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COGNITIVE MECHANISM FOR MEANING OF EMOTIVE WORDS IN DEPRESSED PERSONALITY: AN EVENT-RELATED POTENTIAL STUDY

HIDEKI SHIMIZU[1], HIROFUMI SAITO[2] and MINORU HOSHIYAMA[1]

[1]*Department of Occupational Therapy, Nagoya University School of Health Sciences, Nagoya 461-8673, Japan*
[2]*Cognitive Informatics Unit, Graduate School of Information Science, Nagoya University, Nagoya 464-8601, Japan*

ABSTRACT

We investigated the relationship between the ERP modulation of emotive words and the depression score in thirty-five healthy subjects with both high and low Beck Depression Inventory scores. The event-related evoked potentials (ERP) were measured following a visual presentation of emotive adjectives. Each word was classified into two sets of categories by each subject, i.e., positive or negative, and fit or unfit to his/her personality. The ERP signals were then separately averaged according to the subject's classifications. After stimulation, positive and negative ERP components at 200 ms (P2) and 400 ms (N2), respectively, were enhanced in amplitude in subjects with a high depression score. The enhancement of the P2 and N2 components was not related to the subject's categorization of the words. The results suggest that hypersensitivity to non-specific emotive words might be a neurophysiological phenomenon in a depressive state in healthy subjects.

Key Words: ERP, Emotion, Depression, Human, Word

INTRODUCTION

Abundant evidence has accumulated in the field of clinical neurophysiology concerning the cognitive function of patients with depression.[1-7] However, only a few studies have investigated depressed conditions or borderline depression in healthy persons.[8] The incidence of mild depression or a depressed condition has risen among those accustomed to a modern lifestyle, especially in urbanized societies,[9] since mental stress has become common among office workers as well as physical stress among manual laborers. It is important to diagnose the early symptom of mild reversible depressed conditions and to treat them before they progress to the early stages of major depression.

Symptoms of depression include psychomotor retardation, fatigue, and a diminished ability to think,[10] and such depressed patients are always pessimistic about every event around them. Beck[11] has reported that the origin of depression is a kind of cognitive disturbance that generates pessimism. Recently, cognitive disturbance in depressed patients has been investigated using

Corresponding Author: Hideki Shimizu, Ph.D., OTR
Department of Occupational Therapy, School of Health Sciences, Nagoya University
1-1-20 Daiko-Minami, Higashi-ku, Nagoya 461-8673, Japan
Phone/Fax: +81-52-719-1377 E-mail: shimizu@met.nagoya-u.ac.jp

neurophysiological techniques.[1-7] The results obtained by event-related potentials (ERP) suggest that cognitive disturbance in depressed patients occurs not in the early cognitive or discriminative processes but in the later processes relating to physical and emotive responses.[12,2] Although reaction time is delayed in patients with depression,[12,2] the results of a number of ERP studies are inconsistent. Gielke *et al.*[12] have observed that the latency and amplitude of P300 in patients with depression are not significantly different from those in healthy subjects, while the ERP amplitude is reduced in the former.[2] Sara *et al.* [13] have concluded that there is no change in either reaction time or P300 components. If reaction time is reduced in depressed patients, since it covers both the period for cognitive processing and that for motor performance, it is necessary to clarify which process is disturbed, and whether the disturbance is a pathology specific to patients with depression or a non-specific reaction also observed in healthy persons.

In the present study, we measured both reaction times and ERP responses in healthy subjects, which included the mild depressive condition revealed by the Beck Depression Inventory (BDI).[14] ERPs were recorded following the visual presentation of adjectives that expressed personality traits and emotions. The aim of this study was to investigate how the cognitive process correlates with a depressed state in healthy subjects.

