



Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Brain electrophysiological responses to emotion nouns versus emotionless nouns



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ARTICLE INFO

Keywords:

Abstract concept
Affect
Emotion concept
Mental imagery
N400

ABSTRACT

As the ability to recognize and communicate emotions is crucial to mental health, it is important to understand the representation and processing of emotion concepts. This study examined brain electrophysiological responses to nouns that denote emotions (e.g., *guilt* and *joy*) in comparison to nouns that denote abstract (e.g., *theme*) and concrete entities (e.g., *teapot*) without emotional connotations. Thirty-two participants completed a lexical decision task. Behavioral responses to emotion nouns were faster and more accurate than abstract and concrete nouns. ERP data showed that emotion nouns were associated with a less pronounced N400 that peaked earlier relative to abstract and concrete nouns. Further, N400 amplitude differences between emotion and concrete nouns emerged earlier with a broad distribution, whereas the differences between emotion and abstract nouns appeared later with a fronto-central distribution. These findings demonstrate in the healthy brain processing advantages and representational distinctions of emotion concepts versus other concepts, providing a point of reference for future theoretical and clinical research on affect representations.

1. Introduction

There has been limited research focusing exclusively on the representation and processing of words that denote emotions, e.g., *sadness*, *elation*, and *guilt*, even though the ability to properly identify and communicate different emotions is crucial to our mental health (Aust, Hartwig, Heuser, & Bajbouj, 2013; Thorberg, Young, Sullivan, & Lyvers, 2009). In the literature of concept representations, researchers often include nouns that denote emotion concepts in the category of abstract nouns, e.g., *profit* and *logic* (Citron, 2012). This practice has its theoretical basis. Specifically, in order to be able to recognize and interpret others' emotions, we need to be able to understand our own emotions (Lombardo & Baron-Cohen, 2011). That is, like most abstract concepts, we come to learn emotion concepts mainly through introspection (Barsalou, 1999). Further, Kousta, Vigliocco, Vinson, Andrews, and Del Campo (2011) have argued that affective experience in general plays an important role in the representation of abstract concepts. A statistically greater binding of affective experience distinguishes abstract concepts from concrete concepts; the latter in contrast require a greater binding of sensorimotor experience (Kousta et al., 2011). As emotion nouns represent affective states and processes, it seems that they should be considered typical exemplars of abstract nouns.

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<https://doi.org/10.1016/j.jneuroling.2018.10.003>

Received 18 March 2018; Received in revised form 13 October 2018; Accepted 16 October 2018

Available online 22 October 2018

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Emotion nouns, however, seem to also demonstrate characteristics different from other abstract nouns. Behavioral studies showed that emotion concepts were consistently assigned with higher imageability ratings relative to other abstract concepts (Altarriba & Bauer, 2004; Altarriba, Bauer, & Benvenuto, 1999; Paivio, Yuille, & Madigan, 1968). It appeared that emotion concepts readily evoke mental imagery, which is not characteristic of other abstract concepts. Echoing the high imageability ratings revealed by behavioral studies, fMRI research has demonstrated that processing emotion concepts generates hemodynamic activity in regions of the cortical motor system linking to effectors of face and arm actions (Moseley, Carota, Hauk, Mohr, & Pulvermüller, 2012). Therefore, mental imageries of facial expressions, hand gestures, and body postures activated during the processing of emotion concepts may be the primary basis for their higher imageability ratings reported in past behavioral studies (e.g., Altarriba & Bauer, 2004; Paivio et al., 1968). Together these findings suggest that processing an emotion noun may entail similar imagery processes as does processing a concrete object noun, the representation of which is largely grounded in sensorimotor experience (Barsalou, 1999; Kousta et al., 2011).

In this study, we examined brain responses to emotion nouns in comparison to other nouns in order to further investigate mental representation of emotion concepts. We particularly looked into the two semantic features, as indicated by past research, characteristic of emotion nouns: emotionality and imageability. Specifically, with regard to emotionality, past research has shown that words with emotional connotations, e.g., *wedding* and *mistake*, would entail emotional arousal, which in turn facilitates semantic processing due to preferential allocation of attentional resources to emotionally charged stimuli (e.g., Kissler, Herbert, Peyk, & Junghofer, 2007; Palazova, Sommer, & Schacht, 2013; Sass et al., 2010). On the one hand, emotion nouns denote affective states and processes. When we see an emotion noun, a corresponding affective experience may be activated and we may experience, consciously or preconsciously, an emotional arousal. As a result, emotion nouns, similar to emotionally charged words, may also show a processing advantage over emotionally neutral words. On the other hand, different from emotionally charged words, representations of emotion nouns such as *joy* and *guilt* appear void of key situational elements that elicit and accompany such emotions. Take the word *wedding* as an example, people who attend a wedding experience *joy* and *love*. These emotions are situated in a setting that contains emotionally salient elements such as *flowers*, *a wedding gown*, *a cake*, *a ceremony*, and/or *a reception*. The richness of these semantically related elements facilitate activation of affective experience and the processing the word *wedding* (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008). In contrast, the processing of the word *joy* may or may not boast such advantage. It denotes an affect. Situational elements related to this affect are not necessarily encoded in its representation, and thus may not be readily available in support of the activation of corresponding affective experience. In this study, we compared emotion nouns (e.g., *elation* and *regret*) to nouns that denote non-emotional entities (e.g., *logic* and *teapot*) to verify whether emotion nouns would demonstrate a similar emotionality effect during word processing, as has been demonstrated by past research for nouns with emotional connotations (e.g., Kissler et al., 2007; Palazova et al., 2013; Sass et al., 2010).

