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Interplay of emotional valence and concreteness in word processing: An event-related potential study with verbs

Marina Palazova [a,*], Werner Sommer [a], Annekathrin Schacht [b]

[a] Department of Psychology, Humboldt-Universität zu Berlin, Germany
[b] CRC Text Structures, University of Goettingen, Germany

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ABSTRACT

The functional locus of emotional valence in word processing remains an open question. In event-related potentials, emotion has been found to elicit an early posterior negativity (EPN), which is assumed to reflect attention catching by the words' meaning. Previously, the EPN was modulated by word category with verbs exhibiting longer EPN latencies compared with other word categories. Here we examined whether concreteness, a semantic variable, influences emotion processing. Within a lexical decision task for verbs, emotional valence (positive, negative, and neutral) was orthogonally combined with concreteness (concrete and abstract). EPN onset was found already at 250 ms post-stimulus for concrete verbs, whereas it started 50 ms later for abstract verbs. Concreteness effects occurred after the start of main effects of emotion. Thus, the elicitation of the EPN seems to be based on semantic processes, with emotional valence being accessed before other semantic aspects such as concreteness of verbs.

1. Introduction

Recently, emotion processing in different stimulus domains such as faces (Schupp et al., 2007; Vuilleumier, 2005), pictures (Peyk, Schupp, Elbert, & Junghofer, 2008), gestures (Flaisch, Häcker, Renner, & Schupp, 2011), and words (e.g., Kissler, Herbert, Peyk, & Junghofer, 2007; Schacht & Sommer, 2009a; Schacht & Sommer, 2009b) has received much attention. Because of the presumed evolutionary significance of fast emotion perception in faces (Schupp et al., 2007) and natural scenes (Öhman, Flykt, & Esteves, 2001), their emotional content has been suggested to automatically catch attention and to be preferentially processed within a few 100 ms. In the verbal domain, evidence is more complex. Established models of word processing (for a review see Rastle, 2007) do not include a component of emotion. For example, the dual route cascaded model of word recognition (DRC) by Coltheart, Rastle, Perry, Langdon, and Ziegler (2001) postulates different interacting units such as visual features, letter units, and the orthographic lexicon, which are separable from the semantic system. Most models of reading assume that the different aspects of words are processed in cascade starting with visual features, followed by lexical access and semantic activation (Rastle, 2007). The functional locus of emotional valence within such a word processing cascade, however, remains to be resolved.

For event-related potentials (ERPs) at least two different emotion-related effects have been reported: the early posterior negativity (EPN; e.g., Junghofer, Bradley, Elbert, & Lang, 2001) and the late positive complex (LPC; e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). The EPN consists in an increased occipito-temporal negativity to emotional relative to neutral stimuli, which has been associated with enhanced attention to emotional stimuli. EPNs have been reported for adjectives (Herbert, Kissler, Junghofer, Peyk, & Rockstroh, 2006), nouns (Kissler et al., 2007), and verbs (Schacht & Sommer, 2009a; Schacht & Sommer, 2009b). The LPC consists of an increased centro-parietal positivity to emotional stimuli and has been related to more elaborate processing of emotional words. This idea is based on the finding of reduced LPC amplitudes in superficial tasks where elaborate semantic processing is not required (Schacht & Sommer, 2009b, see also Fischler & Bradley, 2006).

Importantly, during lexical decisions EPN and LPC effects to emotional words have been shown to start after the onset of lexicality effects – the ERP difference between correct words and pseudowords – and might thus be based on the activation of emotional *meaning* (Palazova, Mantwill, Sommer, & Schacht, 2011; Schacht & Sommer, 2009b).

Recent evidence suggests the emotional content to be one aspect of a word's *meaning* since both the EPN and the LPC were elicited only after lexical access (Palazova et al., 2011; Schacht & Sommer, 2009a; Schacht & Sommer, 2009b). However, the picture has been complicated by findings of very early emotion effects, starting as early as 50 ms after stimulus onset (e.g., P1, Bayer,

* Corresponding author. Address: Department of Psychology, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany. Fax: +49 30 2093 4888.
E-mail address: palazova@staff.hu-berlin.de (M. Palazova).

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Sommer, & Schacht, 2012; or C1, Rellecke, Palazova, Sommer, & Schacht, 2011), and of early interactions between emotional valence and lexical factors (Palazova et al., 2011; Scott, O'Donnell, Leuthold, & Sereno, 2009) in ERPs. These findings are difficult to reconcile with the assumption of time-consuming perceptual and lexico-semantic processes preceding these emotion effects; instead they may reflect different mechanisms such as conditioned associations with visual features of emotional words (Schacht, Adler, Chen, Guo, & Sommer, 2012). Importantly, these very early effects of emotion precede the EPN and LPC, and show distinct topographies, suggesting at least partly different underlying mechanisms and neural generators.

In addition, the EPN has been found at variable latencies from 200 ms (e.g., Kissler et al., 2007) to 400 ms after word onset (e.g., Schacht & Sommer, 2009a; Schacht & Sommer, 2009b). Interestingly, at least some variation in EPN latency seems to depend on word category (Palazova et al., 2011); hence the activation of emotional content may depend on non-emotional linguistic features of the words.