METHODS

Subjects

Thirty-five young right-handed volunteers (6 males and 29 females; mean age ± SD, 20.2 ± 2.0 years) who were undergraduate and graduate students at the Nagoya University participated in this study. The subjects consented to participate after being fully informed about the study, which was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the School of Health Sciences, Nagoya University, Nagoya, Japan. The handedness of subjects was determined based on observing their daily performance using questionnaires based on the Edinburgh Handedness Inventory.[15] The subjects were divided into two groups based on the BDI questionnaires: a low-depression score (LD) group with a BDI score of 2 or less (n=13, 3 males and 10 females, mean age ± SD, 20.4 ± 1.7 years), and a high-depression score (HD) group with a BDI score of more than 6 (n=11, 1 male and 10 females, 20.5 ± 2.2 years). The questionnaires were filled out after the ERP measurements were taken to avoid drawing their attention to their own emotive or depressive condition.[16]

Experimental design

Reaction times and ERPs were measured following the visual presentation of adjectives. Sixty Japanese adjectives in everyday use were selected, which were designed to evoke individual character traits and emotions. Adjectives of 5 syllables each were written with two ideographic characters (kanji) and a suffix (kana). The 60 words were comprised of 20 with a positive meaning, e.g., kind, bright, 20 with a negative meaning, e.g., dark, evil, and 20 with an intermediate meaning, e.g., ordinary, plain, all of which the subjects readily understood.

Each word with three Japanese characters in white (two kanji and one kana) was presented in a square format (2.0×6.5 cm, approximately 2.4°×6.7° in the visual field) on a black background on a 17-inch diagonal computer screen placed 1 m in front of the subject. In a series of stimulations, a fixed point in the center of the screen was presented for 1 sec followed by 1 sec of blank screen, after which a single word was displayed for 0.3 sec. The interval between the presentation of the word and the display of the fixed point was 1 sec. Sixty sequences consisting of different words were repeated twice in pseudo random order for a total of 120 sequences of stimulation during one recording session, which included stimulations of 20 words each of positive, negative, and neutral categories. The stimulation was fully controlled by PC software (Super-Lab Pro, Cedrus Co., U.S.A.).

For each subject, the reaction times and ERP recordings were performed sequentially. After the recording, subjects were asked to classify the 60 adjectives into two categories: 1) whether each word fit (Fit) their personality or not (Unfit), and 2) whether each word was considered preferable (positive, Pos) or not (negative, Neg). The BDI questionnaires were then filled out.

Reaction-time study

The subject was seated in armchair in a quiet room, holding a response button in each hand. Asked to judge whether a presented word was preferred or not, the subjects were instructed to respond "Yes" or "No" by pressing the button as quickly as possible in the right or left hand, depending on the screen. Reaction time was measured from the onset of the word presentation to pressing of the button in each stimulus sequence. Each recording session with a 60-stimulus sequence was repeated twice, and in the second session, the response button was held in the alternate hand. The reaction time was separately averaged in each word category, i.e., Fit/Unfit and Pos/Neg.

ERP recording

In the ERP study, electroencephalography (EEG) was used to record responses during the word presentation. In each ERP recording session 120 words were presented at a similar time interval to that in the reaction-time study. Two recording sessions were repeated to confirm the reproducibility of the responses. The subjects were seated in an armchair looking at a monitor screen as during the reaction time study, but they were instructed to simply watch the screen without deciding or reacting.

The exploring electrodes were placed at F3, F4, C3, C4, P3, P4, Fz, Cz, and Pz based on the International 10-20 System, and the referential electrode was linked earlobes. Impedance between the electrodes was kept below 10 kOhm. Electroculogram (EOG) was monitored on the right side, with the electrodes placed 1.5 cm lateral to the canthus and 1.0 cm above the supraorbital ridge. EEG signals were triggered by the onset of stimulation, and epochs of the signal 600 ms in length, including a 100 ms pre-stimulus period, were digitally collected at a sampling rate of 250 Hz with a bandpass filter of 0.1–30 Hz. Each adjective was coded, and the code and stimulus timing were recorded with the EEG signals, thus amounting to 120 epochs of EEG signals collected with the adjectives coded. Epochs containing EEG signals larger than 1 mV or EOG signals larger than 10 mV were rejected.