Second, we investigated imageability of emotion nouns. Given behavioral and fMRI evidence that mental imageries, e.g., facial expressions and hand gestures, extracted from sensorimotor experience, may be integral to emotion concepts (e.g., Altarriba et al., 1999; Moseley et al., 2012), processing emotion nouns, different from other abstract nouns, may elicit imagery processes, similar to processing concrete object nouns. However, neither behavioral nor fMRI measures are particularly informative of early stages of word processing. That is, past behavioral and fMRI evidence may only be indicative of imagery processes that occur at later stages of emotion concept processing such as post-activation semantic evaluation. In this study, we utilized the ERP approach that has been shown to be effective in investigating early-stage imageability effect on word processing (e.g., Kounios & Holcomb, 1994; Nittono, Suehiro, & Hori, 2002). Following procedures in these studies, we included two categories of nouns that represent emotionally neutral entities, abstract nouns (e.g., *logic* and *theme*) and concrete object nouns (e.g., *teapot* and *window*). Inclusion and comparison of these two types of nouns would allow us to pinpoint any imageability effect produced by concrete nouns relative to abstract nouns, as consistently shown in prior research (e.g., Kounios & Holcomb, 1994; Nittono et al., 2002). If emotion nouns produce a similar imageability effect relative to abstract nouns, it would be positive evidence that the representation and processing of emotion nouns, similar to concrete object nouns, also elicit imagery processes.

Findings of this study will add to the limited literature about the processing of emotion nouns and contribute to a better understanding about mental representation of emotion concepts. For example, it may provide a tentative benchmark for psycholinguistic research focusing on or involving emotion concepts. Further, a better understanding about the processing of emotion nouns in the healthy brain may also help to facilitate understanding about affect disorders characterized by abnormal identification and communication of emotions (Aust et al., 2013; Thorberg et al., 2009).

1.1. Analyses of emotionality and imageability effects

We conducted the following analyses to investigate potential emotionality and imageability effects of emotion nouns in word processing. First, we examined an ERP component reportedly responding to both emotion and imagery processing: the N400 (e.g., Herbert, Junghofer, & Kissler, 2008; Kaltwasser, Ries, Sommer, Knight, & Willems, 2013; Kissler & Herbert, 2013; Kounios & Holcomb, 1994). Within the N400 time window, electrophysiological activities signal semantic activation and reflect representational differences across different conceptual categories (Kutas & Federmeier, 2011). Specifically, activities elicited by emotion nouns may differ in both magnitude and topography from those by other nouns due to potential emotionality effect and imageability effect.

1.1.1. Emotionality effect

With regard to the emotionality effect, emotional arousal tends to facilitate semantic processing, leading to a reduced magnitude of the N400 particularly evident over the anterior region (see Citron, 2012 for a review). For example, Sass et al. (2010) examined the

N400 elicited by emotionally charged words (e.g., *birthday* and *victim*) versus neutral words (e.g., *moment* and *carpet*). A region of interest (ROI) analysis comprising electrode sites FC1, FC2, FC3, and FC4 showed that emotionally charged words elicited significantly smaller N400 relative to neutral words. Palazova et al. (2013) conducted an analysis that included all electrode sites within the N400 time window. Results also suggested that emotionally charged words relative to neutral words tended to produce a less pronounced negative deflection over the fronto-central region.

Comparing to abstract and concrete nouns that represent emotionally neutral entities, if the same attenuating effect on the N400 over fronto-central region was found for emotion nouns, e.g., *please* or *upset*, it would be evidence that emotion nouns are similar to emotionally charged words, e.g., *birthday* and *victim*, in triggering emotional arousal and facilitating semantic processing. On the other hand, lack of such attenuating effect on the N400 would indicate that emotion nouns, at least when presented without any contextual support, would not entail similar affect activations. In addition, more efficient processing of emotion nouns, if found, should also manifest in processing speed and accuracy. To verify, we analyzed both peak latency within the N400 time window and behavioral data including response time and accuracy rate.

Lastly, we also examined two other ERP components: the Early Posterior Negativity (EPN) and the Late Positive Component (LPC). Research has shown that they can also be associated with emotion word processing (Kaltwasser et al., 2013; Kanske & Kotz, 2007; Kissler & Herbert, 2013). However, it was evident in this study that, relative to abstract and concrete nouns, emotion nouns did not elicit the EPN or enhance the LPC. For sake of succinctness, we reported and briefly discussed these findings in the Discussion section.

1.1.2. Imageability effect

With regard to the imageability effect, prior ERP studies indicated that concrete concepts were associated with greater N400 relative to abstract concepts. For example, Adorni and Proverbio (2012) demonstrated, starting from 350 ms post word onset, greater negativities associated with concrete words than abstract words over the mesial occipital regions, suggesting imagery processing. Many of these studies further demonstrated that the difference between concrete and abstract word stimuli tended to be right lateralized, suggesting a greater right hemisphere involvement in imagery processing (Kounios & Holcomb, 1994; Nittono et al., 2002). Huang, Lee, and Federmeier (2010) also revealed in the right hemisphere, greater negativities associated with concrete words than abstract words, albeit in a later time window (500–900 ms), which might be a result of the specific presentation approach employed by the study, i.e., visual half-field presentation. Similarly, fMRI research showed that concrete concepts were associated with greater activations in bilateral association areas, whereas abstract concepts were almost exclusively associated with left hemisphere activities (Binder, Westbury, McKiernan, Possing, & Medler, 2005).

Accordingly, in the present study, if emotion nouns, similar to concrete nouns, elicit a greater N400 relative to abstract nouns and the difference is more prevalent in the right hemisphere, it would be an indication for the imageability effect of emotion concepts relative to abstract concepts. Conversely, the lack of such a difference would suggest that emotion concepts are similar to abstract concepts, both primarily encoded in a verbal rather than an imagery system as posited by the Dual-Code Theory (Paivio, 1986). Such findings would indicate that imageries such as facial expressions and body movements are only peripheral features in this conceptual domain, and do not require the same level of imagery encoding as perceptual features possessed by object concepts. That is, peripheral features may not necessarily get activated at the early stage of semantic processing. Evaluation of ERP data would allow us to examine brain responses to emotion nouns at this early stage.

2. Method

2.1. Participants

This study was approved by the Institutional Review Board of the Imaging Center for Brain Research at the university where this study was conducted. The authors declare no conflict of interest. All procedures performed in the study involving human participants were in accordance with the ethical standards of the Institutional Review Board of the Imaging Center for Brain Research. Informed consent was obtained from all individual participants included in the study.