Given the presumable lexico-semantic locus of the EPN (Kissler et al., 2007; Kissler & Herbert, 2012; Palazova et al., 2011; Schacht & Sommer, 2009a; Schacht & Sommer, 2009b), it appears plausible that also concreteness, a semantic factor, might impact the processing of emotional words. Such a finding would provide direct evidence that emotional valence and other semantic aspects may functionally overlap in visual word processing. According to Sternberg (2001), Sternberg (2011), two independent sub-processes should be separately modifiable by different experimental factors. Hence, if concreteness effects in the ERP reflect semantic processes, they should summate linearly with any effects of emotion if the latter are non-semantic in origin. This is also in accord with the additive properties of electrical fields (Nunez, 1981). Alternatively, if emotion effects are semantic in nature, they should differ in amplitude or topography as a function of word concreteness; that is, the effects should interact.

Concreteness refers to whether the correspondence of a mental concept in reality can be perceived by the senses or not. Concrete words are processed faster and more accurately than abstract words (Paivio, 1971; Paivio, 1986; Schwanenflugel, Harnishfeger, & Stowe, 1988). Concreteness also affects ERPs (e.g. Holcomb, Kounios, Anderson, & West, 1999; Lee, & Federmeier, 2008; van Schie, Wijers, Mars, Benjamins, & Stowe, 2005). For example, in three different tasks, West and Holcomb (2000) found two distinct components with larger amplitudes for concrete compared to abstract words: an N400, consisting of a central negativity, most prominent in a semantic task, and a frontal N700, most pronounced in an imagery task. The authors interpreted their findings within the scope of the extended dual-code theory by Holcomb, Kounios, Anderson, and West (1999) and linked the N400 to contextual richness and the N700 to mental imagery. Evidence in support of the extended dual-code theory was also found in fMRI research (e.g., Binder, Westbury, McKiernan, Possing, & Medler, 2005; Sabsevitz, Medler, Seidenberg, & Binder, 2005). A meta-analysis by Wang, Conder, Blitzer, and Shinkareva (2010) revealed a greater involvement of verbal processing regions for abstract words and of perceptual regions for concrete words, which may reflect visual imagery (but see also Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011 for a critical discussion). Evidence that the ERP effects are not restricted to nouns was provided by Lee and Federmeier (2008). In a semantic judgement task, the authors showed that unambiguous but not ambiguous verbs elicit both an N400 and late frontal negativity.

The first study of interactions between emotion and concreteness in words was reported by Kanske and Kotz (2007). They presented concrete and abstract nouns of positive, negative, and neutral valence in the visual hemifields. In a lexical decisions task, emotion and concreteness independently affected the ERPs: There were early (P2) and late (N400, LPC) emotion effects and late concreteness effects (N400, N700, referred to by the authors as LPC). In a second – go/no-go – task, emotion and concreteness interacted in the LPC with larger amplitudes to negative concrete words as compared with concrete neutral and concrete positive words. Based on the extended dual-coding model (Holcomb et al., 1999) of concreteness, the authors interpreted this result as a consequence of mental imagery. These findings indicate *early* emotion effects being unaffected by other aspects of word meaning and a common processing stage of semantics and emotion at a late processing stage.

In the present study, we aimed to replicate the findings of Kanske and Kotz (2007) of an interaction between emotional valence and concreteness with a less difficult central rather than lateralized stimulus presentation. It seemed to be important to conceptually replicate this study because the independence of the emotion and concreteness in a standard lexical decision task reported by these authors is at variance with the idea that emotional valence in visual word processing is anchored in word semantics. As a further difference to the study of Kanske and Kotz (2007), we used verbs rather than nouns to assess whether the results would extent to this stimulus class. In general, we aimed to functionally localize emotion and concreteness effects during visual word processing and to specify the timing and nature of any interactions. In line with previous studies, we expected larger amplitudes of emotion-related ERP components (EPN and LPC) to emotional as compared to neutral words. In accordance with the findings by Lee and Federmeier (2008), we expected concreteness to elicit an N400 and a N700 with higher amplitudes to concrete than to abstract verbs. Using nouns, Kanske and Kotz (2007) found effects of emotion to precede those of concreteness. However, such clear assumptions for the timeline of emotion and concreteness effects during the processing of verbs cannot be made since the EPN to verbs appears later than to nouns and might thus coincide with ERP effects of concreteness (see West & Holcomb, 2000). In case of such temporal coincidence or overlap, respectively, and as pointed out above, it was of primary interest whether emotion and concreteness elicit additive effects – reflecting independent processing of both factors – or an interaction, indicating a common source of both factors within the semantic processing system.

2. Method

2.1. Participants

Forty-two university students (21 women), ranging in age from 18 to 34 years ($M = 24.1$, $SD = 3.7$), participated in the experiment in return for allowance or course credits. All of them were German native speakers, had normal or corrected-to-normal vision, and no history of neurological or psychiatric disorders. Except for one left-handed participant, all were right-handed according to a questionnaire (Oldfield, 1971).

