**Effects of Induced Moods on Semantic Memory Activation in Single-Word
Imagery Processing**

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Abstract

The effect of affective state or mood on language processing has been examined in behavioral and event-related potential (ERP) studies. Although these studies have shown that mood affects the process of context integration of a sentence, it remains unclear whether mood influences processing of single-word imagery. This study examined the effects of word imageability on the N400 and N700 components of the ERP in a reaction time (RT) task, in which 30 university students judged whether or not a word easily evoked visual imagery. Three mood conditions were induced by autobiographical recollection and pictures of facial expressions (neutral, positive, and negative) and conducted in a counterbalanced order. High imagery words produced faster judgments and larger amplitudes of N400 and N700 components than did low imagery words. Although mood did not affect RT or N700 amplitude, N400 amplitude was larger (more negative-going) under positive mood than under negative mood, with neutral mood intermediate, regardless of word imageability. The interaction effect of mood and word imageability was not significant. These results suggest that, compared to negative mood, positive mood facilitates activation of semantic memory and access to lexical representations when imagery processing is required.

Keywords: Mood, Word imageability, Semantic memory, Event-related potential, N400, N700

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Imagery Processing

Moods that we experience in daily life influence our activities and thoughts. We tend to have a broader range of thought-action repertoires when we are in a positive (e.g., happy or joyful) mood than when we are in a negative (e.g., sad or distressed) mood (Fredrickson & Branigan, 2005). According to the affect-as-information hypothesis (Clore, Gasper, & Garvin, 2001), positive and negative moods are likely to result in different processing styles. Positive mood is thought to signal that the environment or situation is safe and benign, thus reducing an individual's motivation to improve his or her situation. Consequently, people in a positive mood should be more likely to rely on their general knowledge structures and on the use of simple heuristics in information processing. In contrast, negative mood, which indicates that the environment poses a problem and might be a source of potential danger, motivates people to change their situation. Negative mood is then thought to be associated with a systematic elaboration of information and greater attention to detail. As a result, people should adopt systematic and detail-oriented processing based on bottom-up processes (Gilet & Jallais, 2012). This difference in processing style may underlie effects of mood states on memory (Bower, 1981), attention (Vanlessen, De Raedt, Koster, & Pourtois, 2016), judgment (Schwarz & Clore, 1983), and language processing (Bolte, Goschke, & Kuhl, 2003; Chwilla, Virgillito, & Vissers, 2011; Federmeier, Kirson, Moreno, & Kutas, 2001; Pinheiro et al., 2013).

Mood states influence long-term semantic memory during language comprehension (Federmeier et al., 2001). In semantic memory, closely related concepts share more semantic features than concepts distantly related. According to the spreading activation model (Collins & Loftus, 1975), the activation of a certain concept spreads to

other related nodes along bidirectional associative links. Behavioral studies have suggested that participants in a positive mood tend to activate wider semantic fields so that semantic processing is facilitated (Bolte et al., 2003; Pinheiro et al., 2013). In contrast, participants in a negative mood tend to restrict the spread of activation in semantic memory. For example, Bolte et al. (2003) had participants perform a coherence judgment task with emotionally neutral materials either in a neutral mood or after the induction of either positive or negative mood. Participants in a positive mood produced stronger intuitive coherence judgments, whereas participants in a negative mood performed at chance level. Bolte et al. concluded that positive mood potentiates the spread of activation to remote associates in memory, thereby improving intuitive coherence judgments. By contrast, negative mood appears to restrict the spread of activation only to close associates and dominant word meanings, thus impairing intuitive coherence judgments.

Recently, event-related potential (ERP) studies have suggested that mood influences the processing of meaning during real-time language comprehension. Especially susceptible is the integration of semantic information into a sentence context, as indexed by the amplitude of the N400 component, which occurs 300–500 ms after stimulus onset (Chwilla et al., 2011; Federmeier et al., 2001; Pinheiro et al., 2013). The N400 reflects the difficulty of integrating a word stimulus into its prior context (for a review, see Kutas & Federmeier, 2011). For example, Chwilla et al. (2011) showed that effects of cloze probability on N400 amplitude were modulated by emotional state. Participants were presented with high and low cloze probability sentences (e.g., *the pillows are stuffed with feathers/books which makes them feel soft*), in which the critical word was always in a mid-sentence position. Happy and sad moods were induced via film clips. The N400 cloze probability effect (i.e., the difference in N400 amplitude between

the high and low cloze probability conditions) was reduced in the sad mood compared with the happy mood condition. Chwilla et al. took these findings as evidence that differences in mood lead to qualitatively different strategies, rather than a general change in attention and/or motivation, with happy people inclined to use a global level of information processing and sad people relying on a local level. Behavioral and ERP studies suggest that mood can impact access to semantic memory.

