. They report that the posterior cingulate gyrus and certain other areas seem to be involved [25].

Thus, there has been considerable research in this field. On the other hand, Yuasa is still the only researcher who has dealt with emoticons, which combine the properties of verbal and nonverbal information [8–11]. But the use of emoticons at the end of a sentence and in some other cases has not yet been sufficiently studied. Comparative brain measurement for sentences ending with emoticons

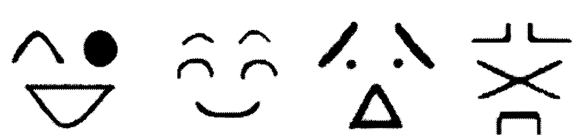
Fig. 2. Face icons [19].

and plain sentences would clarify the effects of emoticons and the properties of verbal and nonverbal communications. In the experiments described below, we focus on how emoticons used in sentences contribute to the activity of the right and left inferior frontal gyri, which are related to verbal and nonverbal information. In addition, we examine the activity of the fusiform gyri, which are related to facial shape, and the lingual gyri, which are related to fuzzy judgment and emotive words.

3. Brain Measurement Using fMRI

3.1 Experimental method

An fMRI (functional Magnetic Resonance Imaging) scanner is a device that detects variations of MRI signals caused by changes in cerebral blood flow, and acquires 3D data on the brain areas where the blood flow changes.

In our experiments, we used a 1.5-T superconducting MRI scanner (Stratis II, Hitachi Medical Corp.). The experimental subjects lay inside the fMRI scanner, wearing prismatic glasses, and viewed visual stimuli projected on a screen near their feet. The experimental setup is illustrated in Fig. 3.

The stimuli were presented in a task-and-rest block design. The task and rest stimuli were alternated three times as shown in Fig. 4. Multiple visual stimulus images were provided. The task and rest periods lasted 50 seconds each, and each image was presented for 5 seconds.

3.2 Experimental stimuli

In order to examine brain activity caused by emoticon-enriched sentences, they were presented to the subjects as task blocks, while plain sentences were presented as rest blocks, and the brain activation was compared. The sentences were cited from previous studies by Takehara and colleagues [3, 26]. As shown in Fig. 5, emoticon-enriched sentences were presented on the screen in a random sequence during task blocks. Some examples of other sample sentences are given in Fig. 7. The task stimuli included some in which emoticons and text conveyed contradictory emotions, for example, “I won the club competition (T_T)” and “I caught a cold (≥∇≤)” in Fig. 7.

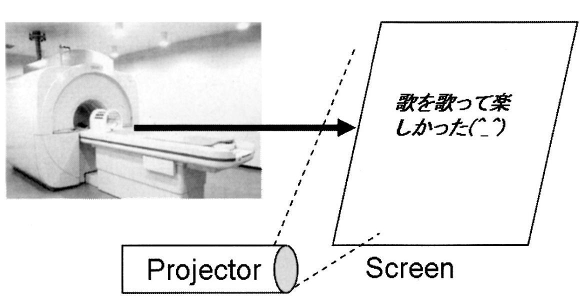

Fig. 3. fMRI and visual stimuli.

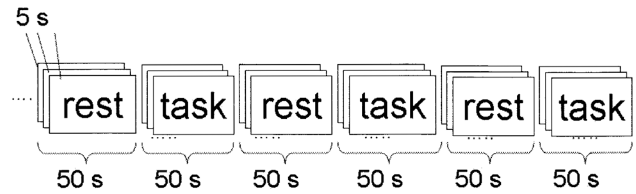

Fig. 4. Task-and-rest block design.

The emoticons added to the sentences were chosen in accordance with the results of preliminary individual questionnaires. The experimental subjects chose those emoticons that they felt to be the most “happy” and “sad” from among those given in the papers of Takehara and colleagues [3, 26]. The emoticons used in the questionnaires are shown in Fig. 6.

In the examples shown in Fig. 7, the subjects chose (≥∇≤) and (T_T) as the most “happy” and “sad” emoticons, respectively. The emoticons were changed for each subject according to their preferences.

The subjects were asked to read to themselves sample sentences, as they did in the case of e-mail or a chat, and to press a button when the emoticons and sentences conveyed the same emotions, or when they read plain sentences (without any emoticons).