2.2. Stimuli

The complete set of stimuli consisted of 480 words and 480 pseudowords. Among those words were 108 verbs, representing a factorial manipulation of emotional valence and concreteness (see Table 1 for descriptive statistics). The other words were not controlled for the factors in question and will be analyzed in a non-orthogonal design for a future publication. Ratings on emotional valence were obtained from our own database and from the Berlin Affective Word List (Vo, Jacobs, & Conrad, 2006); the verbs were unambiguously rated as positive ($z > 1.5$, z-transformed

Table 1
Descriptive statistics (mean and standard deviations (SDs)) for manipulated and controlled variables, and rating results for the set of verbs.

	Positive		Neutral		Negative	
	Abstract	Concrete	Abstract	Concrete	Abstract	Concrete
Concreteness	−0.1 (0.2)	1.6 (0.2)	−0.2 (0.2)	1.4 (0.3)	0 (0.1)	1.4 (0.3)
Valence	1.7 (0.2)	1.8 (0.3)	0 (0.2)	0 (0.2)	−1.8 (0.2)	−1.9 (0.3)
Arousal	2.9 (.2)	2.8 (0.4)	2.7 (0.2)	2.7 (0.3)	3.2 (0.2)	3.4 (0.3)
Frequency	86 (123)	42 (37)	62 (47)	71 (82)	31 (47)	49 (55)
Letters	7.8 (1.3)	7.6 (1.6)	7.4 (1.2)	7.4 (1.7)	8.2 (1.4)	7.8 (1.3)
Syllables	2.6 (0.4)	2.4 (0.5)	2.6 (0.5)	2.4 (0.5)	2.5 (0.6)	2.4 (0.5)

values from a seven-point scale), neutral ($-0.5 < z < 0.5$), or negative ($z < -1.5$). Concreteness ratings were obtained in a pre-experimental rating study with a seven-point scale (−3 very abstract to 3 very concrete) with a sample of 62 participants not overlapping with the experiment proper. Concreteness ratings of the stimulus set significantly differed between experimental conditions, (abstract verbs: $M = -.15$; concrete verbs: $M = 1.5$; $F(1, 102) = 1114$, $p < .001$). Stimuli like "to dance" (tanzen) or "to disappoint" (enttäuschen) constitute examples for concrete positive and abstract negative conditions, respectively. Words were controlled for length (number of letters and syllables) and word frequency according to CELEX (Baayen, Piepenbrock, & van Rijn, 1995). Arousal ratings were acquired in a post-experimental rating using a computerized version (5-point scale) of the Self Assessment Manikin (SAM; Lang & Cuthbert, 1984) with a new sample of 35 participants. Arousal ratings significantly increased from neutral ($M = 2.6$) over positive ($M = 2.9$) to negative words ($M = 3.3$), all $ts > 2.9$; $ps < .05$.

Pronounceable and orthographically correct pseudowords were constructed from verbs – others than those used as correct words – by substituting one letter at a random position within the word, except for the initial and last position, and prefixes. The verbs from which pseudowords were derived were matched to the correct verbs with respect to length. Pseudoword generation was not based on the target words used in the experiment. We did so mainly because basing pseudowords on the proper words in the study requires a complex and material-consuming balancing procedure to avoid feature based matching strategies, priming, and recognition effects between words and pseudowords. In addition, it seemed to be permissible because our main aim was a comparison between concrete and abstract target words of different valence rather than between words and pseudowords.

2.3. Procedure

Participants attended the experiment in a dimly lit, sound-attenuated chamber facing a computer monitor at a distance of approximately 90 cm. All words were presented in black letters (Arial font) on a grey background. Letters were 8 mm high and the length of the strings varied between 35 and 75 mm with a maximal visual angle of 4.5°. A trial started with a fixation cross, displayed for 500 ms, followed by a letter string. After a response, the letter string was replaced by a blank screen; 1500 ms after word onset, the next trial started even if no response has been given by then. Thus, each trial lasted for 2 s. All words and pseudowords were presented in random order. After a complete run, the whole set of stimuli was repeated once, yielding a total of 20 blocks of 60 trials each. Between blocks there was a short, self-terminated break.

Stimulus presentation and response collection were controlled by Presentation software (Neurobehavioral Systems©). Participants were instructed to indicate as fast and accurately as possible whether or not the presented letter string was a correct German word by pressing one of two buttons with the index or middle finger of their dominant hand. The stimulus–response mapping was counterbalanced. A practice block consisting of 12 trials was given prior to the first block.