These studies above have mainly focused on mood effects on contextual integration, and few studies have examined such effects on single-word processing. In the present research, we used ERPs to examine the effect of mood on word imagery processing. Imageability is the attribute that captures how well a word evokes a sensory image (Paivio, Yuille, & Madigan, 1968). Concreteness is a similar concept that expresses the degree to which the word can be experienced through one's senses. Although imageability and concreteness are not the same, ratings of the two concepts correlate well (e.g., $r = .83$ in Paivio et al., 1968). Therefore, previous ERP studies of both imageability and concreteness effects are relevant to the present research.

A number of studies have reported that the processing of high- and low- imagery words (or concrete and abstract words) differs. High imagery words are processed more efficiently and memorized better than low imagery words (Paivio et al., 1968). This *imageability effect* has yielded relatively consistent findings in ERP studies using a variety of tasks, such as lexical decision, imageability rating, and imageability judgment (Barber, Otten, Kousta, & Vigliocco, 2013; Gullick, Mitra, & Coch, 2013; Kanske & Kotz, 2007; Kounios & Holcomb, 1994; Nittono, Suehiro, & Hori, 2002; West & Holcomb, 2000). These results can be summarized as follows: (1) high imagery words elicit a larger N400 than low imagery words; (2) the N400 imageability effect appears most

prominently at centroparietal sites; and (3) the ERP imageability effect extends beyond the latency range of the N400.

Kounious and Holcomb (1994) compared the ERPs in response to concrete and abstract words in a lexical decision task. Concrete words elicited a more negative N400 than abstract words (300–500 ms after word onset), suggesting that semantic memory is activated more by concrete words than by abstract words. In addition, concrete words continued to produce more negative-going ERPs than abstract words for 500 ms and 800 ms. This late component following the N400 has also been documented in other studies. West and Holcomb (2000) termed this the *N700* component and reported it was dominant over anterior scalp sites. They suggested that the N700 may reflect “the access of specific characteristics of the imaged item or activation in a working memory system specific to mental imagery” (p. 1024). Gullick et al. (2013) recorded ERPs elicited by concrete and abstract words in a within-participants design with two experimental tasks: one requiring search for a target letter (surface task) and one requiring evocation of mental images (visualization task). The N400 amplitude was larger for concrete words than for abstract words, and larger in the visualization task condition than in the surface task condition, with no significant interactions. Further, the anterior N700 was elicited only by concrete words in the visualization task. Gullick et al. proposed that elicitation of the N700 is dependent on a combination of stimulus characteristics and task demands.

In a single word imageability rating task, Nittono et al. (2002) reported a larger N400 and a larger late negative component (which they called the *N800*) in response to high imagery words. They suggested that the N800 is a “second N400” reflecting further semantic processing specific to high imagery words. Kanske and Kotz (2007) examined the ERP responses to concrete and abstract words with negative, neutral, or positive

valence in a lexical decision task. They found that concrete words elicited a larger N400 than did abstract words, and this difference continued at a later latency range, which they analyzed as a reduction of the late positive component (LPC, 550–800 ms). They suggested that this late difference might be related to the use of mental imagery for concrete words. Taken together, these studies consistently show that high imagery words elicit two negative-going potentials, N400 and N700, unlike low imagery words, although the functional significance of the N700 remains unclear.

The main purpose of the present study was to investigate the effect of mood (positive, neutral, and negative) on single word imagery processing by comparing N400 and N700 components in a within-participants design. Based on previous results of word processing tasks (Gullick et al., 2013; Kanske & Kotz, 2007; Kounios & Holcomb, 1994; Nittono et al., 2002), high imagery words should elicit larger (more negative) N400 and N700 components than low imagery words. Regarding the effect of mood on the N400, there are two possibilities. First, the N400 imageability effect (i.e., the difference between high- and low-imagery words) may be greater with positive mood than with negative mood, given the findings of the N400 cloze probability effect (Chwilla et al., 2011; Federmeier et al., 2001; Pinheiro et al., 2013). On the other hand, if positive mood generally facilitates the semantic access that is related to imagery processing, the N400 itself may be larger under positive mood than under negative mood, regardless of the word's imageability. In support of the latter possibility, Moriya, Takeichi, and Nittono (2013) reported that the amplitudes of the N400 elicited by both words and pseudowords in a lexical decision task increased with high-arousal positive mood compared to neutral mood. This suggests that positive mood can promote the activation of semantic representation regardless of stimulus type. Thus, the N400 amplitude for both high- and

low-imagery words may increase under positive mood. No prediction can be made about mood effects on the N700, because no previous research has addressed this question.

Method

Participants

Thirty-six student volunteers participated in the experiment.¹ All were right-handed according to a questionnaire (Oldfield, 1971) and were native speakers of Japanese with normal or correct-to-normal vision. Five participants were excluded from the analysis because excessive eye movement artifacts resulted in insufficient numbers (< 30) of averaged trials. To maintain proportionate counterbalancing of the order of mood conditions, the last participant was also removed. Therefore, the data of 30 participants (15 men and 15 women, 19-24 years old, $M = 21.6$) are reported here. (Analysis of the 31 participants' data produced almost the same results.) This study was approved by the Research Ethics Committee of the Graduate School of Human Sciences, Osaka University. All participants gave written informed consent. The entire dataset is available at <https://osf.io/xyt42/>.

