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# Analysis of Facial Expression Recognition by Event-related Potentials

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***Abstract.*** Recognition of facial expression is an important ability in human life, and it is related with emotion closely. In this article we performed the psychophysical experiments for the purpose of clarifying the process of facial expression recognition by analyzing event-related potentials (ERP). We examined the difference of ERP between smile and anger faces, and classified the results of smiling faces with the mouth opened or closed. From a viewpoint of the late positive ERP components, experimental results suggest that (i) an anger face is handled than smile earlier, (ii) the smile with the mouth closed is processed similar to an anger face in comparison with a grinning face, and (iii) N400 and P500 responses are related to the final categorization of emotions. Moreover, differences of ERP in the prefrontal cortex were obtained between participants, in which it is argued by the difference in scheme that they took for expression discrimination. Based on the hypotheses, we proposed an information processing model to recognize smiling and anger faces.

*Keywords:* Event-related potential (ERP), Facial expression recognition, Emotion, Psychophysical experiment, Information processing model

## 1. Introduction

In the human communication, facial expression becomes the important clue to guess the feelings of the partner. If the information processing about emotion becomes clear, it is expected to help the development of technologies for smooth communication, such as the robot which can understand human feelings better.

Event-related potentials (ERP) is one of the useful measures to study the mechanism of information processing in the human brain, and several studies detected the components of ERP specific for face recognition [Olivares, *et al.*, 2015]. Since ERP is superior in temporal resolution, it is thought that applying it is suitable to analyze the information processing of facial expression.

In this article we perform psychophysical experiments for the purpose of clarifying the process of the facial expression recognition. By analyzing measured ERP, we identify the characteristics of electric potentials related to the facial expression information processing.

## 2. Psychophysical Experiment

### 2.1. Stimulus

We used 10 Japanese female portraits in JAFFE database [Lyons, *et al.*, 1998]. Based on the attached evaluations, 10 images were chosen for each expression, e.g., smiling (*happy*), anger (*angry*), sad, and surprised faces. The stimuli were displayed in random order, at the area of an angular size 7.9 x 8.8 degrees in the LCD monitor (Samsung SyncMaster 2233RZ). PST E-Prime 2.0, which is a suite of applications for psychological experiments, was used for control of the stimulus presentation.

### 2.2. Procedure

The experiment was conducted in a darkroom. The participant attached the electroencephalograph Emotiv EEG headset during the experiment.

We instructed to the participants that they replied by pushing the button of PST Serial Response Box whether a displayed face image was an appointed expression, *happy* or *angry*. Only in the case of the appointed expression, the participants were directed to react.

After showing a fixation point during 500 milliseconds, a face stimulus was displayed in 100 milliseconds. Then a random-dot image was presented for masking. The screen which forces a participant to answer was displayed for up to 2,000 milliseconds. This trial was repeated 320 times (40 stimuli presentation a set). Between the sets when an intermission screen was displayed, the participants could take a rest in the darkroom.

### 2.3. Participants

8 males and 3 females for *happy* condition from 20 to 22 years old with (corrected) normal vision were participated as volunteers, and also 6 males and 2 females for *angry* condition.

## 3. Results

The average rate of incorrect answers was 7.5%. The analysis was carried out along the answers of the participants, not expressions connected with face images. We employed EEGLAB [Delorme and Makeig, 2004], which is a MATLAB toolbox for processing EEG.

### 3.1. Comparison between smiling and anger faces

Figure 1 and 2 show the event-related potential (ERP) of the right hemisphere for *happy* and *angry* conditions, which is obtained by the average of 11 participants for *happy* condition and 8 participants for *angry* condition respectively. The averaged ERP are derived from the trials when the participants pushed the button.

P300 are observed with the electrodes at middle temporal gyrus for both *happy* and *angry* conditions. It is thought that the attention of the participants is surely turned to the face images, because P300 is an endogenous potential to reflect processes involved in stimulus discrimination.

In *angry* condition, the individual differences are occurred for the latency of P300. Since each participant's latency of P300 is about 200 milliseconds, 400 milliseconds, or nothing, the averaged ERP include two positive components dispersively. As an overall tendency, the positive components are distinctly visible in the ERP in the right hemisphere, but not clearly in the left because of the differences between the participants.