2.4. EEG recording and preprocessing

The electroencephalogram (EEG) was recorded from Ag/AgCl electrodes at 57 sites according to the extended 10–20 system (Pivik et al., 1993). Four external electrodes below and lateral to the eyes were used to record the vertical and horizontal electrooculogramms, and two more were placed at left and right mastoids. All other electrodes were mounted within an electrode cap. AFz served as ground and left mastoid as initial reference. Electrode impedance was kept below 5 kΩ, using ECI electrode gel (Expressive Constructs Inc., Worcester, MA). Data were recorded with BrainAmps© amplifiers at a band pass of 0.032–70 Hz; sampling rate was 250 Hz. Offline, the continuous EEG was segmented into epochs of 1200 ms, starting 200 ms prior to stimulus presentation, and transformed to average reference. Blinks were corrected using Surrogate Multiple Source Eye Correction (MSEC; Ille, Berg, & Scherg, 2002) as implemented in BESA (Brain electric source analysis, MEGIS Software GmbH). Only epochs with correct responses were analyzed. Epochs were discarded as artifact-contaminated when any amplitude exceeded −100 or +100 μV or when any voltage step between adjacent sampling points exceeded 50 μV in any channel. The percentage of remaining trials was above 85% in all conditions. Average ERPs were calculated for each participant, electrode, and experimental condition, referred to a 200-ms prestimulus baseline.

2.5. Data analysis

2.5.1. Behavioral data

Reaction times (RTs) and error rates were analyzed with analyses of variance (ANOVA) with repeated measures on factors emotional valence (positive, negative, neutral) and word concreteness (abstract, concrete).

2.5.2. Electrophysiological data

ERP mean amplitudes were calculated for consecutive time windows of 50 ms duration. Overall ANOVAs were conducted, including the factors emotional valence, concreteness, and electrode site (57 levels). For pair-wise comparisons between emotion conditions, a directed hypothesis, that ERP amplitudes are larger to emotional compared to neutral words, was tested one-sided. Please, note that the average reference sets the mean amplitude across all electrodes to zero within a given condition. Therefore, in ANOVAs including all electrodes only interactions with electrode site are meaningful, and would be considered as main effects of the respective factors concreteness and emotion. Huynh–Feldt correction was applied to adjust degrees of freedom for violations of the sphericity assumption. Please note that all ANOVAs will be reported with uncorrected degrees of freedom but corrected p-values. For pair-wise comparisons, alpha levels were Bonferroni-corrected.

To assess whether effects obtained in the ANOVAs are distinguishable with regard to their scalp distributions (topographies), overall amplitude differences were eliminated by normalization with the vector scaling method (profile analyses; McCarthy & Wood, 1985). Vector scaling adjusts for effects of amplitude by dividing the voltage at each electrode by the root mean square of activity across all electrodes for the same time window and condition. Therefore, one can infer that any difference across electrodes between two conditions – reflected in significant interactions between electrode and an experimental factor – is due to the spatial distribution of ERPs rather than amplitude. After adjusting for amplitude, repeated measures ANOVAs were performed, including all electrodes as within-subject factor levels.

3. Results

3.1. Performance

Table 2 presents mean RTs and error rates as a function of emotion and concreteness. Responses were faster to concrete than to abstract words, $F(1,41) = 26.4$, $p < .001$; a main effect of emotion, $F(2,82) = 11.1$, $p < .001$, resulted from decreased RTs to neutral as compared to both positive and negative words, $Fs(1,41) \geqslant 11.6$, $ps < .001$. ANOVA further revealed a significant Concreteness by Emotion interaction, $F(2,82) = 6.1$, $p < .05$, due to increased RTs to abstract positive and negative as compared to abstract neutral words, $Fs(1,41) \geqslant 20.1$, $ps < .001$; in concrete words no effect of emotion was found.

Responses to concrete words were more accurate than to abstract words, $F(1,41) = 47.8$, $p < .001$. A main effect of emotion, $F(2,82) = 26.5$, $p < .001$, was due to increased error rates for positive as compared to both neutral and negative words, $Fs(1,41) \geqslant 33.9$, $ps < .001$. This decrease in accuracy was especially pronounced for positive abstract words ($M = 8.7\%$) in comparison to all other conditions ($Ms = 2.8–4.3\%$), resulting in a significant interaction between emotion and concreteness, $F(2,82) = 8.7$, $p < .001$. Since RTs were also increased for positive abstract words, this effect cannot be accounted for by a speed accuracy trade-off.

3.2. Event-related brain potentials

Results of ANOVA on ERP amplitudes are summarized in Table 3. Main effects of Emotion occurred in the intervals 250–550, 600–650, and 700–800 ms post-stimulus, $Fs(112,4592) \geqslant 2.4$, $ps < .05$, $\varepsilon = .07$. Pairwise comparisons revealed that the main emotion effect consisted of significant differences between both positive and negative verbs and neutral verbs in the intervals 250–550 ms, $Fs(112, 4592) \geqslant 2.9$, $ps < .05$, $\varepsilon = .07$, and 700–800 ms, $Fs(112,4592) \geqslant 2.8$, $ps < .05$, $\varepsilon = .07$. In the 600–650 ms interval only ERPs to negative verbs differed significantly from ERPs to neutral verbs, $F(112,4592) = 4.7$, $p < .05$, $\varepsilon = .09$.