Materials

A total of 270 words (135 high-imagery and 135 low-imagery nouns) consisting of two Japanese Kanji characters were selected for the imageability judgment task, controlling for log frequency of occurrence in print, length (the number of moras), and number of writing strokes between high- and low-imagery words. Table 1 summarizes these characteristics. Imageability ratings were based on a normative database of Japanese lexical properties (Sakuma et al., 2005). High-imagery words included *doctor*, *hospital*, and *baseball*, and low-imagery words included *aesthetics*, *principle*, and *theorem*. Word frequency and number of moras were based on the same database series (Amano & Kondo,

2000; Amano & Kondo, 1999, respectively). The number of writing strokes was determined by the authors. Although these properties were matched, high- and low-imagery words differed in familiarity ratings (Amano & Kondo, 1999) and in valence and arousal ratings obtained in a survey in which 24 students who did not participate in the ERP experiment (14 men and 10 women, mean age = 23.0) rated 330 nouns, including the 270 nouns used in this study. Imageability was positively correlated with familiarity ($r = .86, p < .001$), valence ($r = .39, p < .001$), and arousal ($r = .56, p < .001$). This difference between high- and low-imagery words may not exclude the possibility that effects of imageability and other lexical properties may be confounded. However, because the main goal of this study was to examine the effect of mood on ERP responses, the crucial requirement was to prepare three equivalent word sets for the three mood conditions. To meet this goal, the 270 words were quasi-randomly divided into three sets of 90 words each, keeping the mean levels of the above lexical properties equivalent. The equivalence was confirmed by the finding that Word Type (high vs. low imageability) $\times$ Set (1, 2, and 3) ANOVAs on imageability, log frequency, familiarity, valence, arousal, number of moras, and number of writing strokes produced no significant interaction effects ($F_s < 1$). Thus the three word sets did not differ in imageability or other lexical properties.

As visual aids to remind participants of the intended mood condition, pictures of faces of nine different female models expressing happy, sad, and neutral moods were selected from the Karolinska Directed Emotional Face database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Three models were chosen for each mood expression based on normative ratings of emotional intensity and prototypicality (Sánchez, & Vázquez, 2013).² Only female faces were used because female facial expressions represent

emotional prototypes better than male expressions (Sánchez, & Vázquez, 2013).

Mood Induction

A standard mood induction procedure of autobiographical recall was used (e.g., D'Argembeau, Comblain, & Van der Linden, 2003; Forgas, 2011; Gino, Brooks, & Schweitzer, 2012). Participants were asked to remember, re-experience, and write in detail about a happy or sad episode in their past; in the neutral mood condition, they were simply asked to describe the area where they live. They used a sheet of paper to describe each episode, taking 7 minutes to do so. To facilitate recall, a slide show of emotional facial pictures corresponding to the mood condition appeared on a tablet PC (Acer Iconia W700) placed near the paper. The three facial pictures were presented one by one for 2 minutes 20 seconds each (i.e., 7 minutes in total). The effect of mood induction was assessed with the Affect Grid (Russell, Weiss, & Mendelsohn, 1989). Participants were asked to rate their current mood (pleasantness and arousal) on a 9×9 grid rating scale ranging from 1 to 9. Participants completed the Affect Grid three times in each condition: before mood induction (baseline), after mood induction (post-induction), and at the end of the imageability judgment task (after task). The level of physiological arousal during the imageability judgment task was measured with skin conductance level (SCL).

Procedure

After electrode application, participants sat in a comfortable chair in a dimly lit, sound-attenuated chamber. The experiment included three mood conditions, with the order of conditions counterbalanced across participants. At the beginning of each condition, participants went through the mood induction procedure. Participants then performed the imageability judgment task. Figure 1 illustrates an example of a trial block. Stimuli were presented on a 17-inch cathode ray tube display (Dell E773s, refresh rate =

60 Hz) against a black background. The viewing distance was 100 cm. Stimulus presentation was controlled by Inquisit 4.0 (Millisecond Software, Seattle, WA). Responses were corrected with a response pad (Cedrus RB-530, San Pedro, CA). First, a 500-ms white rectangle subtending 2.0° vertically and 4.0° horizontally appeared on the screen. A word stimulus (2.0° in width) then appeared at the center of the rectangle in white MSP Gothic font for 2,000 ms, followed by a 500-ms blank screen. Participants were asked to judge if the word easily evoked visual imagery by responding Yes versus No by pressing the left or right button as quickly and accurately as possible before the word disappeared ($< 2,000$ ms). The combination of Yes/No responses and left/right buttons was counterbalanced across participants. Trials in which participants did not press a button within 2,000 ms were regarded as no response trials. To reduce artifacts, participants were told not to look away or blink while the word was on the screen.