There were 32 university students (18 women, 22.31 ± 2.06 years old). All were native speakers of Mandarin Chinese, right-handed, with normal or corrected-to-normal vision, without known neurological or mental health issues. Each participant gave informed consent prior to the study and received monetary compensation. To ensure sufficient statistical power (> 90%), the number of participants was determined using G*Power based on effect sizes estimated in an earlier ERP study using a similar set of word stimuli.

2.2. Procedure and stimuli

Participants completed a lexical decision task with their ERP and behavioral responses recorded. The task stimuli consisted of 144 Chinese two-character nouns, including 48 emotion nouns (e.g., *despair* and *joy*), 48 abstract nouns (e.g., *logic* and *theme*), and 48 concrete nouns (e.g., *teapot* and *car*). These nouns were sampled from a database constructed for purposes of psycholinguistic research in our lab. The database contained over 2200 two-character words with lexical properties such as word frequency and part-of-speech extracted from extant written corpora and semantic properties such as emotionality and concreteness rated by native speakers of Mandarin Chinese. Table 1 presents example stimuli sampled for the present study, and Table 2 presents their property ratings. The three types of nouns were matched on frequency and number of strokes. Emotion and abstract nouns were also matched on

Table 1
Example stimuli of abstract, concrete, and emotion nouns with English translations in parentheses.

Abstract	Concrete	Emotion
差别 (difference)	板栗 (chestnut)	仇恨 (hatred)
传统 (tradition)	茶壶 (teapot)	愤怒 (anger)
法则 (rule)	蜡烛 (candle)	敬意 (respect)
逻辑 (logic)	纤维 (fiber)	幸福 (happiness)

Table 2
Means (SDs) of property ratings for abstract, concrete, and emotion nouns.

	Abstract	Concrete	Emotion	<i>F</i> (2, 141)	<i>p</i>
Frequency (Ln)	3.03 (1.50)	2.84 (1.24)	3.02 (1.20)	1.27	.28
Number of strokes	16.75 (3.39)	17.98 (4.23)	18.42 (4.18)	2.30	.10
Abstractness	4.07 (.56)	1.46 (.31)	4.20 (.23)	743.48	< .001
Imageability	3.06 (.76)	6.41 (.43)	4.19 (.59)	377.95	< .001
Emotionality	.16 (.11)	.10 (.11)	2.40 (.36)	1583.54	< .001

Note: Abstractness and Imageability were rated on a 7.0 scale ranging from 1 to 7; Emotionality was rated on a 5.0 scale ranging from 0 to 4.

abstractness, both rated significantly higher than concrete nouns, both $ps < .001$, on a 7.0 scale (1 = highly concrete; 7 = highly abstract). Imageability was also evaluated using a 7.0 scale (1 = not imageable at all; 7 = highly imageable). Concrete nouns, as expected, were rated significantly more imageable than both abstract and emotion nouns, both $ps < .001$. After controlling for abstractness level, it appeared that emotion nouns relative to abstract nouns had significantly higher imageability ratings, $p < .001$, consistent with previous reports (Altarriba et al., 1999; Paivio et al., 1968). Further, abstract and concrete nouns were matched on emotionality, both rated significantly lower than emotion nouns, both $ps < .001$. Emotionality was defined, according to Lang, Bradley, and Cuthbert (1997), as the degree of activation associated with an affect, i.e., how intense an emotion is. It was assessed using a 5.0 scale (0 = neutral; 4 = very intense). As Chinese words can be ambiguous in grammatical class, nouns that met the selection criteria outlined above were extracted from the database based on their marked part-of-speech, and further verified by the authors. In addition to the nouns, there were 144 pseudo-words matching the nouns on number of strokes. These were meaningless two-character combinations of real Chinese characters.

The experiment included three randomized blocks. Each block contained 96 trials: 16 emotion nouns, 16 abstract nouns, 16 concrete nouns, and 48 pseudo-words. A trial began with a cross fixation (+) displayed for 300 ms at the center of the screen, followed by a black screen for 200 ms. Then a word or pseudo-word appeared for 1000 ms. Participants indicated as quickly and accurately as possible whether it was a meaningful word by using their right index or middle finger to press one of two response keys (YES or NO). Positions of response keys were counterbalanced across participants. At the end of each trial, a black screen was displayed for a randomly determined duration (1200–1800 ms) before the start of the next trial. Participants completed two practice blocks of 18 trials with a different set of words and pseudo-words at the beginning of the experiment. There was a break between blocks, with its duration determined by the participants.

2.3. EEG recording

The experiment was conducted in a soft-lit and soundproof recording room. All stimuli were presented white-on-black, 2.7 cm high and 6.5 cm wide, in the middle of a computer screen. Participants sat about 100 cm from the screen. Their Electroencephalograms (EEG) were recorded from a 32-channel Quik-cap (NeuroScan, Inc.) with the right mastoid as the reference. Vertical eye movements were recorded by two electrodes attached above and below the left eye. Horizontal eye movements were monitored by two electrodes placed at the left and right outer canthi. Impedances of all electrodes were kept below 5 k Ω . The sample rate was 500 Hz with a band-pass of .05–100 Hz. Data were re-referenced offline to the average of two mastoids.

The continuous data were segmented from 100 ms pre-stimulus to 800 ms post-stimulus, and filtered offline with a low pass of 30 Hz (24 dB). The mean voltage of the 100 ms pre-stimulus interval acted as the baseline. Trials associated with incorrect responses or contaminated by eye blinks, eye movements, or muscle potentials exceeding $\pm 100 \mu\text{V}$ at any electrode were excluded from analysis, resulting in an exclusion of 7.29% of all trials. To ensure adequate signal-to-noise ratio, there were at least 30 trials in each word condition for each participant to compute average ERPs. The segmented data were then averaged for each word condition within each participant.