Main effects of Concreteness started at about 500 ms post-stimulus and lasted for 300 ms, $Fs(56, 2296) \geqslant 2.5$, $ps < .05$, $\varepsilon = .05$. Both latency and topography of this effect (cf. Fig. 1) resembled the previously reported late effects of concreteness, referred to as N700.

Importantly, Emotion and Concreteness interacted in the time windows 250–300 ms, $F(56, 2296) = 4.2$, $p < .001$, $\varepsilon = .06$ and 400–450 ms, $F(56,2296) = 2.2$, $p < .05$, $\varepsilon = .07$, overlapping with the main effect of emotion. Therefore, emotion effects will be reported separately for concrete and abstract verbs for these intervals.

In the 250–300 ms interval, only concrete verbs elicited emotion effects for both positive and negative words compared with neutral words, $Fs(56, 2296) \geqslant 4.8$, $ps < .01$, $\varepsilon = .07$. For abstract verbs, emotion effects started in the subsequent 300–350-ms interval.

In the 400–450-ms interval pairwise comparisons showed significant differences between both positive and negative as compared with neutral verbs in the concrete as well as in the abstract condition, $Fs(56,2296) \geqslant 2.7$, $ps < .05$, $\varepsilon = .08$. Therefore, the interaction of concreteness and emotion might be caused by both amplitude and topography differences.

As can be seen in Figs. 2 and 3, all emotion effects consisted in posterior negativities. We conducted an additional region of interest (ROI) analysis including the electrodes PO7, PO8, PO9, PO10, O1, and O2, at which the EPN was most prominent. The ROI analysis was performed for concrete verbs in the intervals 250–300 ms and 400–450 ms, and for abstract verbs in the interval 400–450 ms. Almost all comparisons showed significant effects of Emotion, $Fs(1, 41) \geqslant 7.8$, $ps < .05$, $\varepsilon = 1$, except for the positive–neutral comparison within abstract words at 400–450 ms.

To further examine topographic differences of emotion effects, topographical analyses were carried out for the difference ERPs of positive and neutral verbs within the concrete condition between early and late intervals (250–300 vs. 400–450 ms) and within the late interval (400–450 ms) between concrete and abstract conditions in analogy to ROI analysis (see Fig. 2). All three topographies significantly differed from each other, $Fs(56, 2296) \geqslant 2.5$, $ps < .05$, $\varepsilon = .09$. These results indicate that the posterior negativities found here differ dynamically over time and between conditions.

ERPs to pseudowords were compared to those of abstract and of concrete words, separately, within consecutive windows of 50 ms. Lexicalitiy effects were observed starting at 200 ms after stimulus onset in abstract words, $Fs(56,2296) \geqslant 2.8$, $ps < .05$, $\varepsilon = .06$; in concrete words, from 250 ms post-stimulus onwards, $Fs(56,2296) \geqslant 2.8$, $ps < .05$, $\varepsilon = .06$.

4. Discussion

In order to examine how concreteness influences processing of emotional valence of single verbs these factors were orthogonally combined in a lexical decision task while performance and ERP data were acquired. The manipulated factors influenced both performance and ERPs. As a main result, an early ERP interaction between Concreteness and Emotion was present at 250–300 ms post-stimulus, due to an earlier occurrence of emotion effects in concrete than in abstract words.

According to performance data, concrete verbs were processed faster than abstract ones, which replicates the concreteness effects found in previous studies (e.g., Kanske & Kotz, 2007; Schwanenflugel et al., 1988). In concrete verbs no emotion effects were present, in abstract verbs, however, reaction times for neutral verbs were shorter than for emotional verbs. This result differs from the findings of Kanske and Kotz (2007) of a classical emotion effect for lexical decisions to emotional nouns presented in the visual hemifields. In a recent study, Rodriguez-Ferreiro, Gennari, Davies, and Cuetos (2011) used abstract verbs and abstract emotion verbs

Table 2
Mean reaction times (RTs) in milliseconds with standard deviations (SDs), and mean error rates with standard deviations (SDs) for emotion and concreteness conditions.

	Mean RTs (SD)		Mean error rates in % (SD)	
	Abstract	Concrete	Abstract	Concrete
Positive	622 (82)	597 (76)	8.7 (4.9)	4.2 (3.8)
Negative	621 (86)	605 (80)	4.3 (3.9)	2.9 (3.7)
Neutral	597 (77)	596 (73)	3.1 (3.8)	2.8 (3.8)
	613 (79)	599 (74)	5.4 (3.2)	3.3 (2.7)

Table 3
Statistical analysis (*F*-value, *p*-value) of event-related potentials in 18 consecutive windows of 50 ms after verb stimulus onset.