The task consisted of nine blocks, each of which contained five high-imagery and five low-imagery words presented in a random order. At the end of each block, following presentation of a gray rectangle for 5,000 ms, a facial expression picture (subtending 8.0° vertically and 6.0° horizontally) corresponding to the mood condition was presented for 5,000 ms. During the picture presentation, participants were asked to call up the episode they had described during the mood induction phase. The picture was followed by a blank screen for 3,250 ms to facilitate task switching from the recollection task to the imageability judgment task. Three facial pictures of each emotional expression (happy, sad, or neutral) were randomly presented three times in the nine blocks. Each condition lasted 6.5 minutes.

Before the first condition, a brief practice session was conducted using four high-imagery and four low-imagery words that were not used in the experimental trials.

Between the conditions, a five-minute pause was inserted to reduce carry-over effects of an induced mood.

Physiological Recording

Biosignals were recorded with a sampling rate of 1,000 Hz using QuickAmp (Brain Products, Munich, Germany). Electroencephalograms (EEG) were recorded from 34 scalp sites according to the 10-20 system using an elastic cap with Ag/AgCl electrodes (Fp1/2, F7/8, F3/4, Fz, FT9/10, FC5/6, FC1/2, T7/8, C3/4, Cz, TP9/10, CP5/6, CP1/2, P7/8, P3/4, Pz, O1/2, PO9/10, and Iz). The ground electrode was placed at AFz. The EEG data were re-referenced to the averaged earlobes offline. The horizontal electrooculogram (EOG) was recorded from two electrodes placed at the outer canthi, and the vertical EOG was recorded from two electrodes placed above and below the right eye. Electrode impedances were kept less than 10 k Ω .

SCL was recorded with the canonical 0.5 V constant voltage method using the galvanic skin response (GSR) sensor of QuickAmp. Two Ag/AgCl electrodes filled with 0.05 M NaCl electrolytes (Biopac GEL101) were placed on the volar side of the middle phalanges of the index and middle fingers of the left hand. High-pass filtering was not used for recording and analysis. Mean SCL values were calculated for a 60-s epoch before mood induction (baseline) and for six 60-s epochs in the imagery judgment task for each mood condition.

Data Reduction

The correct response on each trial was determined by the pre-defined high or low imagery word category. In calculating mean RTs, incorrect and no response trials were removed ($M = 3.4\%$ of all trials). There were no trials in which the RT was shorter than 200 ms or longer than the mean plus 2.5 standard deviations of the RTs for that condition

and that participant.

The electrophysiological data were analyzed with Brain Vision Analyzer version 2.0 (Brain Products, Munich, Germany). EEG data were resampled at 250 Hz. A digital bandpass filter of 0.05–60 Hz (24 dB/octave) and a 60 Hz notch filter were applied. Eye blink and movement artifacts were corrected using the method of Gratton, Coles, and Donchin (1983). ERP waveforms were calculated separately for each mood condition and word type by averaging a 1200-ms period from 200 ms before to 1000 ms after the stimulus onset. Periods in which EEG or EOG (after correction) exceeded $\pm 100 \mu\text{V}$ were removed from ERP analysis. Trials including incorrect or no responses were also excluded. On average, 8.2% of the trials were discarded. The mean numbers of averaged trials for high- and low-imagery words were 42.6 and 41.3 in the positive mood condition, 40.6 and 40.4 in the neutral mood condition, and 42.1 and 40.5 in the negative mood condition. The minimal number of trials was 30.

The amplitudes of the N400 and N700 components were quantified as the mean amplitudes within the 300–400 ms and 500–800 ms intervals after word stimulus onset. Based on visual inspection of the grand mean waveforms, we set the time window of the N400 shorter than that in previous studies (300–500 ms). This was because a large positive wave followed the N400 in the 400–500 ms latency range. Since the N400 is largest over the centroparietal sites (Kutas & Federmeier, 2011), analysis of this component was restricted to these electrodes: C3/4, CP1/2, CP5/6, and P3/4. Based on the finding that the N400 imageability effect was larger over the right hemisphere than over the left hemisphere (Kounios & Holcomb, 1994; Nittono et al., 2002), the mean amplitudes over the right and left areas were calculated separately. For the N700, the mean amplitudes over the four areas were calculated separately: Anterior Left (Fp1, F3,

F7, FC1, FC5, and FT9), Anterior Right (Fp2, F4, F8, FC2, FC6, and FT10), Posterior Left (CP1, CP5, TP9, P3, P7, PO9, and O1), and Posterior Right (CP2, CP6, TP10, P4, P8, PO10, and O2).