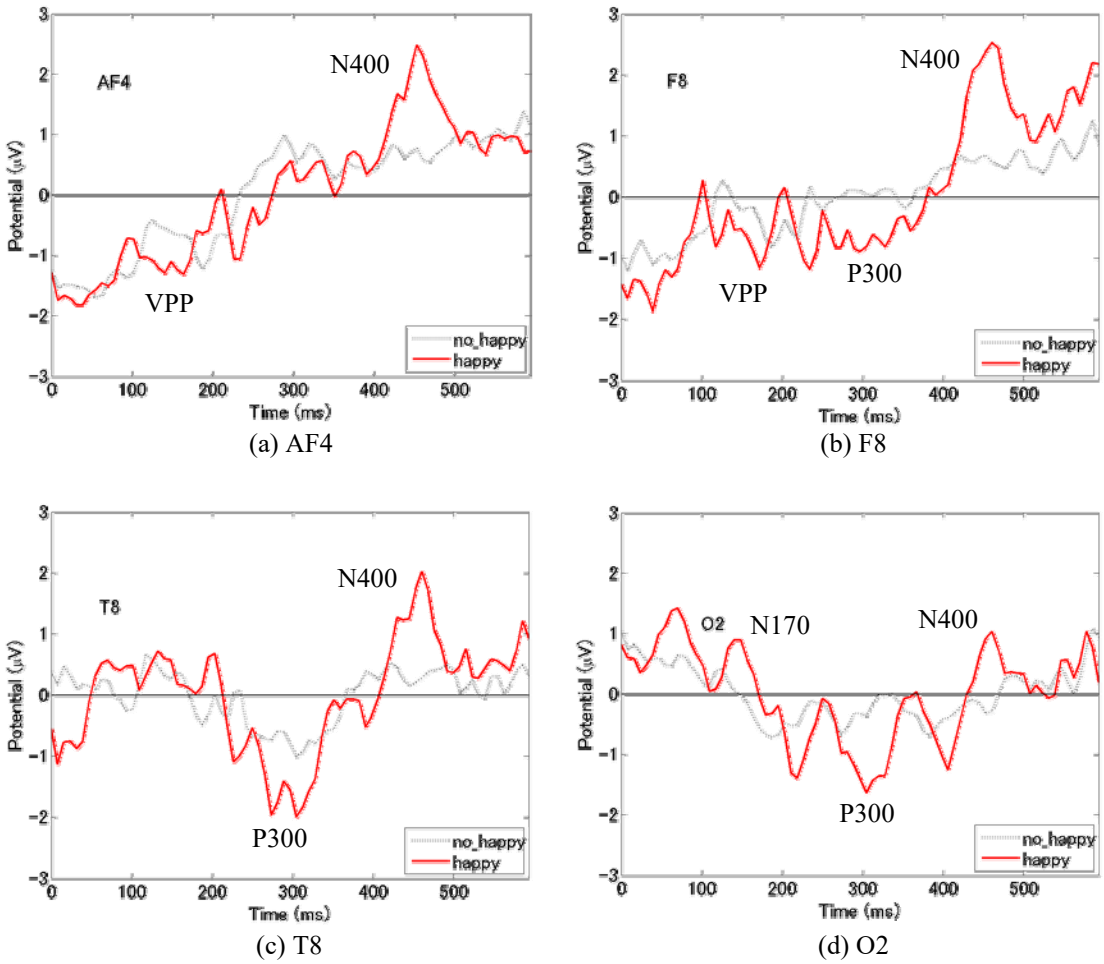
Although the P500 component is commonly appeared for most participants, the latency or existence of N400 is highly individual. Compared between Figure 1 and Figure 2, the latency of P500 for the *angry* condition is clearer, in which it is about 450 milliseconds in Figure 2. The difference suggests that processing of anger faces in brain is performed earlier than smiling.

Focusing the ERP components observed with the electrodes at the occipital lobes for both *happy* and *angry* conditions, participants were divided into two types: N400 clearly appeared, or fibrillation of potentials were recorded. Basically, individual differences emerged more greatly than the expression differences. That tendency might be dispersed by the scheme that participants took for the tasks.