Window in ms	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	800–850	850–900
Electrode *Emotion				3.74 (.000)	3.83 (.000)	3.90 (.000)	7.32 (.000)	4.87 (.000)	2.93 (.002)		2.41 (.01)		3.26 (.001)	3.22 (.002)		
Electrode *Concreteness									5.54 (.000)	11.60 (.000)	8.57 (.000)	3.46 (.007)	3.25 (.007)	2.50 (.034)		
Electrode *Emotion *Concreteness				4.19 (.000)			2.20 (.02)									

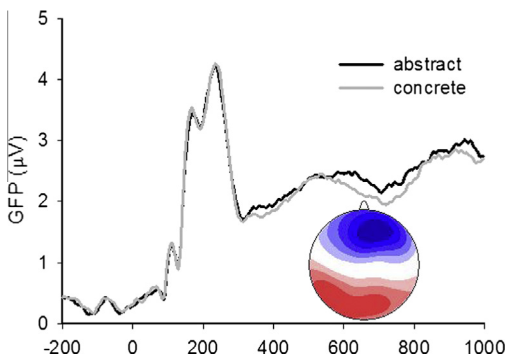

Fig. 1. Concreteness effects. Global field power (GFP) of event-related potentials (ERPs) to correct concrete and abstract verbs and scalp topography in the interval of significant differences between ERPs to concrete and abstract verbs.

in an LDT and found no emotion effect in RTs. From their fMRI data the authors concluded that abstract verbs including emotional verbs might impose greater demands on semantic retrieval and/or property integration. This might be also the case for our emotional abstract verbs, resulting in longer reaction times.

Behavioral data alone would not reveal the timing of functional interaction between factors, whereas interactions in ERPs allow for a specification of a common processing stage. Both emotion and concreteness influenced the ERPs between 250 and 800 ms post-stimulus, and – most importantly – interacted in the time windows of 250–300 ms and 400–450 ms.

4.1. Early emotion effects depend on concreteness

The main aim of the present study was to examine whether emotion processing in verbs depends on their concreteness. The early interaction of both factors in ERP amplitudes indicates that this is indeed the case, and, in particular, that the timing of emotion effects differs between concrete and abstract verbs. Pair-wise comparisons of emotion conditions within the concrete and the abstract verbs showed that the EPN in the concrete condition started already at 250 ms post-stimulus for both positive and negative verbs compared to neutral ones. Pairwise comparisons within the abstract condition revealed no earlier EPN than 300 ms post-stimulus, which corresponds to the timing of previous findings (Palazova et al., 2011; Schacht & Sommer, 2009a; Schacht & Sommer, 2009b). The timing difference in the EPN latency indicates therefore that word concreteness is an important factor for the processing of valence.

Word concreteness effects are consensually assumed to be based on activation of the word's semantics. Access to meaning of abstract concepts takes more time than of concrete ones as replicated in the present results. The emotion-related EPN exhibited a similar pattern of results, being observed earlier in concrete than in abstract verbs. Lexicality effects, the difference in ERP between words and pseudowords, are assumed to reflect lexical processing. Importantly, an analysis of lexicality effects showed an opposite onset pattern between concreteness conditions with earlier lexical activation in abstract compared to concrete words. Together, these results indicate that the EPN onset is independent of lexical processing, but depends on semantic activation. Given the interaction between concreteness and emotional valence in reaction times and in a later interval in ERPs, we conclude that both factors do not affect the measures separately and, therefore, activation of words' concreteness and valence aspects are most likely to be functionally dependent. The present findings are in line with the assumption of a lexico-semantic locus of emotion effects (Kissler et al., 2007) and with the assumption that the EPN is based on the access to word meaning (Schacht & Sommer, 2009b).

Interestingly, EPN topographies as revealed by ROI and scalp distribution analysis in different time windows and conditions showed that the EPN develops dynamically over time: First, EPN components occurred with different latencies between conditions, and second, they re-ocurred in later time windows with at least partly different topographies. Future research should examine whether such topographic differences are the outcome from separable brain processes.

With a similar LDT as used here – but with hemifield presentation of nouns –, Kanske and Kotz (2007, Exp. 1)found no interaction of emotion and concreteness for early emotion effects in ERPs. Between 210 and 300 ms they found a P2 (positivity across frontal and centro-parietal areas) modulation by emotion, which was not influenced by concreteness. The contrast to our findings may result from the different word categories used, but also from the hemifield versus central stimulation. A second major difference to the results of Kanske and Kotz is the late interaction between emotion and concreteness in their data, which was not replicated here. In a time window from 590 to 750 ms Kanske and Kotz found emotion effects only for concrete but not for abstract words. In similar time windows (600–650 ms and 700–800 ms) we also found main effects of emotion but without an interaction with concreteness. Overlapping main effects of concreteness and emotion may indicate that imagery processing of concrete verbs is taking place at the same time, but is unaffected by emotional valence.

Although an EPN was observed in concrete verbs in the present experiment, there were no emotion effects in reaction times. This is in contrast with expected performance facilitation due to the enhanced allocation of sensory resources to emotional words as reflected in the EPN. However, reaction time is the result of the interplay of several processing stages, thus an enhanced processing on an early stage might go lost on later stages as response selection or motor activation. Moreover, the lexical decision task does not depend on the processing of emotional content of verbs. This explanation is in line with the absence of an emotion-related LPC in either concrete or abstract verbs. The LPC is interpreted to reflect elaborate processing of the emotional stimuli (Schacht & Sommer, 2009b). The absence of LPC effects might indicate that an elaborate stimulus analysis is not a necessary consequence of initial allocation of attention to valence aspects (cf. Kissler et al., 2007 in nouns; Schacht & Sommer, 2009b in verbs) and, moreover, the LPC might be needed to elicit facilitated performance of emotional stimuli.