Statistical Analysis

For subjective measures, a Mood (neutral, positive, and negative) $\times$ Time (baseline, post-induction, and after task) multivariate analysis of variance (MANOVA) with repeated measures was performed on the pleasantness and arousal scores of the Affect Grid. MANOVA, rather than ANOVA, was used because it can solve the Type I error inflation inherent in repeated-measures designs (Vasey & Thayer, 1987). A Mood $\times$ Epoch (baseline, 1, 2, 3, 4, 5, and 6 min) MANOVA was performed on SCL data.

RT data were submitted to a Mood $\times$ Word Type (high imagery vs. low imagery) MANOVA. For the N400 amplitude, a Mood $\times$ Word Type $\times$ Hemisphere (left vs. right) MANOVA was conducted. The N700 amplitude was analyzed with a Mood $\times$ Word Type $\times$ Site (anterior vs. posterior) $\times$ Hemisphere (left vs. right) MANOVA. The significance level was set at .05 for all analyses. Post hoc multiple comparisons were conducted by means of two-tailed paired t tests with Bonferroni correction. Effect sizes were calculated as η_p^2 for MANOVAs and d_z for post-hoc t tests because a within-participants design was used (Lakens, 2013).

Results

Mood Manipulation Check

Table 2 shows mean pleasantness and arousal scores at baseline (before mood induction), after mood induction, and after the task (at the end of each mood session). A Mood $\times$ Time MANOVA on pleasantness scores revealed a significant interaction, $F(4, 26) = 22.10$, $p < .001$, $\eta_p^2 = .77$. Simple main effects were significant at all three time

points, as shown in Table 2. Post hoc comparisons indicated that, after mood induction, pleasantness scores differed between the conditions, such that the ratings of the positive condition were higher and those of the negative condition were lower than those of the neutral condition. These differences lasted until the end of each mood condition. This result confirmed that the mood induction procedure was successful. Unexpectedly, the simple main effect of mood was also significant at baseline, with pleasantness ratings higher before the negative mood condition than before the positive mood condition. This was possibly a carry-over effect from the previous mood condition. For arousal scores, a Mood $\times$ Time MANOVA did not produce a significant interaction, $F < 1$, although the main effect of mood was significant, $F(2, 28) = 6.75$, $p = .004$, $\eta_p^2 = .33$. Post hoc comparisons indicated higher arousal ratings in the positive mood condition than in the neutral mood condition. For SCL, a Mood $\times$ Epoch MANOVA showed a significant main effect of epoch, $F(6, 24) = 15.41$, $p < .001$, $\eta_p^2 = .79$. SCL decreased through the imagery task ($M = 6.07 \mu\text{S}$ to $M = 4.46 \mu\text{S}$ from the first epoch to the last epoch). Neither the main effect of mood nor the interaction effect was significant, $F_s < 1.16$, $p_s > .33$. Taken together, these results indicate that autobiographical recall combined with occasional exposure to facial expressions induced a positive, neutral, or negative mood, without physical arousal differences.

Behavioral Performance

Table 3 shows mean RTs and number of correct trials for high- and low-imagery words in each mood condition. For RT data, a Mood $\times$ Word Type MANOVA did not indicate a significant main effect of mood or an interaction effect, $F_s < 1.16$, $p_s > .32$. The main effect of word type was significant, $F(1, 29) = 14.54$, $p < .001$, $\eta_p^2 = .33$, with mean RTs shorter for high-imagery ($M = 736$ ms) than for low-imagery words ($M = 793$

ms), $dz = 0.70$. The number of correct trials was generally high ($M = 96.6\%$). As most of the participants made only one or two misclassifications, no statistical analysis was conducted on accuracy data.

ERPs

Figures 2 and 3 display the waveforms elicited by high and low imagery words and the scalp topographical maps of the word imageability effect (high-imagery words – low-imagery words) in each mood condition. As Figure 2 indicates, high-imagery words elicited a larger N400 than low-imagery words around 300–400 ms after stimulus onset at centroparietal sites. Following the N400, high-imagery words elicited a larger N700 than low-imagery words around 500–800 ms after stimulus onset at anterior sites, as shown in Figure 3.

N400 (300–400 ms). The main effect of word type was significant, $F(1, 29) = 10.97$, $p = .002$, $\eta_p^2 = .27$. High-imagery words elicited a larger N400 ($M = -2.43 \mu V$) than did low-imagery words ($M = -1.78 \mu V$), $dz = 0.60$. The interaction between word type and hemisphere was not significant, $F < 1$. Importantly, the main effect of mood was significant, $F(2, 28) = 4.11$, $p = .027$, $\eta_p^2 = .23$. Post hoc comparisons indicated that N400 amplitude was larger for the positive mood condition ($M = -2.43 \mu V$) than for the negative mood condition ($M = -1.85 \mu V$), $p = .021$, $dz = 0.53$, but these did not differ significantly from N400 amplitude for the neutral mood condition ($M = -2.04 \mu V$; $ps > .60$, $dzs = 0.34$ and 0.02 , respectively). No other interactions that included mood or word type were significant, $Fs < 1$. Figure 5 shows the scalp topographical maps of the amplitude difference between high- and low-imagery words, collapsed across mood conditions, and the amplitude difference between the positive and negative mood conditions, collapsed across word types. As noted above, both contrasts were statistically significant, with no

interaction. The two maps look similar, and both have a centroparietal distribution, which is typical of the N400 component.