After the EEG recording, EEG epochs were divided into two categories in two series according to the subject's self-classification of the words, i.e., Fit or Unfit and Pos or Neg. The epochs of each category were averaged in each series. Thus, two pairs of ERP waveforms (Fit/Unfit and Pos/Neg) in each subject group (LD/HD) were finally obtained.

Data analysis

Reaction times and ERP waveforms for word categories were compared between two groups, using two-way factorial analysis of variance (ANOVA), i.e., 2 (Fit/Unfit) × 2 (LD/HD), and 2 (Pos/Neg) × 2 (LD/HD). For ERP waveforms, the peak latency and baseline-to-peak amplitude were measured and compared.

RESULTS

Reaction time study

Figure 1 shows the mean reaction time for each word category. Although these reaction times tended to be somewhat longer in the HD subjects, there was no significant difference in reaction times between the groups, nor did the values differ between Pos and Neg, and Fit and Unfit.

ERP study

ERP responses were consistently recorded from all subjects (Fig. 2, 3). There was a major positive deflection around 240 ms after the onset of stimulation, in which two peaks were consistently recognized at approximately 160 (P1) and 240 ms (P2) after the stimulation. The P1 component was found to be large in the frontal and central areas, but small in the parietal area. The P2 component was observed in all areas. Between the P1 and P2 components, a small negative notch was identified, but that component was not consistent in all subjects. Following the P1 and P2 components, a large negative deflection distributed in all areas was identified, peaking at 400 ms (N2). Table 1 shows the peak latency of deflections in the P1 and P2 components recorded from each electrode on the midline in each group of subjects.

The peak latency of the P1 and P2 components did not differ between the two groups (HD/LD), nor between the word categories (Pos/Neg or Fit/Unfit). However, the baseline-to-peak amplitude for the P2 component was significantly larger in the HD group than that in the LD group in the Fit/Un-fit series at recording sites C3 ($p<0.02$), C4 ($p<0.05$), P3 ($p<0.002$), P4 ($p<0.001$), and Pz ($p<0.01$), as well as in the Pos/Neg series at C3 ($p<0.02$), C4 ($p<0.05$), P3 ($p<0.001$), P4 (p<001), and Pz ($p<0.01$), although the P1 amplitude was the same between the groups (Fig. 5).

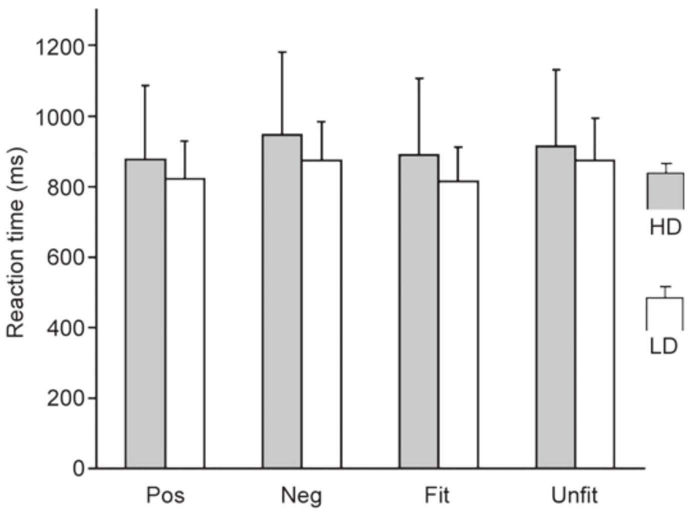

Fig. 1 Reaction times for self-assessed judgment of words. Gray and white columns indicate high-depressive (HD) and low-depressive (LD) groups, respectively. Each vertical line indicates standard deviation. Words presented were classified by subjects into two sets of categories after the study: 1) whether each word was fit (Fit) or not (Unfit), 2) whether each word was preferable (positive, Pos) or not (negative, Neg). Although reaction times for each category tended to be long in HD subjects, they showed no significant difference between the two groups.