For example, the emoticon and the sentence convey the same emotion in the case of “Something good happened today (≥∇≤).” On the contrary, in the case of “I won the club competition (T_T),” the message consists of good

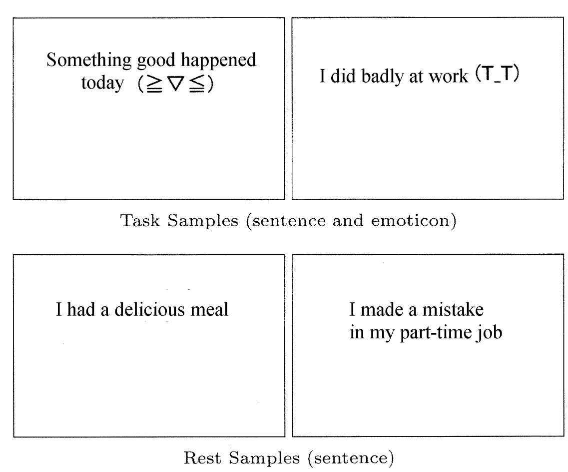

Fig. 5. Stimuli.

A.

(^o^) (*^_^*) (^u^) (^_^) (^ε^) (^◇^) (^^)
(≧▽≦) (^V^) (●^o^●)

B.

(T_T) (+o+) (ToT) (;_;) (>_<) (;o;) (X_X)
(,o,) (¥_¥) (t_t)

Fig. 6. Emoticons: happy (A) and sad (B).

news, but the emoticon means "crying"; in such cases, the button is not pressed.

This task corresponds to the syntactic judgment task implemented by Sakai and colleagues. When emoticons are employed, the meaning of the emoticons must be understood in addition to the meaning of the text, and therefore this task indicates whether the process of emoticon comprehension is identical to syntactic judgment, or to judgment about verb subjects and pronouns.

(Task)

I lost an important photo (T_T)
I won the club competition (T_T)
Something good happened today (≧▽≦)
I made a mistake in my part-time job (T_T)
My test score was low (T_T)
I had a delicious meal (≧▽≦)
I caught a cold (≧▽≦)
I got a prize in a lottery (≧▽≦)
My pet died (T_T)
I picked up some money (T_T)
... etc.

(Rest)

I picked up a wallet
I won the club competition
I made a mistake in my part-time job
I got a prize in a lottery
My pet died
My test score was low
I had a delicious meal
Something good happened today
I lost an important photo
I caught a cold
... etc.

Fig. 7. Examples of task (emoticon-enriched sentences) and rest (plain sentences).

3.3 Scanning method

The contents and procedures of the experiments were explained to the subjects, and their consent was obtained.

In these experiments, a statistical significance test was applied to the BOLD (Blood Oxygenation Level Dependent) signals from the task and rest blocks, and brain images were obtained by mapping significant signals onto standard brain templates. The scans were implemented using EPI-GE sequences under the following conditions.

- Scan width: 240 mm
- TR/TE: 4600/50.5 ms
- Flip angle: 90°
- Slice thickness: 4.0 mm
- Slice interval: 1.0 mm

The voxel dimensions in the EPI images were $3.75 \times 3.75 \times 5.0$ mm. The maximum half-width (FWHM) was set to 10 mm, and the analysis was performed as follows.

- Realignment: Correction of position shifts caused by body movements of the subjects during the experiments.
- Normalization: Conversion of an individual subject's brain configuration to a standard brain template.
- Smoothing: Suppression of noise included in observed signals.
- Statistics: Variance analysis of the observed signals for all experimental subjects.

The above processing was implemented using the SPM99 (Statistical Parametric Mapping) medical image analysis software [27]. The use of SPM99 made it possible to detect the regions where the signal strength was statisti-

Table 1. Activated areas

Designation	X	Y	Z	Site
A	-50	34	-6	Left inferior frontal gyrus
B	48	16	22	Near right inferior frontal gyrus ~ middle frontal gyrus
C	-54	16	24	Near left inferior frontal gyrus ~ middle frontal gyrus
D	0	20	60	Anterior cingulate gyrus
E	44	34	-16	Near right middle frontal gyrus ~ inferior frontal gyrus