N700 (500–800 ms). The main effect of word type was significant, $F(1, 29) = 19.50, p < .001, \eta_p^2 = .40$. High-imagery words elicited a more negative N700 ($M = 0.62 \mu V$) than did low-imagery words ($M = 1.50 \mu V$), $dz = 0.81$. The interaction between word type and site (anterior vs. posterior) was significant, $F(1, 29) = 78.4, p < .001, \eta_p^2 = .73$. The N700 imageability effect (high-imagery – low-imagery words) was larger at anterior sites ($M = -1.83 \mu V$) than at posterior sites ($M = 0.08 \mu V$), $dz = 1.62$. The Word Type $\times$ Site $\times$ Hemisphere interaction was significant, $F(1, 29) = 5.69, p = .024, \eta_p^2 = .16$. The topography map suggests that the N700 imageability effect was larger at the left anterior sites; however, post-hoc analysis did not reveal a significant hemispheric difference at anterior sites, $F = 2.61, p = .117$. Neither the main effect of mood nor the interaction effects that included mood were significant, $F_s < 1$.

Discussion

This study examined the effects of imageability and mood on ERPs. The results confirmed previous findings that high-imagery words elicited a larger N400 than did low-imagery words at centroparietal sites. Further, high-imagery words elicited a larger (more negative) N700 than did low-imagery words at frontal sites. Importantly, N400 amplitude was significantly greater for the positive mood condition than for the negative mood condition, regardless of word imageability. The interaction effect of mood and word imageability was not significant.

Effects of Imageability and Mood on Performance

Mean RTs were shorter for high-imagery words than for low-imagery words. This is consistent with previous studies in which participants made a two-choice response

based on the target word's imageability (West & Holcomb, 2000) or concreteness (Kounios & Holcomb, 1994). The RT difference may be attributable to the process of decision making. In the present study, the participants likely attempted to retrieve evidence for imageability (e.g., the visual features) from semantic memory until it exceeded a certain threshold, whereupon they pressed the Yes button. If the threshold was not reached within a certain time window, they pressed the No button. Given this type of decision-making process, it is unsurprising that the Yes response was faster than the No response.

Mood condition did not affect RTs, regardless of imageability. If positive mood had facilitated imagery-related memory access, RTs may have been shortened in the positive mood condition. However, this did not occur. The mood effect on imagery processing may be so weak that it is insufficient to affect behavior, at least in the two-choice RT task used in the present study.

Imageability Effect on ERPs

The imageability effect on N400 amplitude was consistent with previous studies (Barber et al., 2013; Gullick et al., 2013; Kanske & Kotz, 2007; Kounios & Holcomb, 1994; Nittono et al., 2002; West & Holcomb, 2000). As the N400 has been linked with semantic processing, this result suggests that high-imagery or concrete words activate more semantic information in memory than low-imagery or abstract words (e.g., Kounios & Holcomb, 1994). Gullick et al. (2013) proposed that imagery processing calls on semantic knowledge about the visual attributes or features of the target word. This semantic knowledge may be better recruited by the processing of high-imagery words than by that of abstract words, as high-imagery words are thought to have stronger and denser connections with other concepts in a network of semantic memory than low

imagery words (de Groot, 1989). When semantic knowledge is called on, high-imagery words would activate the network more extensively than low-imagery words. This more extensive activation may be reflected in a larger N400 for high-imagery words.

Previous studies indicated that the N400 imageability/concreteness effect was larger over the right hemisphere than over the left hemisphere (Kounios & Holcomb, 1994; Nittono et al., 2002). In the present study, no statistically significant hemispheric difference was obtained, although the effect appears slightly larger over the right hemisphere (see Figure 5).

The imageability effect after the latency range of the N400 was also consistent with previous studies on word imageability or concreteness (Barber et al., 2013; Gullick et al., 2013; Kanske & Kotz, 2007; Kounios & Holcomb, 1994; Nittono et al., 2002; West & Holcomb, 2000). West and Holcomb (2000) suggested that the N700 concreteness effect may represent activation in a mental imagery subsystem that is used more for concrete words than for abstract words. Supporting this idea, Gullick et al. (2013) reported that elicitation of the N700 depends on the combination of word property and task demand, occurring only for concrete words in a task that requires imagery processing. The present study met this condition, producing the N700.