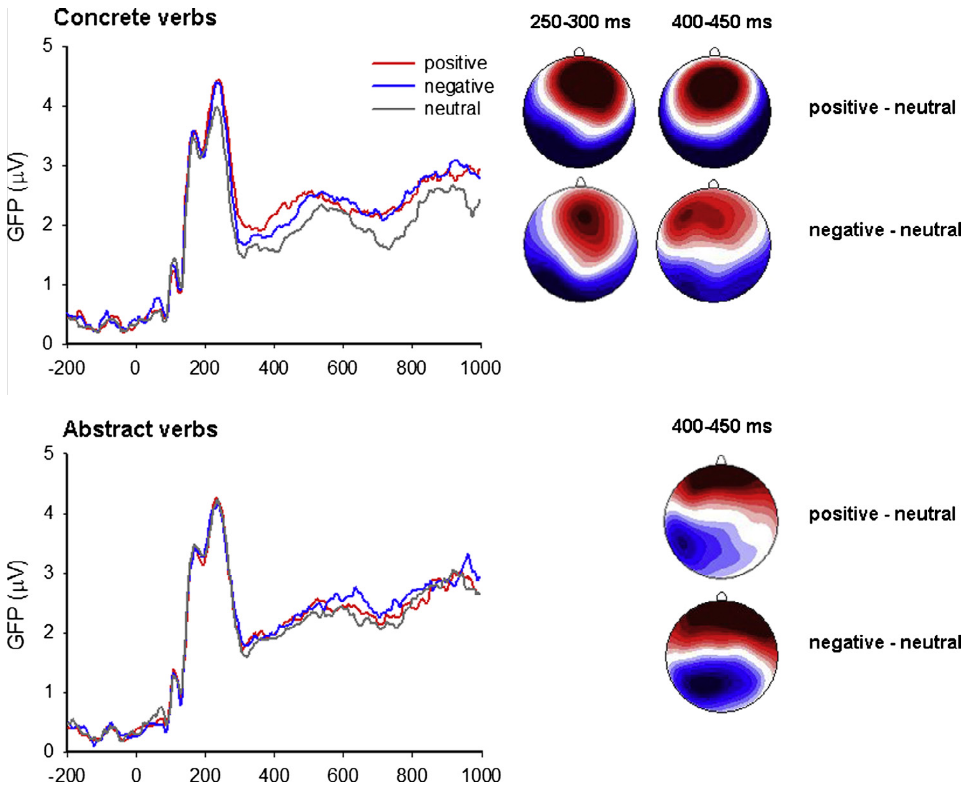

Fig. 2. Effects of emotional valence on event-related potentials for the concrete and for the abstract condition reported as global field power contrasted for emotionally positive, negative and neutral verbs. Topographies are shown separately for positive–neutral and negative–neutral comparisons within the windows of emotion and concreteness interaction.

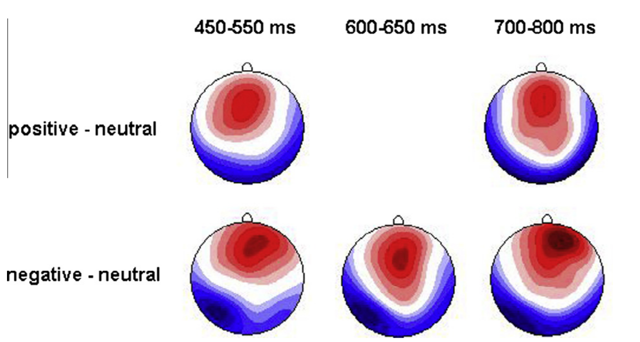

Fig. 3. Topographies of late emotion effects shown separately for positive–neutral and negative–neutral comparisons within the windows of main emotion effects.

Also, very early emotion effects (such as N1, P1, or C1 modulations) were not found in the present experiment. In general, such effects are inconsistent across studies (Rellecke et al., 2011; Scott, O'Donnell, Leuthold, & Sereno, 2009) and seem to depend on the task and material specificities. The present data do not deliver any evidence for emotional valence activation due to associative conditioning with visual features (Schacht et al., 2012). To conclude, the present findings of emotion and concreteness interactions in the EPN support the idea that emotional valence processing underlying the EPN takes place during or in parallel with a lexico-semantic stage.