2.4. ERP data analysis

Fig. 1 depicts grand average ERP waveforms for the three word conditions at nine representative electrode sites. To examine relative processing efficiencies of three word categories, N400 peak latencies were analyzed in addition to the analyses of behavioral data. Because of reports about temporal and topographical variations of the N400 effect across different word categories, we included all electrode sites for this analysis. For each site, peak latency was taken at the lowest value of amplitude within the 250–450 ms time

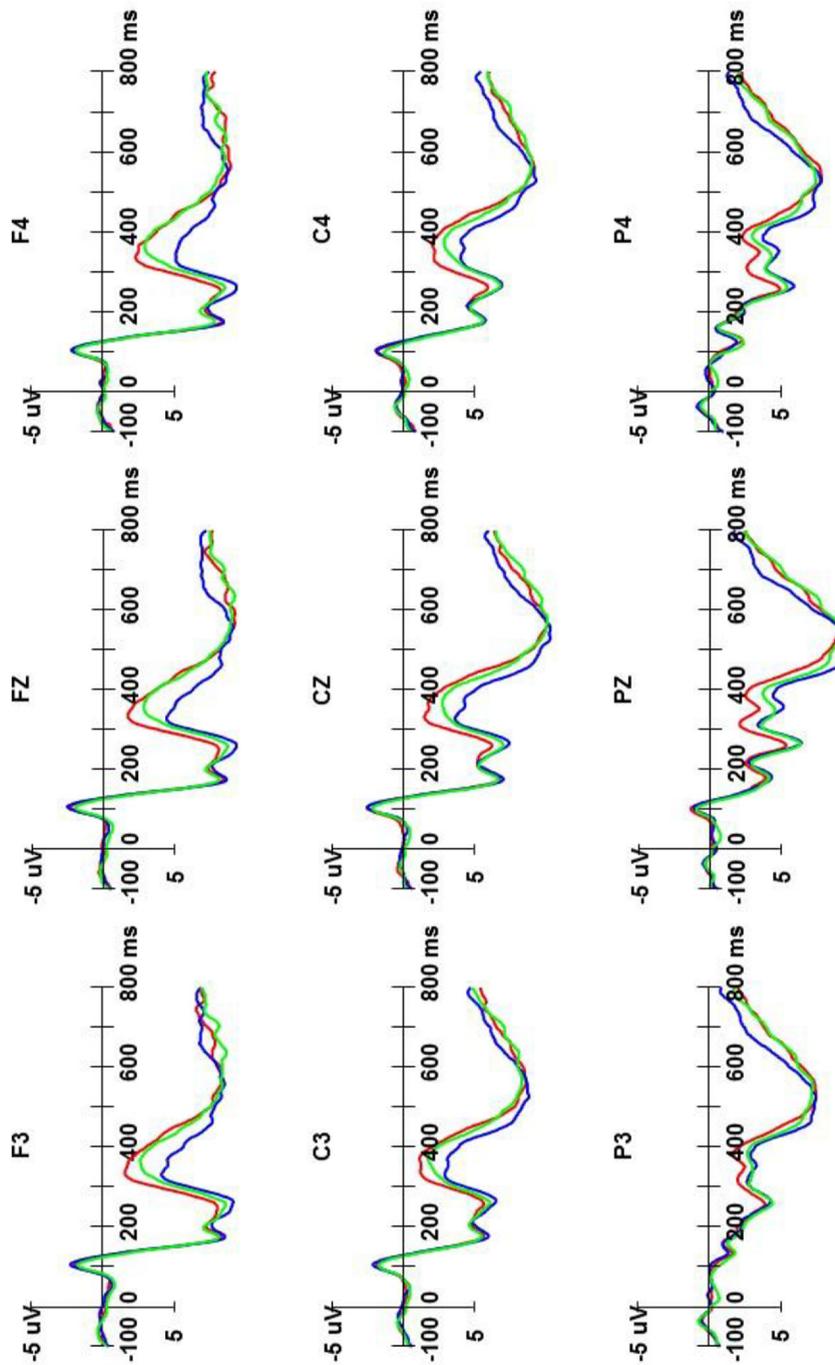


Fig. 1. Grand average ERP waveforms for three word categories from nine representative electrode sites. (Red: concrete nouns; Green: abstract nouns; Blue: emotion nouns). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 3

Means (SDs) of response time, accuracy rate, and peak latency in left hemisphere, midline, and right hemisphere within the N400 time window for abstract, concrete, and emotion nouns.

	Abstract	Concrete	Emotion
Response time (ms)	617.88 (9.66)	626.06 (10.65)	597.30 (10.17)
Accuracy rate (%)	94.20 (.65)	92.64 (.72)	97.59 (.45)
Peak latency (ms)			
Left hemisphere	346.84 (4.73)	346.22 (5.37)	342.89 (6.10)
Midline	346.73 (7.23)	347.24 (7.06)	332.31 (7.71)
Right hemisphere	358.08 (6.20)	351.33 (5.27)	341.44 (6.49)

window. Acknowledging downsides of this approach, we followed up with careful visual inspection to verify the validity of the peak amplitudes. Then, analyses were conducted separately for midline and lateral sites. For midline sites, a 3 (word conditions: emotion, abstract, and concrete) * 5 (sites: FZ, FCZ, CZ, CPZ, and PZ) repeated-measures ANOVA was performed. For lateral sites, a 3 (word conditions: emotion, abstract, and concrete) * 2 (hemispheres: left and right) * 10 (sites: F7/8, F3/4, FT7/8, FC3/4, T7/8, C3/4, TP7/8, CP3/4, P7/8, and P3/4) repeated-measures ANOVA was performed. Occipital sites were excluded as there were no evident deflections within the N400 time window. (Analysis including these sites revealed essentially the same outcome.)