### 3.2. Comparison between smiling with the mouth closed and grinning faces

A human face may be an expression with different characteristics even if it expresses the same emotion. We divided 10 images of the *happy* condition into 2 groups; 4 smiling faces with the mouth closed (*smile*) and 6 grinning faces (*laugh*). Figure 3 shows ERP for both stimuli which is obtained by the average of 11 participants. The averaged ERP are derived from the trials when the participants pushed the button.

Although presence or latency of P300 and N400 is inconsistent by the participants, the late positive ERP components P500 is commonly observed in the frontal lobes. The amplitude for the *smile* stimuli appears more definitely than the *laugh* stimuli. The latency of P500 for *smile* stimuli is later than *angry* condition. For the participants who P300 and N400 appear for both stimuli, the latency of the *angry* condition tends to be the shortest. As a result of individual participant, the electric potential of the late ERP shows a tendency to raise. The positive component VPP around 170 milliseconds is recorded as for almost all participants for the *smile* stimuli, but not for the *laugh* stimuli.




(a) AF4 (b) F8

(c) T8 (d) O2

***Figure 1.*** *Averaged ERP in the right hemisphere for happy condition.*

In the temporal lobes, P300 and N400 are observed for both *smile* and *laugh* stimuli. The difference of the latency is not consistent, but P500 component is appeared only for the *smile* stimuli.

In the occipital lobe, multiple positive components arise from 200 to 400 milliseconds. Similar to the other electrodes, the amplitude of P500 for the *smile* stimuli is larger as for several participants.

## 4. Discussion

Based on the features of ERP components, we propose an information processing model to recognize smiling and anger faces, as shown in Figure 4.

When an anger face was displayed, unconscious processing to detect the menace might occur, mainly in the amygdala. However, since the activation of the amygdala was not observed under our experiment that imposed the emotional category discrimination for the expression, it is suggested that activation of the right lateral prefrontal cortex affects inhibitory action of the amygdala [Nomura, *et al.*, 2004]. Results of independent component analysis, in which the estimated sources would be around AF3 and AF4, argue that P300 recorded in the electrodes of frontal lobe may be the component related to the inhibition.

We consider that it is branching after the recognition of a target face, in which it seems to be represented by P300 components at the temporal lobes and the source may be the superior temporal sulcus, by the difference in scheme which the participants took. The process from the early perception represented by VPP and N170 components to the face recognition in the superior temporal sulcus corresponds to the *Core system* by [Haxby, *et al.*, 2000]. We hypothesize that the features of ERP are caused by the difference in scheme in the following *Extended system* [Haxby, *et al.*, 2000].