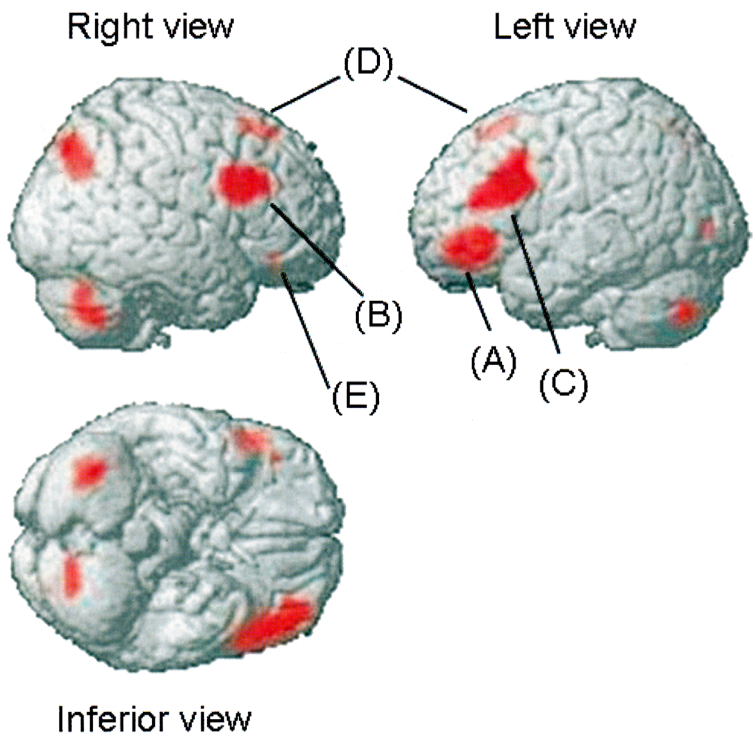

Fig. 8. Brain activities (shaded areas indicate activated areas after correction). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

cally significant relative to the rest blocks. Variance tests were applied to the signals across multiple experimental subjects, and across alternating rest and task blocks, with correction for multiple comparison ($p < 0.05$). The detected significant portions, superimposed on 3D surface rendering images of the cerebral cortex, are shown in Fig. 8 [27–31]. The statistical significance of the signal variation is shown by the color strength; the darker the area, the higher the blood flow, and the greater the likelihood of activation. Table 1 gives the *XYZ* coordinates of the peak locations.

Table 2. Brain activities in our experiments and previous research

Site	Site description in previous research	Detection of activation in our experiments
Right fusiform gyrus	Face recognition	-
Right inferior frontal gyrus	Emotion discrimination	○
Left inferior frontal gyrus		
(-- left lateral premotor cortex)	Broca's area, text comprehension	○
(near ventral portion)	Broca's area, syntactic judgment	○
Left superior temporal gyrus	Wernicke's area	-
Anterior cingulate gyrus	Ambiguous facial expressions	○
Posterior cingulate gyrus	Comprehension of emotional words	-

3.4 Experimental results

The experimental subjects were right-handed university students majoring in science, 10 males and 2 females, who regularly used emoticons in e-mails and chats. The experimental results indicated significant activity near the left inferior frontal gyrus at $(X, Y, Z) = (-50, 34, -6)$ [(A) in Fig. 8]. This is Broca's area, which is involved in verbal communications. On the other hand, no significant activity was observed in Wernicke's area. In addition, activation was detected near the right inferior frontal gyrus [(B) and (E) in Fig. 8]. In the previous experiments of Sakai and colleagues, (A) and (C) in Fig. 8 correspond, respectively, to the ventral portion of the left inferior frontal gyrus, which is related to text comprehension, and to the area from the left inferior frontal gyrus to the left lateral premotor cortex, which is related to syntax processing. In addition, significant activity was observed near the anterior cingulate gyrus (D), but not at the posterior cingulate gyrus. The above results are summarized and collated with previous studies in Table 2.

4. Discussion

In the case of emoticon-enriched sentences, the right fusiform gyrus was not activated, although it is activated when seeing faces. This coincides with previous results obtained for separate emoticons [8–11]. Emoticons represent facial shapes by the sparse means of combined letters and symbols, which may explain why the right fusiform gyrus is not activated significantly.