Analyses of response times and N400 peak latencies indicated that emotion nouns were processed faster than both abstract and concrete nouns (Table 3; see Results section for details). Based on these analyses and visual inspection of the ERP waveforms, two epochs were delineated to capture potential temporal variation of N400 differences across word conditions: 250–350 ms and 350–450 ms. Following previous studies that included multiple word categories and anticipated potential topographical differences within the N400 time window, our analysis included all but occipital electrode sites (Kaltwasser et al., 2013; Kounios & Holcomb, 1994; Palazova et al., 2013). Specifically, within each of the two epochs of the N400 time window, the following analyses were conducted. For midline sites, a 3 (word conditions: emotion, abstract, and concrete) * 5 (sites: FZ, FCZ, CZ, CPZ, and PZ) repeated-measures ANOVA was performed on mean amplitude. For lateral sites, a 3 (word conditions: emotion, abstract, and concrete) * 2 (hemispheres: left and right) * 10 (sites: F7/8, F3/4, FT7/8, FC3/4, T7/8, C3/4, TP7/8, CP3/4, P7/8, and P3/4) repeated-measures ANOVA was performed on mean amplitude. The Geisser-Greenhouse correction for non-sphericity was applied when appropriate, with uncorrected degrees of freedom and corrected probabilities presented. Out of primary interest, only main effects or interactions involving the factor of word condition are reported. Bonferroni *t*-tests were applied to pair-wise comparisons in order to control family-wise error rate. Reported differences from these comparisons had corrected *p*-values less than 0.05.

3. Results

3.1. Response time and accuracy rate

Simple ANOVAs showed that three word conditions differed in response time, $F(2, 62) = 41.13, p < .001$, partial $\eta^2 = 0.57$, and accuracy rate, $F(2, 62) = 25.58, p < .001$, partial $\eta^2 = 0.45$. Participants responded to emotion nouns more quickly and more accurately than to abstract and concrete nouns (all $ps < .001$). The difference in response time, but not in accuracy rate, between abstract and concrete nouns was also significant ($p = .040$, Table 3). The faster response time of abstract nouns than concrete nouns was consistent with past reports that, when other lexico-semantic factors were controlled, the concreteness effect on response time tended to disappear or even reverse (Kousta et al., 2011; Xu, Kang, Sword, & Guo, 2017).

3.2. Activities within the N400 time window

3.2.1. Peak latency

At midline sites, the 3 (word) * 5 (site) ANOVA revealed a main effect of word condition, $F(2, 62) = 4.70, p = .013$, partial $\eta^2 = 0.13$. Emotion nouns ($M = 332$ ms) showed earlier peaks than both abstract ($M = 347$ ms) and concrete nouns ($M = 347$ ms), $ps < .035$. There was no word by site interaction, $F(8, 248) < 1$.

At lateral sites, the 3 (word) * 2 (hemisphere) * 10 (site) ANOVA did not reveal a significant main effect of word condition, $F(2, 62) = 2.58, p = .080$. However, the word by hemisphere interaction approached significance, $F(2, 62) = 3.14, p = .050$, partial $\eta^2 = 0.09$. We therefore carried out analyses on simple effect of word category in the left and right hemisphere, respectively. There was no simple effect of word category in the left, $F(2, 62) < 1$. In the right, the effect was significant, $F(2, 62) = 3.93, p = .025$, partial $\eta^2 = 0.11$. Emotion nouns ($M = 341$ ms) showed significantly earlier peaks than abstract nouns ($M = 358$ ms), $p = .018$. Emotion nouns also showed earlier peaks than concrete nouns ($M = 351$ ms), but the difference did not reach significance, $p = .150$ (Table 3).

3.2.2. Mean amplitude of 250–350 ms epoch

Table 4 listed mean amplitudes of each of the two epochs. At midline sites, the 3 (word) * 5 (site) ANOVA revealed a main effect of word condition, $F(2, 62) = 15.63, p < .001$, partial $\eta^2 = 0.34$, and a word by site interaction, $F(8, 248) = 3.17, p = .026$, partial

Table 4

Mean amplitudes (SDs) of in each of the two epochs in left hemisphere, midline, and right hemisphere for abstract, concrete, and emotion nouns (uV).

	Abstract	Concrete	Emotion
250–350 ms			
Left hemisphere	3.06 (.48)	2.65 (.48)	3.83 (.53)
Midline	5.19 (.68)	3.83 (.70)	5.65 (.73)
Right hemisphere	4.33 (.61)	3.18 (.62)	4.74 (.61)
350–450 ms			
Left hemisphere	2.41 (.53)	2.04 (.53)	3.67 (.54)
Midline	4.31 (.70)	3.45 (.70)	5.88 (.67)
Right hemisphere	3.11 (.57)	2.42 (.56)	4.30 (.53)

$\eta^2 = 0.09$. Concrete nouns elicited greater negative going activities than both abstract and emotion nouns. Simple effect analyses showed that these differences were significant at all sites, $ps < .003$, but slightly more evident at anterior relative to posterior sites.

At lateral sites, the 3 (word) * 2 (hemisphere) * 10 (site) ANOVA again revealed that there was the main effect of word condition, $F(2, 62) = 17.18, p < .001$, partial $\eta^2 = 0.36$, with concrete nouns associated with significantly greater negative going activities than abstract and emotion nouns, $ps < .004$. In addition, a three-way interaction of word, hemisphere, and site was significant, $F(18, 558) = 4.30, p < .001$, partial $\eta^2 = 0.12$. Simple effect analyses indicated that the differences between concrete and emotion nouns had a broad distribution, $ps < .020$, whereas the differences between concrete and abstract nouns were widespread in the right hemisphere, $ps < .030$, but limited to some medial sites in the left hemisphere: F3, FC3, C3, and CP3, $ps < .020$.

In sum, in this epoch, concrete nouns generated greater negative going activities than both abstract and emotion nouns. The differences between concrete and emotion nouns were widespread, whereas the differences between concrete and abstract nouns were more prevalent over the right hemisphere. There was no sufficient evidence for differences between abstract and emotion nouns (Fig. 2).

