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Emotions in word and face processing: Early and late cortical responses

Annekathrin Schacht *, Werner Sommer

Department of Psychology, Humboldt-University at Berlin, Rudower Chaussee 18, D-12489 Berlin, Germany

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ABSTRACT

Recent research suggests that emotion effects in word processing resemble those in other stimulus domains such as pictures or faces. The present study aims to provide more direct evidence for this notion by comparing emotion effects in word and face processing in a within-subject design. Event-related brain potentials (ERPs) were recorded as participants made decisions on the lexicality of emotionally positive, negative, and neutral German verbs or pseudowords, and on the integrity of intact happy, angry, and neutral faces or slightly distorted faces. Relative to neutral and negative stimuli both positive verbs and happy faces elicited posterior ERP negativities that were indistinguishable in scalp distribution and resembled the early posterior negativities reported by others. Importantly, these ERP modulations appeared at very different latencies. Therefore, it appears that similar brain systems reflect the decoding of both biological and symbolic emotional signals of positive valence, differing mainly in the speed of meaning access, which is more direct and faster for facial expressions than for words.

1. Introduction

Many texts in newspapers, magazines, and books elicit emotions and are appreciated for the pleasure or excitement given to the reader. Although much is known about the reading process itself (e.g., Kutas, Van Petten, & Kluender, 2006; Rayner, 1998), only little information is available about the impact of emotional content on the reading process. Thus, one would like to know, when in time or, more precisely, at which stage of word or sentence processing emotional valence or arousal exerts its impact on the reader's mind. Until now, evidence for emotion effects in word processing is scant and mostly heterogeneous (for a review see Kissler, Assadollahi, & Herbert, 2006). In contrast to affective pictures and emotional facial expressions, the emotional significance of written words is ontogenetically learned and symbolic. Therefore, extracting emotional information from script may appear as qualitatively different from processing of emotional information with more direct biological relevance such as pictures, voices, or faces. Nevertheless, it has recently been suggested that emotional processes elicited by words, pictures, or faces may be similar (e.g., Kissler, Herbert, Peyk, & Junghofer, 2007; Sprengelmeyer & Jentzsch, 2007). To test this assumption was the primary aim of the present study. Using the high temporal resolution of event-related brain potentials (ERPs), we assessed the presence and time course of emotion effects during word processing and compared their temporal and spatial characteristics to those elicited by emotional expressions of faces.

Two emotion-related components, first shown for affective pictures and distinguished by their time course as well as their scalp distribution, have been suggested to reflect different stages of emotion processing. The early posterior negativity (EPN; e.g., Junghöfer, Bradley, Elbert, & Lang, 2001) is an enhanced negativity at temporo-occipital electrode sites around 200 and 320 ms and is suggested to result from reflex-like visual attention to emotional stimuli, which facilitates sensory encoding processes. This causes more elaborative processing of emotional stimuli, presumably giving rise to the second emotion effect, augmented amplitudes of the late positive complex (LPC; e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). The LPC typically develops in the time range of the P300 component (around 300 ms) and lasts for several hundred milliseconds.

Previous studies of emotional word processing have consistently reported that the amplitude of the LPC in the ERP with latencies around 500 ms is modulated by emotional content. This modulation mostly consisted in enhanced LPC amplitudes for both positive and negative compared to neutral words (e.g., Fischler & Bradley, 2006; Naumann, Bartussek, Diedrich, & Laufer, 1992; Naumann, Maier, Diedrich, Becker, & Bartussek, 1997).

Unfortunately, several studies that reported emotional ERP effects preceding the LPC had not controlled lexical variables like word frequency (e.g., Begleiter & Platz, 1969; Chapman, McCrary, Chapman, & Bragdon, 1978; Kostandov & Arzumanov, 1977) or had repeatedly presented a small number of words (e.g., Bernat, Bunce, & Shevrin, 2001; Ortigue et al., 2004; Skrandies, 1998; Skrandies & Chiu, 2003). Therefore, it remains unclear to what extent these early effects relate to variables other than emotion. Only recently, studies with well-controlled stimulus material have pro-

* Corresponding author. Fax: +49 30 2093 4888.
E-mail address: schachta@hu-berlin.de (A. Schacht).