4.2. Concreteness effects

A replication of a concreteness effect in ERPs was observed for the N700 (Lee & Federmeier, 2008; West & Holcomb, 2000) with concrete verbs eliciting a larger frontal negativity. However, an increased N400 to concrete relative to abstract words as shown by Holcomb et al. (1999), Kounios and Holcomb (1994), and Kanske and Kotz (2007) was not found in the present experiment. This discrepancy might be caused by many factors: task-specifics (Huang, Lee, & Federmeier, 2010; West & Holcomb, 2000), stimulus repetition or stimulus order (Kounios & Holcomb, 1994; Tolentino & Tokowicz, 2009, respectively), word category in general (Federmeier, Segal, Lombrozo, & Kutas, 2000; Lee & Federmeier, 2006), or the applied language (compared to Chinese: Zhang, Guo, Ding, & Wang, 2006, but see also Tsai et al., 2009; also in German, Kellenbach, Wijers, Hovius, Mulder, & Mulder, 2002). Despite the missing N400, concreteness impacted ERPs in the present study between 500 ms and 800 ms with a frontal negativity, which largely overlapped with emotion effects but was not modulated by them. According to its topography the concreteness effect found here replicated the previously reported N700 (Lee & Federmeier, 2008; West & Holcomb, 2000) and may reflect imagery of concrete verbs as assumed by the dual coding model (Paivio, 1971).

Most importantly, the latency of concreteness effects was longer than the latency of main effects of emotion. This result pattern replicates the findings of Kanske and Kotz (2007) who showed a shorter latency of emotion effects than of concreteness effects in an LDT and extends them for the word category of verbs. It can be assumed that both emotion and concreteness effects are part of the words' semantic processing, but, most importantly, with emotion drawing attention earlier than concreteness and thus being processed preferentially than concreteness. Emotional valence might be one of the first semantic aspects accessed in the stream of visual word processing. In favor of such an interpretation would be the general timing of early emotion effects in word processing starting from 200 ms post-stimulus onset (please see Kissler, Assadollahi, & Herbert, 2006, for a discussion), the fact that

Table A1
Stimulus material and translation in English.

Verbs											
Concrete						Abstract					
Positive		Negative		Neutral		Positive		Negative		Neutral	
Aufatmen	To respire	Berauben	To bereave	Werfen	To throw	Guttun	To do so. good	Heucheln	To pretend	Neigen	To decline
Feiern	To party	Vernichten	To demolish	Regnen	To rain	Aufleben	To revive	Betrügen	To cheat	Treiben	To drift
Begrüßen	To greet	Entführen	To abduct	Bedienen	To handle	Erstarken	To strengthen	Versagen	To fail	Ahnen	To forebode
Reisen	To travel	Drohen	To threat	Fernsehen	To watch tv	Hoffen	To hope	Scheiden	To part	Erteilen	To accord
Zujubeln	To acclaim	Erkranken	To fall ill	Zerlegen	To dismantle	Gelingen	To succeed	Schulden	To owe	Bedürfen	To need
Zublinzeln	To wink	Begraben	To bury	Drücken	To push	Mögen	To like	Verraten	To betray	Vermuten	To suppose
Duften	To scent	Zertrümmern	To break down	Heben	To lift	Anhimmeln	To idolize	Hassen	To hate	Wundern	To wonder
Tanzen	To dance	Betteln	To beg	Unterrichten	To teach	Umsorgen	To shepherd	Plagen	To trouble	Belegen	To prove
Singen	To sing	Stehlen	To steal	Greifen	To catch	Vorstellen	To imagine	Trauern	To grieve	Kriegen	To get
Berühren	To Touch	Heulen	To howl	Aufräumen	To clean up	Fühlen	To feel	Verfeinden	To make an enemy of so	Einsetzen	To apply
Lächeln	To smile	Sterben	To die	Rufen	To call	Meistern	To master	Versauen	To bugger	Ermitteln	To detect
Streicheln	To stroke	Zerstören	To destroy	Hinsetzen	To sit down	Gefallen	To like	Enttäuschen	To disappoint	Ersetzen	To replace
Lachen	To laugh	Brennen	To burn	Wandern	To hike	Wünschen	To wish	Hintergehen	To deceive	Weisen	To show
Umarmen	To embrace	Zittern	To shiver	Stapeln	To pile	Begehren	To adore	Wuchern	To proliferate	Bieten	To afford
Sonnen	To sun	Foltern	To Torture	Einfetten	To grease	Empfinden	To sense	Herrschen	To reign	Anlegen	To establish
Frühstücken	To breakfast	Schlagen	To bang	Tropfen	To drip	Anfreunden	To make friends	Schinden	To maltreat	Erheben	To charge
Massieren	To massage	Stinken	To stink	Sitzen	To sit	Betören	To infatuate	Gefährden	To endanger	Freikaufen	To ransom
Schlafen	To sleep	Ertrinken	To drown	Rennen	To run	Befreien	To free	Entlassen	To dismiss	Auslösen	To elicit

emotion effects start simultaneously or shortly after lexicality effects that are supposed to indicate lexical processing (Palazova et al., 2011), and that other semantic aspects such as concreteness elicit later effects in ERPs. Nevertheless, such a conclusion should be examined for other semantic aspects or features in future research.

In conclusion, the present findings support the assumption that emotional valence as reflected in the EPN is anchored in word meaning. Interestingly, in concrete words emotional meaning appears to be accessed very early on – even prior to the availability of sensory aspects of the verb – in line with the importance assigned to these meaning aspects.

Appendix A.

See Table A1.

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