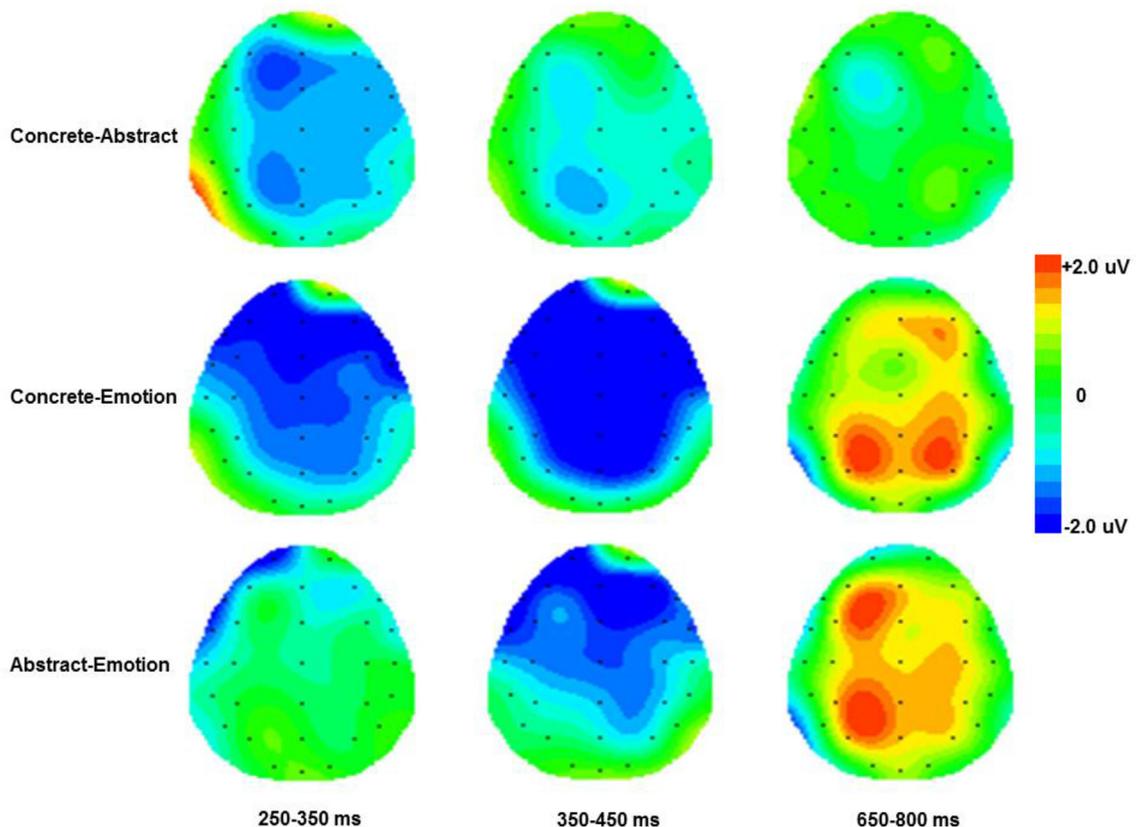


Fig. 2. Scalp distributions of amplitude differences between word categories in three epochs.

3.2.3. Mean amplitude of 350–450 ms epoch

At midline sites, there were main effect of word condition, $F(2, 62) = 21.91, p < .001$, partial $\eta^2 = 0.41$, and word by site interaction, $F(8, 248) = 4.51, p < .001$, partial $\eta^2 = 0.13$. On average, concrete nouns were associated with the greatest magnitude of negative going activities, followed by abstract nouns, and then by emotion nouns (Table 4). Simple effect analyses showed that the greater negative going activities of concrete and abstract nouns relative to emotion nouns were significant at all sites except the posterior site PZ, $ps < .020$, whereas the greater negative going activities of concrete nouns relative to abstract nouns were limited to posterior sites: CPZ and PZ, $ps < .045$.

At lateral sites, there was the main effect of word condition, consistent with midline analysis, $F(2, 62) = 24.03, p < .001$, partial $\eta^2 = 0.44$. The interaction of word, hemisphere, and site was also significant, $F(18, 558) = 2.36, p = .015$, partial $\eta^2 = 0.07$. Simple effect analyses indicated that, whereas the differences between concrete and emotion nouns were widespread, $ps < .040$, the differences between abstract and emotion nouns were primarily evident at frontal and central sites, $ps < .030$.

In sum, in this epoch, the differences between abstract and emotion nouns became evident in fronto-central areas. Though present in a restricted region, the differences between concrete and abstract nouns became abated, whereas the differences between concrete and emotion nouns were still widely evident (Fig. 2).

4. Discussion

4.1. Salience of emotion concepts

This study examined the processing of emotion nouns (e.g., *sadness*) in comparison to abstract (e.g., *reason*) and concrete nouns (e.g., *window*) without emotional connotations. Behavioral data showed that people responded to emotion nouns more quickly and more accurately than to abstract and concrete nouns, suggesting more efficient processing of nouns that denote emotion concepts. Analysis of the N400 corroborated behavioral evidence for salience and distinctions of emotion concepts relative to both abstract and concrete concepts. The N400 of emotion nouns peaked significantly earlier and was significantly less pronounced than the N400 of abstract and concrete nouns. Furthermore, in terms of timing, the differences in N400 amplitude between emotion and concrete nouns emerged earlier and lasted longer than the differences between emotion and abstract nouns. In terms of topography, the differences between emotion and concrete nouns had a broad scalp distribution, whereas the differences between emotion and abstract nouns had a fronto-central distribution (Fig. 2).

The fronto-central distribution of amplitude differences between emotion and abstract nouns is consistent with past reports on the emotionality effect (see Citron, 2012 for a review). As discussed earlier, both ROI analysis based on current source density (e.g., Sass et al., 2010) and whole scalp analysis (e.g., Palazova et al., 2013) indicated less pronounced N400 for emotionally charged words relative to neutral words over the fronto-central region. As for temporal characteristics of the emotionality effect, past reports slightly varied due to different ways of segmenting continuous data for analysis purposes, which in turn were results of different task demands across studies, e.g., the emotion Stroop task, semantic judgment task, and the lexical decision task (Citron, 2012). Analogous to the present study, Kanske and Kotz (2007) employed the lexical decision task and reported emotionality effect in the 390–590 ms time window. Another study by Palazova et al. (2013), also using the lexical decision task, reported emotionality effect particularly evident in the 400–450 ms time window. These reports are comparable to current findings that the N400 differences between emotion and abstract nouns became evident in the 350–450 ms epoch. Therefore, the greater N400 magnitude of abstract nouns relative to emotion nouns seems to primarily reflect a difference in level of emotionality between the two word categories. As past studies utilized emotionally charged words (e.g., *birthday* and *victim*) instead of exclusively emotion nouns (e.g., *please* and *upset*), the current findings suggest that, in the healthy brain, reading a word that represents an emotion has a similar effect as does reading a word with a strong emotional connotation, both effectively inducing emotional arousal and facilitating semantic processing.