Mood effects on N400 and N700

In the present study, the N400 amplitude was larger in the positive mood condition than in the negative mood condition, irrespective of word imageability. This finding is consistent with Moriya et al. (2013), in which the N400 amplitude elicited by both words and pseudowords in a lexical decision task was greater with a high-arousal positive mood compared to a neutral mood. On the other hand, the present N400 imageability effect was not affected by mood, unlike the N400 cloze probability effect

that was modulated by mood (Chwilla et al., 2011; Federmeier et al., 2001; Pinheiro et al., 2011). Chwilla et al. (2011) reported that the N400 cloze probability effect was larger in the happy mood condition than in the sad mood condition. Pinheiro et al. (2013) showed that a word slightly unexpected in the context was processed like an expected word under positive mood, while slightly unexpected and clearly unexpected words were processed in a similar way under negative mood. These results can be explained by qualitatively different processing styles associated with the two moods (Chwilla et al., 2011). Specifically, positive mood facilitates the use of top-down processing, whereas negative mood facilitates the use of bottom-up processing. When a word appears in context, as in studies on the N400 cloze probability effect, top-down processing facilitates recognition of the target word, and thus positive mood can enhance this facilitation effect. However, when a word appears in isolation, as in the present study, there is little chance of using top-down processing. Consequently, mood did not affect the N400 amplitude in the same manner as the N400 cloze probability effect. Instead, the greater N400 amplitude in the positive mood condition regardless of imageability can be interpreted as a result of facilitation of the spread of activation in semantic memory and access to lexical representations under positive mood. Pinheiro et al. (2013) suggested that mood can influence language processing by changing the gradient of connections among words in semantic memory. In the present study, this type of change may have boosted the semantic processing of single isolated words, regardless of the strength and density of the connections with other concepts in the network of semantic memory.

An ERP component is usually defined as the difference between two conditions that differ only in the experimental variable of interest. This is conventional for a component that does not have a distinct peak with a specified polarity, like the N400. In

light of this, it may seem irregular to argue that the N400 amplitude itself, not the amplitude difference between word types, is affected by mood, as the possibility remains that a different component, other than the N400, appeared in the positive mood condition and overlapped in the N400 latency range. However, as shown in Figure 5, the amplitude difference between the positive and negative mood conditions shows a centroparietal scalp topography that is typical of the N400. Therefore, it is reasonable and parsimonious to assume that mood affects the amplitude of the N400 itself, rather than induces a new ERP component in the same latency range.

Unlike the N400, the N700 amplitude was not affected by mood. The N700 may reflect qualitatively different processing than the N400. Nittono et al. (2002) speculated that the N700 (which they called “N800”) was a second N400. However, this argument is not tenable, because scalp topography is different between the N400 (centroparietal) and the N700 (anterior). Rather, the N700 may be linked to a controlled process related to mental imagery that is called out when the task requires imagery processing (Gullick et al., 2013). Its anteriorly dominant scalp distribution implies the involvement of the prefrontal cortex. The present study suggests that this process is not influenced by mood. However, given that it is a controlled process, stronger emotional states that deplete attentional resources may affect the amplitude of the N700.

Lastly, a caveat in the interpretation of the present findings should be noted. Because imageability is positively correlated with familiarity, valence, and arousal, the N400 and N700 amplitude differences between the high- and low-imagery word categories may not be due to the difference in imageability alone. For example, words with positive valence elicit a smaller N400 than words with negative valence (Yao et al., 2016). Despite this limitation, the main finding that the N400 amplitude is larger under

positive mood than under negative mood is still tenable, because the effect did not depend on word type.

Conclusion

This study examined the effects of word imageability on the N400 and N700 components of the ERP in a single word imageability judgment task. High-imagery words elicited a larger (more negative) N400 and N700 than did low-imagery words. Regardless of word imageability, the amplitude of N400 was larger under positive mood than under negative mood. N700 amplitude was not affected by mood. These results suggest that, compared to negative moods, positive moods facilitate activation of semantic memory and access to lexical representations during imagery processing.

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Footnotes

¹This number of participants was chosen because it was the the largest number that could be recruited in the laboratory (due to time and space limitations) when this study was conducted. Retrospectively, however, the number could be justified by the following consideration. The main purpose of this study was to examine the effect of mood on ERP amplitude (either the amplitude itself or the amplitude difference between high- and low-imagery words). For a medium effect size ($d_z = 0.5$) between the most distant mood conditions (positive vs. negative) in a within-participants design ($\alpha = .05$ and power = .80), G*Power (ver. 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007) calculates the total required sample size to be 34 (two-tailed) or 27 (one-tailed). Based on previous studies, there was a strong one-directional prediction that the N400 amplitude should be larger under a positive mood condition than under a negative one, if it exists. Therefore, around 30 participants is an acceptable number to address the main question of the present study.

²The KDEF pictures used in this study were as follows: Happy: AF24HAS, AF33HAS, AF35HAS; Sad: AF17SAS, AF26SAS, AF30SAS; Neutral: AF04NES, AF09NES, AF34NES.