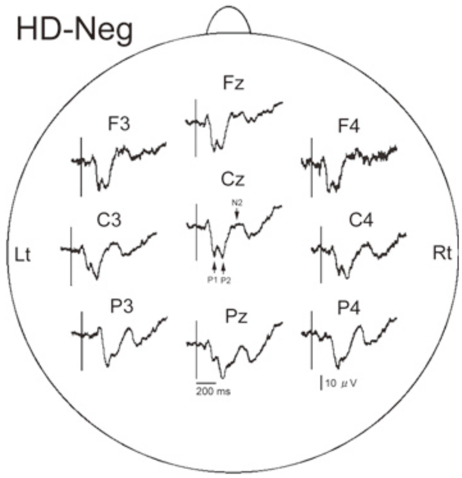

Fig. 2 Grand-average ERP waveforms obtained in high-depression score (HD) following a negatively emotional word (Neg) (see text). P1 component was recognized in the frontal and central areas of the brain, but less so in the parietal area. P2 and N2 components were observed in all areas. Vertical lines indicate onset of stimulus.

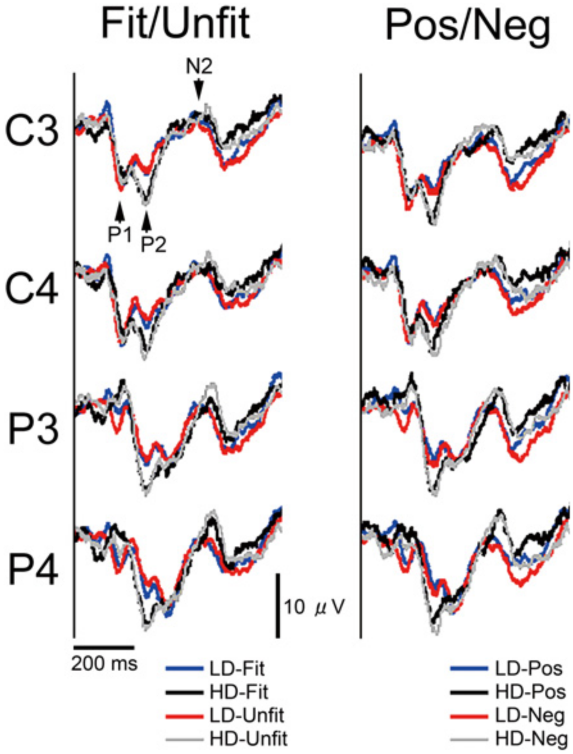

Fig 3 Grand average ERP waveforms recorded from all subjects (13 in LD and 11 in HD) at C3, C4, P3, and P4 in the International 10-20 System. Two positive deflections (P1 and P2) were recognized, and the baseline-to-peak amplitude of P2 was significantly larger in the HD than in the LD group (See text for abbreviations). However, there was no difference in ERP response between word categories (Fit/Unfit and Pos/Neg).

Table 1 Peak latency of ERP component (ms, mean ±SD).

P1		Fit	Unfit	Pos	Neg
LD	Fz	158.8 ± 10.0	160.0 ± 10.0	158.8 ± 10.5	163.1 ± 10.3
	Cz	154.0 ± 10.0	156.3 ± 8.9	158.2 ± 10.6	156.8 ± 10.6
	Pz	154.0 ± 12.8	150.8 ± 11.5	147.2 ± 21.3	149.2 ± 12.6
HD	Fz	162.5 ± 10.0	161.1 ± 11.4	161.6 ± 10.7	160.2 ± 12.9
	Cz	162.2 ± 10.7	158.4 ± 11.2	157.8 ± 12.8	159.6 ± 13.2
	Pz	141.5 ± 22.1	141.5 ± 22.9	140.7 ± 21.5	146.4 ± 21.1

P2		Fit	Unfit	Pos	Neg
LD	Fz	242.8 ± 24.7	237.8 ± 18.0	240.8 ± 28.2	243.4 ± 21.3
	Cz	240.5 ± 22.6	238.9 ± 15.9	241.5 ± 25.1	242.6 ± 20.4
	Pz	247.5 ± 21.6	242.5 ± 15.1	248.2 ± 24.1	245.7 ± 21.4
HD	Fz	242.4 ± 22.1	239.5 ± 17.6	246.5 ± 23.8	240.0 ± 19.9
	Cz	242.2 ± 21.1	241.5 ± 19.6	246.7 ± 24.8	240.2 ± 23.5
	Pz	238.2 ± 16.4	246.5 ± 15.0	247.3 ± 19.7	238.7 ± 11.5