One may argue that the amplitude differences between emotion and abstract nouns could be due to imageability. That is, although the two word categories were matched for abstractness, they differ in imageability with emotion nouns being rated more imageable than abstract nouns. However, more imageable concepts tend to elicit a greater N400, which is opposite to the direction of amplitude differences between emotion and abstract nouns found in this study. See below for more discussion on the imageability effect.

Relative to the contrast between abstract and emotion nouns, the longer duration and broader distribution of the contrast between concrete and emotion nouns might reflect differences not only in emotionality but also in other semantic dimensions such as imageability. Specifically, the greater N400 of concrete nouns relative to emotion nouns became evident as early as in the 250–350 ms epoch when the magnitude differences of concrete and abstract nouns, which substantially differed in imageability level, were most prominent (Fig. 2). That is, in addition to the attenuating effect that emotion nouns produced on the N400 relative to abstract and concrete nouns, concrete nouns might have evoked imagery processes, hence producing an enhancing effect on the N400 relative to abstract and emotion nouns. Therefore, semantic differences in multiple dimensions, e.g., emotionality and imageability, may have had a cumulative effect, contributing to the longer duration and broader distribution of the N400 differences between concrete and emotion nouns. However, further research is certainly necessary to identify semantic features involved in different stages of word processing and to investigate the mechanism of the interplay among these features in neural representations of different conceptual categories.

4.2. “Imageability” of emotion concepts

As mentioned above, concrete nouns elicited a greater N400 than abstract nouns, consistent with the commonly reported

concreteness effect of N400 (e.g., Kounios & Holcomb, 1994). More importantly, the N400 differences were more prevalent in the right hemisphere, which has been attributed to activations of a unique set of neural generators in the right hemisphere during imagery processing (Kounios & Holcomb, 1994; Mayda et al., 2004; Nittano et al., 2002).

Whereas the greater N400 of concrete nouns relative to abstract nouns were evident and more prevalent in the right hemisphere, emotion nouns did not show such an effect on the N400 relative to abstract nouns in this epoch (250–350 ms). On the contrary, in the later epoch (350–450 ms), abstract nouns generated greater N400 relative to emotion nouns, mainly evident in fronto-central areas, which was attributable to the emotionality effect (e.g., Citron, 2012; Palazova et al., 2013). As discussed earlier, this may indicate that imageries of facial expressions and bodily movements are only peripheral features of emotion concepts, which do not need to be activated at this early stage of word processing, at least for the task utilized in the present study. Activation of imageries induced by emotion concepts might only manifest in controlled processes such as elaborate semantic evaluation captured by behavioral measures. The differences in imageability ratings across word categories (Table 2) may have reflected such late-stage processing differences. Alternatively, as reflected in the differences of imageability ratings, it might be the case that the difference in imageability between emotion and abstract nouns was simply insubstantial relative to that between concrete and abstract nouns. The ERP approach may not be sensitive enough to detect such a subtle difference. Another possible explanation may be that the imagery encoding involved in emotion concepts is not the same as that involved in the concrete object concepts. Apparently, more research is needed to evaluate the “imageability” of emotion nouns.

Taken together, the emotionality effect and the lack of detectable imageability effect of emotion nouns revealed in the present study corroborate and expand a previous study conducted in the same lab (Xu et al., 2017). The earlier study compared emotion nouns to abstract (e.g., *wisdom* and *failure*) and concrete nouns (e.g., *flower* and *coffin*) with emotional connotations. The results also demonstrated processing differences of emotion nouns relative to the other nouns. Also, the lack of imageability effect of emotion nouns was consistent between the two studies. Different from the present study, with emotionality ratings being held at the same level across three word categories, the N400 associated with emotion nouns did not peak significantly earlier than the other nouns. In addition, there did not appear to be a fronto-central distribution of N400 amplitude differences between emotion nouns and other nouns, showing a lack of emotionality effect when comparing nouns that denote emotions and nouns that are emotionally-charged. However, this could be a false equivalence. That is, emotion nouns might not be as salient as emotionally charged nouns, and they alone might not be capable of inducing emotional arousal or facilitating word processing. Instead, it might have been the emotional tenor of the entire stimuli set that had created a generalizing effect on participants’ arousal levels and hence their responses. The findings of the present study helped to rule out this possibility and provided evidence for the emotionality effect of emotion nouns relative to emotionless nouns.

4.3. Other ERP components potentially associated with emotionality

Some research has shown that emotionally charged stimuli tend to elicit the Early Posterior Negativity (EPN) and enhance the Late Positive Component (LPC). However, in the literature, there were mixed reports about the emotionality effect on both components (e.g., Kaltwasser et al., 2013; Kanske & Kotz, 2007; Kissler & Herbert, 2013). In the present study, the grand average ERPs seemed to suggest a negative going component in the 250–350 ms time window at posterior sites, including the parietal sites, which appeared to resemble the EPN. However, it was evident that neither this EPN-like component nor LPC was amplified by emotion nouns relative to abstract and concrete nouns. In line with past research (e.g., Kaltwasser et al., 2013; Kanske & Kotz, 2007), we conducted the following region of interest analyses to verify this observation.