On the other hand, activity of the right inferior frontal gyrus was observed in our experiments. This brain region is activated in emotion discrimination tasks [20, 21], which indicates judgment about emotions based on facial expressions, speech prosody, and other nonverbal information. The activation of the right inferior frontal gyrus suggests that emoticons, although they are primitive facial models not capable of activating the right fusiform gyrus, serve as emotional indicators similarly to other nonverbal means.

In addition, we detected activation of the left inferior frontal gyrus, related to text comprehension and syntactic processing. The above-mentioned studies of Kawashima and colleagues and Nakamura and colleagues point out the possibility that verbal and nonverbal functions are divided between the left and right inferior frontal gyri [20, 21]. Therefore, we may assume that when emoticons are added to sentences, the left and right inferior frontal gyri are activated more strongly than in the case of plain text, and that verbal processing and nonverbal processing take place near the left gyrus and right gyrus, respectively.

No significant activity was detected at the posterior cingulate gyrus. Since activation of the posterior cingulate gyrus was reported in experiments with discrimination between "happy" and "sad" emotional nouns and adjectives [25], we may conclude that emoticons are different from emotive words.

The present study can be summarized by the following two conclusions.

First, we confirmed by brain measurement that emoticons are a kind of nonverbal information, and that the other party's emotions are perceived in communications using emoticons. Emoticons have spread widely as a means for enhanced communications over computer networks. Explanation of this fact by brain measurement seems very significant.

Second, we confirmed that brain sites dealing with both verbal and nonverbal information are activated more strongly when emoticons are added to sentences, than in the case of plain text. Since no significant activity was detected at the fusiform gyrus or the posterior cingulate gyrus, we may assume that emoticons do not carry clear semantic content, in contrast to subjects or adjectives, and thus are a simple means of communication. Therefore, communications using emoticons constitute very basic symbolic communications via electronic media (e-mail and chats) using both verbal and nonverbal functions [32] located in the right and left hemispheres. This is much different from emotional speech or facial expressions. For example, in emotional speech, judgments about emotions are based on voice loudness, prosody, sound duration, and other information. In the case of facial expressions, judgments about emotions are based on a complex combination of the position and shape of the eyes, mouth, and other facial features, while time-varying emotions are expressed by subtle nuances. Thus, emoticons can be considered as a means of verbal and nonverbal communications characterized by a simple form of emotional enhancement.

Further research based on the results of this study should reveal more details of verbal and nonverbal communications. For example, we may consider varying the emotional strength of emoticons, or using abstract facial expressions other than emoticons, as well as contradictory combinations of emotional expressions and semantic content ("I enjoyed singing (T_T)") so as to obtain detailed explanations of the sites and mechanisms of brain functions involved in verbal and nonverbal communications.

Furthermore, this study may contribute to the development of design methodologies for humanoid robots and computer characters by using both verbal and nonverbal expression techniques. For example, brain measurements show that emoticons are a nonverbal means of communication, and thus robots and computer characters can be designed properly by choosing emotional representations that activate brain sites dealing with nonverbal information, or by testing their compatibility with verbal expressions.

In this study, the experiments were designed to include pressing a button when reading a plain sentence during the rest blocks, or when reading an emoticon-enriched sentence with a noncontradictory emotional representation during the task blocks. In this design, brain activities may overlap in the two mentioned cases. However, this design seems realistic, because when reading emoticon-enriched sentences in real e-mail or chats, a reader makes two judgments, about the presence of emoticons, and about their emotional agreement. In addition, when the two judgments were separated in preliminary experiments, the subjects felt discomfort and boredom, and thus we decided on the realistic design. In the future, we plan to improve the experimental design for further analysis of verbal and nonverbal elements.

5. Conclusions

We considered electronic communications using facial images, and used an fMRI scanner to examine brain activity caused by the reading of emoticon-enriched sentences. The experimental results showed activation near the right and left superior frontal gyri, which suggests the possibility that verbal processing and nonverbal processing are performed near the left and right gyri, respectively.

In the future, we plan to perform additional experiments with more subjects in order to allow an in-depth analysis of the mechanisms underlying communication by emoticons.

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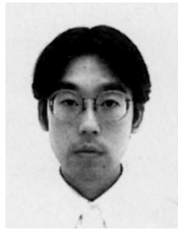  

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