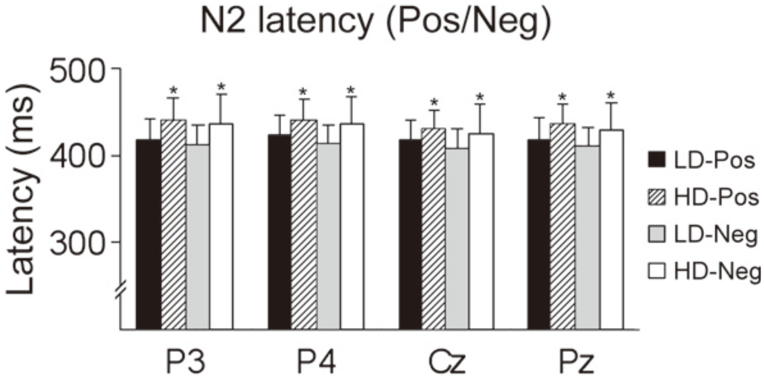

Fig. 4 Peak latency for N2 component in Pos/Neg series. Peak latency of HD group was significantly more delayed than the one in LD group at P3, P4, Cz, and Pz (*), but no values differed between word categories in either group. Vertical lines indicate standard deviations.

As for the N2 component of the Pos/Neg series, the peak latency of the HD group was significantly longer in relation to the LD group at P3 ($p<0.005$), P4 ($p<0.01$), Cz ($p<0.05$), and Pz ($p<0.02$) (Figs. 3 and 4). Moreover, the amplitude from the baseline to the peak for the N2 component in the HD group was significantly larger than that in the LD group in the Fit/Un-fit series at F3 ($p<0.001$), F4 ($p<0.001$), and Fz ($p<0.005$), and in the Pos/Neg series at F3 ($p<0.005$), F4 ($p<0.001$), and Fz ($p<0.02$) (Fig. 6). There was no difference in amplitude between either Fit and Unfit words or between Pos and Neg words.