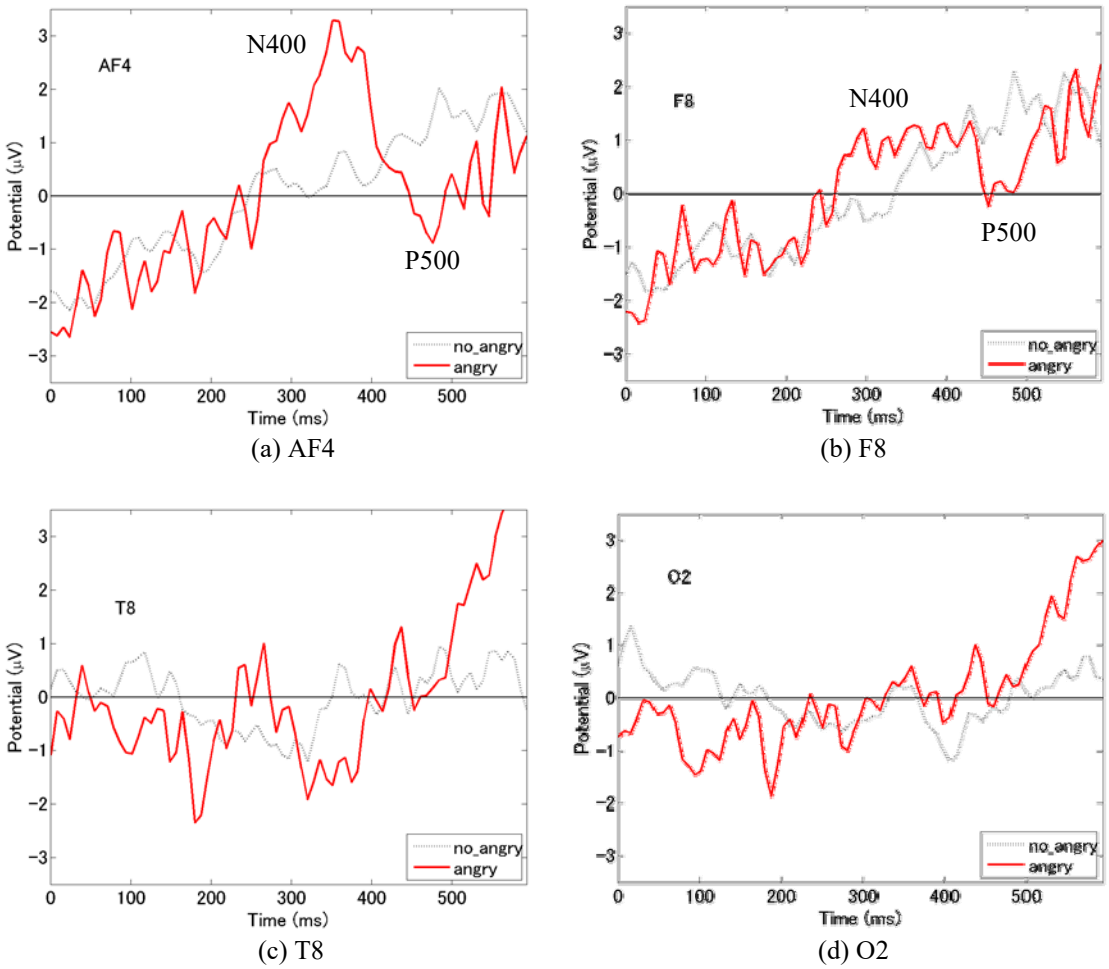
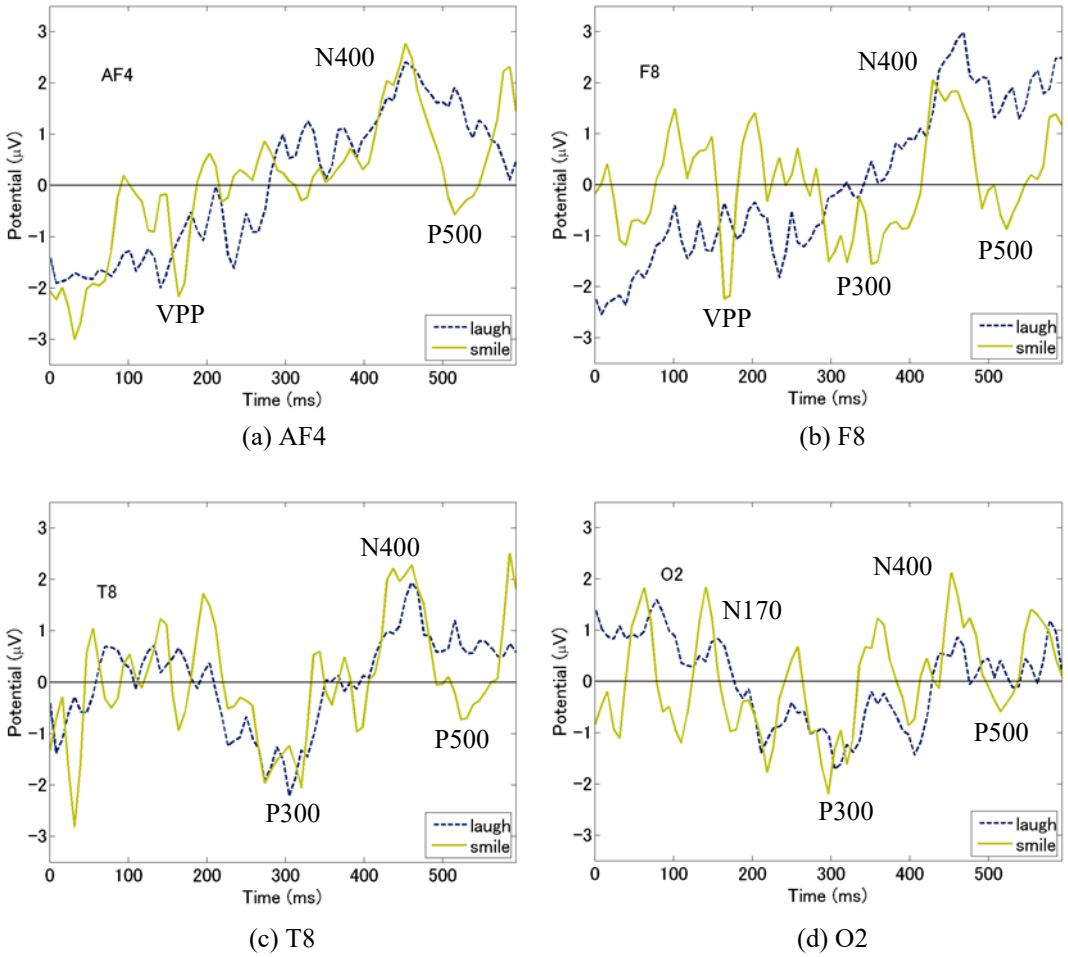