For the EPN, a 3 (word) × 7 (site) repeated measures ANOVA including P7, P3, P4, P8, O1, Oz, and O2 was carried out in the 250–350 ms time window where a negative deflection was seen at posterior sites. For the LPC, a 3 (word) × 12 (site) repeated measures ANOVA including these sites: FC3/Z/4, C3/Z/4, CP3/Z/4, and P3/Z/4 in the 650–800 ms time window was performed. Results confirmed the lack of emotionality effect on these components (Table 5). In fact, the EPN analysis showed that concrete nouns elicited significantly greater negative going activities than did both abstract and emotion nouns (both $ps < .007$). In addition, these differences were more evident in the right hemisphere, which appeared attributable to the imageability effect. The LPC analysis showed that both abstract and concrete nouns appeared to be associated with more pronounced positivity relative to emotion nouns (both $ps < .040$). Fig. 2 includes topographical maps of magnitude differences between word categories within these time windows.

It has been argued that mixed findings about the EPN and the LPC might be due to different tasks or word samples across studies (e.g., Kaltwasser et al., 2013; Palazova et al., 2013). Similar to some of the studies that revealed an emotionality effect on the EPN and the LPC, the present study utilized the lexical decision task (e.g., Kanske & Kotz, 2007; Palazova et al., 2013). Therefore, the lack of EPN and enhanced LPC for emotion nouns was possibly due to representational and processing differences between emotion nouns (e.g., *distress* and *joy*) utilized in this study and emotionally charged words (e.g., *cancer* and *birthday*) utilized in past research. Specifically, the EPN signifies allocation of attentional resources (Potts & Tucker, 2001; Schacht & Sommer, 2009). Words that

Table 5
Mean amplitudes (SDs) in ROI analysis of EPN and LPC for abstract, concrete, and emotion nouns (uV).

	Abstract nouns	Concrete nouns	Emotion nouns
EPN	1.07 (.40)	.44 (.38)	1.09 (.42)
LPC	6.13 (.59)	6.00 (.63)	5.08 (.56)

represent emotional states or processes may not be as attention catching as words that denote emotionally significant experiences. The LPC is considered an index for elaborate processing of emotional stimuli (e.g., Schacht & Sommer, 2009). The lack of enhanced LPC may suggest that the LPC reflect elaborate processing of a concept that can induce an emotional arousal, but not the processing of a particular emotional state or process per se. That is, when a word with emotional connotation (e.g., *birthday*) is presented, the emotional tone of the word leads to more elaborate processing of semantic and contextual information associated with the emotion. In contrast, a word (e.g., *joy*) that denotes an emotion does not seem to produce such an effect, at least not to the same extent. Alternatively, Citron (2012) argued that a greater LPC associated with neutral stimuli may signify a greater processing demand. That is, the greater LPC elicited by abstract and concrete nouns relative to nouns that label emotion states and processes may suggest that these emotion-less nouns relative to emotion nouns require a greater level of processing effort not only at an earlier stage of word processing as indexed by the N400, but also at a later stage as indexed by the LPC. These results combined with the results of the analysis within the N400 time window therefore appear to highlight the distinctness of emotion concepts.

Lastly, as a note, emotionality in this study was characterized as intensity of an affect, be it positive or negative (Lang et al., 1997). In Lang et al.'s model, valence and intensity are not two separate dimensions. However, it should be acknowledged that the emotionality effect reported in this study would be considered as the arousal effect according to theories that consider arousal and valence two separate dimensions (e.g., Feldman Barrett & Russell, 1998). To study the effect of valence, a greater sample of stimuli including both positively and negatively valenced words are required. Although the present study sampled both positive and negative emotion nouns, there were not enough stimuli to achieve an adequate signal-to-noise ratio. Given the limited number of common emotion nouns in everyday languages, a specific design, e.g., stimuli repetition, would be necessary. We hope to look into the valence effect in future research and to help disentangle inconsistencies with regard to the effect of this factor. Take the LPC as an example, some researchers found no valence effect on the LPC (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Kaltwasser et al., 2013), while others reported mixed findings whereby the valence effect seemed to be moderated by word concreteness (Herbert et al., 2008; Kanske & Kotz, 2007; Kissler & Herbert, 2013).

Another improvement to make in future research would be to achieve better control over lexico-semantic factors. For example, orthographic neighborhood size has been shown to impact the N400 magnitude (e.g., Holcomb, Grainger, & O'Rourke, 2002). The present study utilized two-character Chinese words, and the impact of orthographic neighborhood size on the processing of this type of word stimuli has yet to be fully investigated. Furthermore, as a two-character word contains two meaningful characters that each has its own orthographic neighbors, the optimal definition of orthographic neighborhood size of two-character words and its impact on word processing remain to be determined (Huang et al., 2006; Li, Lin, Chou, Yang, & Wu, 2015). Future research conducted in Mandarin Chinese will need to further investigate the effects of different lexico-semantic factors such as orthographic neighborhood size and emotionality in order to achieve a better understanding about word processing in this language.

5. Conclusion

Findings of this study revealed the salience of emotion nouns relative to both abstract and concrete nouns. Whereas, unlike for concrete nouns, the imageability effect did not appear to manifest for emotion nouns at early stages of semantic processing, the emotionality effect of emotion nouns was prominent. ERP data within the N400 time window displayed accelerated and attenuated activations associated with emotion nouns, and behavioral data showed faster and more accurate responses to emotion nouns. All indicated more efficient processing for this category of words. Past research indicates that emotionally charged words (e.g., *enemy* and *success*) can facilitate semantic processing as emotional arousal cued by the words helps to quickly engage attentional resources and to expedite the activation process (e.g., Kissler et al., 2007). The findings from this study indicate that the brain responds in a similar way to words that are simply labels of different affects, which certainly relies on knowledge about the significance of different moods, emotions, and feelings and the ability to identify and communicate these affective experiences. Lack of knowledge and ability to name and discuss one's own and others' emotions has clinical implications. This study therefore not only adds to our knowledge about affect representations as a unique conceptual category, but also offers future clinical research a point of reference based on responses generated by a healthy sample.

Acknowledgement

This study was supported by the Natural Science Foundation of China (31871079).
The authors would like to thank Alex Titus for proofreading.

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