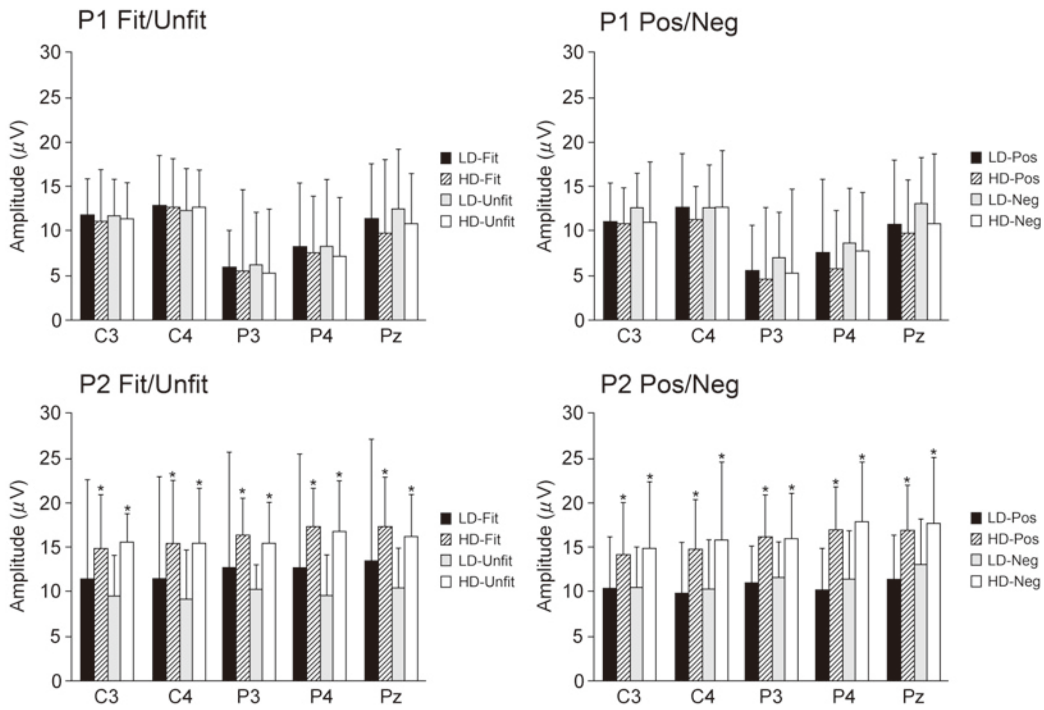

Fig. 5 Baseline-to-peak amplitudes for ERP components of word categories. P1 components did not differ between subject groups or word categories. P2 amplitudes were significantly larger in HD subjects than those in LD subjects (*). However, no difference in amplitude was observed between word categories, nor in response recorded at Cz and Fz (graphs omitted). Vertical lines indicate standard deviations.

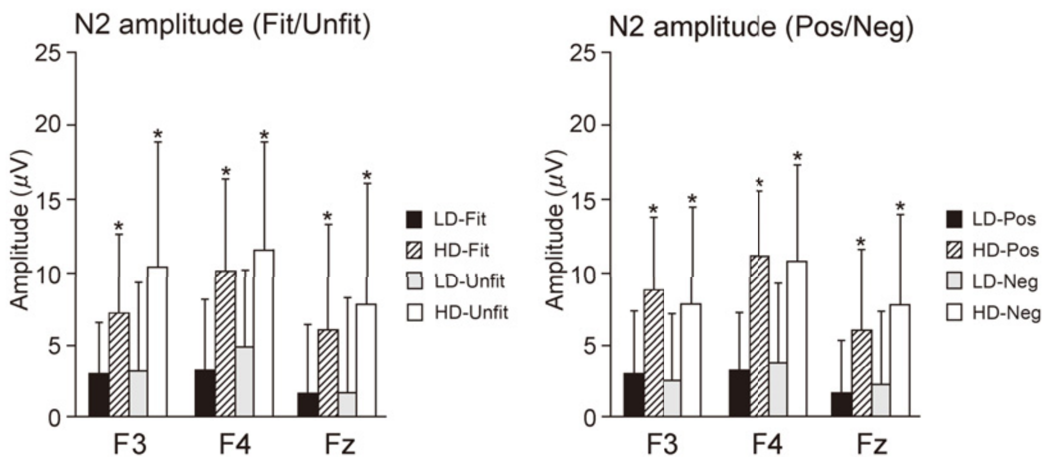

Fig. 6 Baseline to peak amplitude for the N2 component in Pos/Neg and Fit/Unfit series. The peak amplitude in the HD group was significantly larger than that in the LD group in Fit/Unfit series and Pos/Neg series at the F3, F4, and Fz (*). Vertical lines indicate standard deviations.

DISCUSSION

A negative deflection around 200 ms after word presentation has been known to contribute to the initial lexical processing in healthy subjects,[17,18] and that a pathological response to words occurs at a similar latency after word presentation in patients with schizophrenia.[19] In the present study, the amplitude of the positive ERP components was different between the LD and HD subjects around 200 ms after the word presentation. These results suggest that the depressive state in normal subjects affects the cognitive response to the word processing. Previous reports have indicated that the ERP response occurs at a latency around 200 ms involving intentional lexical processing, which reflects categorization of words when the subject pays attention to them words.[20-22]

In the present study, we asked subjects to judge the presented words generally as positive or negative, and to press buttons as faster as possible. Therefore, the baseline-to-peak amplitude of P2 might reflect the level of attention paid to the words. One plausible explanation for this result is that the HD subjects might have been more attentive to the words than the LD subjects. When mental condition related to the depressive state differed between the subjects groups, this condition might have affected the ERP response. Although the subjects did not receive any specific instructions related to their mental condition during the ERP recording, the HD subjects might have been more sensitive to emotive words than the LD subjects.