***Figure 2.*** *Averaged ERP in the right hemisphere for angry condition.*

If a participant takes a simple perceptual scheme for a clear expression of the emotional category such as grinning, the prefrontal cortex may not be activated so much but the recognition process in the temporal and occipital lobes may be carried out based on the rough morphological characteristics of a face. In the case where the complex scheme is taken for the expression stimulus hard to discriminate its emotion perceptually, it is supposed that the wide area of subcortical system cooperates on the process. Although we could not estimate the sources of N400 or P500 which arise from the latter process, such components were observed at the broad field, similar to the process when an emotionless or an ambiguous face is displayed.

Patient-based evidence [Bate and Bennetts, 2015] suggests that the expression processing is atypical and independent to the facial identity. We suppose that N400 and P500 components observed at most electrodes involve final discrimination process of expressions. Since the latency of P300 or N400 was highly individual, however, further experiments would be necessary.




(a) AF4 (b) F8

(c) T8 (d) O2

***Figure 3.*** *Difference of averaged ERP in the right hemisphere between smiling (smile) and grinning (laugh) faces for happy condition.*

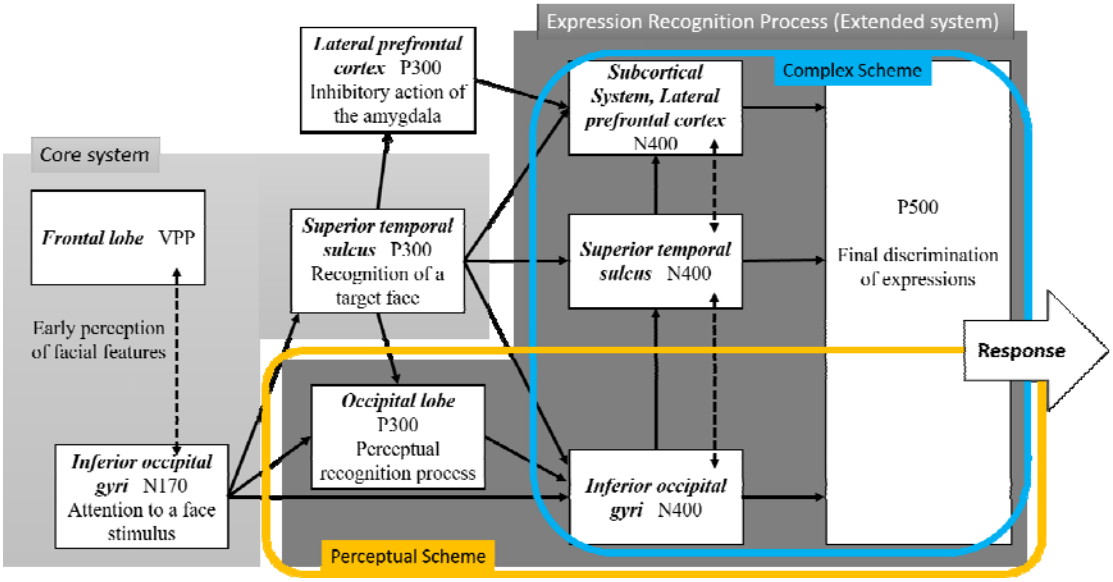



***Figure 4.*** *Proposed information processing model to recognize smile and anger faces.*

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