Figure 1. An example of a trial block in the imagery judgment task. Each block consisted of 10 judgment trials (5 high-imagery and 5 low-imagery words), followed by an episode recollection trial with one facial picture that corresponded to the mood condition. Participants performed nine blocks in each mood condition.

Figure 2. Grand mean ERP waveforms at the left and right centroparietal areas and the imageability effect in the N400 latency range for each mood condition. Electrode sites were grouped into two areas, and the waveforms were calculated by averaging over each area: Left (mean of C3, CP1, CP5, and P3) and Right (mean of C4, CP2, CP6, and P4). Gray shading indicates the time window (300–400 ms) used for the N400 analysis.

Figure 3. Grand mean ERP waveforms and topographical maps of the imageability effect in the N700 latency range for each mood condition. Electrode sites were grouped into four areas, and the waveforms were calculated by averaging over each area: AL (anterior left; Fp1, F3, F7, FC1, FC5, and FT9), AR (anterior right; Fp2, F4, F8, FC2, FC6, and FT10), PL (posterior left; CP1, CP5, TP9, P3, P7, PO9, and O1), and PR (posterior right; CP2, CP6, TP10, P4, P8, PO10, and O2). Gray shading indicates the time window (500–800 ms) used for the N700 analysis.

Figure 4. (A) Mean amplitudes of the N400 latency range (300–400 ms) over the Left (C3, CP1, CP5, and P3) and Right (C4, CP2, CP6, and P4) centroparietal areas in the three mood conditions. (B) Mean amplitudes of the N700 latency range (500–800 ms) over the AL (anterior left; Fp1, F3, F7, FC1, FC5, and FT9), AR (anterior right; Fp2, F4, F8, FC2, FC6, and FT10), PL (posterior left; CP1, CP5, TP9, P3, P7, PO9, and O1), and PR (posterior right; CP2, CP6, TP10, P4, P8, PO10, and O2) areas in the three mood conditions. Error bars indicate standard errors of means.

Figure 5. Topographical maps of the imageability effect (high-imagery words – low-imagery words, collapsed across mood conditions) and the mood effect (positive mood - negative mood, collapsed across word types) on the N400.

Table 1. Summary of lexical properties of high- and low-imagery words (n = 135 each)

	High imagery	Low imagery			
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>t</i> (268)	<i>p</i>	<i>d</i>
Imageability ^a	5.93 (0.26)	3.27 (0.12)	107.88	< .001	13.13
Frequency (log 10[n]) ^b	2.91 (0.71)	2.90 (0.59)	0.14	.886	0.02
Familiarity ^c	6.05 (0.29)	4.72 (0.50)	26.63	< .001	3.24
Length (number of moras) ^c	3.48 (0.63)	3.41 (0.59)	0.90	.372	0.11
Valence ^d	4.63 (0.88)	4.10 (0.55)	5.99	< .001	0.73
Arousal ^d	2.61 (0.70)	1.94 (0.35)	10.06	< .001	1.22
Number of writing strokes	18.20 (4.51)	18.51 (4.73)	−0.55	.581	0.07

^aAccording to Sakuma et al. (2005).

^bAccording to Amano and Kondo (2000).

^cAccording to Amano and Kondo (1999).

^dBased on ratings of 24 participants who did not participate in the ERP experiment.

Table 2. Mean pleasantness and arousal scores at baseline, after mood induction, and after task in each mood session

	Positive		Neutral		Negative				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> (2, 28)	<i>p</i>	η_{p}^2
<i>Pleasantness</i>									
Baseline	5.53 ^a	1.01	5.67	0.96	5.97 ^b	0.89	5.39	.010	.28
Post-induction	6.57 ^a	1.04	5.17 ^b	0.83	4.20 ^c	1.40	32.45	< .001	.70
After task	6.03 ^a	1.00	5.30 ^b	0.95	4.23 ^c	1.25	17.73	< .001	.56
<i>Arousal</i>									
Baseline	5.43	1.61	4.97	1.77	5.23	1.91	1.72	.198	.11
Post-induction	6.23 ^a	1.74	5.57 ^b	1.77	5.57	1.81	6.46	.005	.32
After task	5.40	1.90	4.80	1.86	5.30	1.88	2.50	.100	.15

Note. Scores range from 1 (unpleasant feelings, sleepiness) to 9 (pleasant feelings, high arousal). Means in the same row that do not share superscripts differ at $p < .05$.

Table 3. Mean reaction times (RTs) and number of correct trials (accuracy) in response to high- and low-imagery words in each mood condition

	Mean RT (ms)				Number of Correct Trials (Max: 45)			
	High imagery		Low imagery		High imagery		Low imagery	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Positive	733.2	127.7	791.6	130.8	44.1	1.5	42.8	2.1
Neutral	745.4	121.2	790.7	131.1	43.7	1.8	43.5	2.1
Negative	728.5	122.8	796.2	148.1	44.0	1.7	42.6	3.0

Note. Maximum number of correct trials within each mood condition and word type was 45.