Since the P2 amplitude did not differ between the word categories in either group, the P2 component in this study did not reflect brain activity related to the lexical processing of words categorized by the subject's self-assessments (Pos/Neg and Fit/Unfit), but rather might have been a response to non-specific emotive words. This suggests that, in a situation without specific attention to word meanings, a depressive condition enhances sensitivity to non-specific emotive words. Therefore, the cognitive process governing the categorization of emotive words (Pos/Neg and Fit/Unfit) is not likely to be activated automatically as long as subjects fail to pay attention to the specific words correlated with their own mental conditions. We suppose that the HD subject's categorization of the words is essentially similar to that of the LD subjects, except that a part of the cognitive process for words is hypersensitive.

Negative deflection around 400 ms expressed as N2 in the present study has been reported as N400, and has been understood to reflect semantic processing. [23] For this N2 component, the amplitude was larger in HD than in LD subjects, though there was no difference between them in word categories (Pos/Neg and Fit/Unfit). This result suggests that HD subjects expend more processing resources in semantic processing than LD subjects. However, reaction times did not differ between the two groups, suggesting that HD subjects might compensate for their delay in the time required to execute the semantic processing of words by paying closer attention to the words than the LD subjects do. In addition, the larger amplitude of N2 in the HD group was evident in areas F3, F4, and Fz, so that the level of frontal brain activity that reflects cognitive efforts to execute the present task, might contribute to that larger amplitude. Accordingly, we consider that the large and delayed N2 component was due to the enhancement and continuation of semantic processing of emotive words in HD subjects, relative to that in the LD group.

In a study of major depressed patients, the ERP response was modulated by the meaning of a word correlated with their depressive condition.[24] However, the affected ERP component in that study was P300, which is evoked by an intentional paradigm. Another study has suggested that, in depressed healthy subjects, an instruction to pay closer attention to their mental state enhanced the responses to the negative words corresponding to their depressive emotions.[25] Such a modulation of ERP was not observed in the present study. When a depressive state in healthy subjects involves a pathology similar to that in patients with depression, one of the mild modulations in the cognitive process associated with their emotions might result in an enhancement of their response to non-specific emotive words.

The results of previous studies of brain activity in patients with depression are controversial. Brain activity triggered by target stimulation has generally been observed to decrease in depressed patients,[2,26,27)] while their response to non-target stimulation is enhanced.[28)] Ogura *et al.*[28)] have speculated that patients with depression are in a hyper-aroused condition. Our present results appear to agree with those of the latter report.

If the large amplitude of the P2 component were related to the amount of attention to non-specific word stimulation (including non-target word stimulation), HD subjects might pay more attention to every stimulus than LD subjects do. This suggests that HD subjects need to expend more subconscious mental effort to perform a task. We consider that a cognitive disturbance to specific emotive words or phenomena is not the initial sign of a depressed state, but rather a kind of hypersensitivity to word stimuli, which relieves them of the need to pay special attention to their own mental condition.

Though we did not attempt a source estimation of ERP responses, we did observe differences in P2 amplitude in lateral part of the cerebral hemisphere (P and C areas). There is general agreement that the semantic processes are usually observed to be dominant in the left hemisphere in right-handed subjects. However, there was no hemispheric difference in the P2 amplitude. This result suggests that enhancement of the P2 amplitude involves not only a word-specific phenomenon, but may also be a visually related enhancement of the response at a latency of around 240 ms.

In conclusion, we investigated the relationship between the ERP modulation of emotive words and the depression scores of healthy subjects. The amplitude of the P2 response was enhanced by non-specific emotive words classified by the subjects with high depression scores. These results suggest that the neurophysiological phenomenon among healthy subjects in a depressive state might be non-specifically caused by their hypersensitivity to emotive words. Therefore, the P2 amplitude has the potential to enable us to detect an early depressive state in healthy persons.

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