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vided evidence for EPN effects of emotional content. In a covert emotional judgment task Herbert, Kissler, Junghofer, Peyk, and Rockstroh (2006) showed enhanced ERP amplitudes to emotionally positive and negative as compared to neutral adjectives at centro-parietal electrodes, starting 180 ms after stimulus onset. In line with these findings, Inaba, Nomura, and Ohira (2005) reported that both emotionally positive and negative nouns elicited a pronounced frontal positivity relative to neutral nouns at similar latency during a recognition task. Finally, Kissler et al. (2007) found a comparable effect of emotion in a passive reading paradigm, consisting in an enhanced negativity at occipito-temporal electrode sites.[1]

Also the present authors observed emotion effects in word processing in two experiments (Schacht & Sommer, 2004, in press). During lexical decisions for single verbs, both positive and negative items elicited a distinct ERP effect relative to neutral words, starting around 370 ms. Interestingly, emotions enhanced both a posterior negativity and fronto-central positivity which occurred approximately 50 ms after the first differentiation between correct words and pseudowords (lexicality effect). This finding was the first direct evidence for the activation of emotional meaning immediately succeeding lexical access (cf., Kissler et al., 2007). In our second experiment, the verbs were embedded into a semantic, emotionally neutral context provided by single preceding nouns. Again, the first emotion effect consisted in an enhanced negativity to both positive and negative target verbs relative to neutral verbs at occipito-temporal electrodes. This result was similar to EPN effects in affective picture processing and to ERP findings for single emotional words (e.g., Kissler et al., 2007; Kissler, Herbert, Winkler, & Junghöfer, 2008). Importantly, however, in our second experiment the emotion effect started as early as 180 ms after stimulus onset and was unaffected by the different processing requirements induced by structural, lexical, and semantic decision tasks. However, it has to be noted that both the emotion and the lexicality effect in lexical decisions on single verbs in our previous study appeared at longer latencies than in other single word studies (e.g., Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006; Herbert et al., 2006; Kissler et al., 2007, 2008), which might be due to lexical variables (e.g., word length) of the stimulus material, task specifics, and further, word class. Therefore, it was a primary aim of the present study to replicate the emotion effects found in our previous study.

As compared to written words, faces are of more direct biological and social relevance. The facial expression of a person provides rather specific information about her affective state and about possible action tendencies towards the perceiver, other persons, or objects, be it, for example, a welcoming smile or a threatening grimace. The influential model of face recognition by Bruce and Young (1986) postulates several successive processing stages. In an initial stage pictorial codes are derived from the retinal input when a face is encountered. From these pictorial codes structural information is derived, which is viewpoint- and expression-independent. One pathway of processing leads to the recognition and identification of the perceived person and towards the retrieval of semantic and name information. Other pathways branch off during structural encoding and lead towards the analyses of facial speech (lip movements) and facial expressions.

One focus of face research concerns the question at which stage in the face recognition process emotional information is extracted and the independence of the affective and identity routes. Whereas the Bruce and Young (1986) model postulates separate processing pathways, this has been called into question by recent findings (for review see Calder & Young, 2005). Some of these findings concern the N170 component in ERPs, a negative-going deflection at occipito-temporal sites appearing at around 170 ms after face presentation (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996; Deffke et al., 2007). The N170 has been related to configural processing of facial features and the holistic face percept (Bentin & Deouell, 2000; Carbon, Schweinberger, Kaufmann, & Leder, 2005; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002) and therefore to structural encoding. Several findings showed the N170 component to be unaffected by the presence or type of emotional facial expression (Carretié & Iglesias, 1995; Eimer & Holmes, 2002; Herrmann et al., 2002; Holmes, Kiss, & Eimer, 2006; Schupp, Öhman, et al., 2004; Streit et al., 1999). However, there is also some evidence for a modulation of the N170 by emotional expressions. For instance, larger N170 amplitudes have been reported to fearful faces as compared to other emotional (Batty & Taylor, 2003) or neutral expressions (Blau, Maurer, Tottenham, & McCandliss, 2007; Stekelenburg & de Gelder, 2004). Also, N170 amplitudes were found to be enhanced for happy as compared to neutral and sad expressions (Marinkovic & Halgren, 1998). Interestingly, Eimer, Holmes, and McGlone (2003) reported a facial expression effect in the N170 time range that differed from the N170 itself in terms of scalp distribution, indicating distinct underlying neural sources.

Others have reported negative-going deflections at posterior electrodes around 250 ms in response to faces with negative compared to neutral or positive facial expression (Balconi & Pozzoli, 2003; Schupp, Öhman, et al., 2004; Schutter, de Haan, & van Honk, 2004) which resembles the EPN component found in studies on affective picture processing. Schupp, Öhman, et al. (2004) related their finding of an EPN (230–280 ms) to threatening compared to neutral and happy stimuli to the hypothesis of facilitated automatic processing of fear-inducing stimuli. From an evolutionary perspective, it was argued that this 'fear system' enables rapid flight reactions and thereby may subserve survival (Öhman & Mineka, 2001). However, an ERP modulation in this time period is apparently not specific for threatening faces, as it was also found for fearful and surprised (Balconi & Pozzoli, 2003), for sad and happy (Marinkovic & Halgren, 1998), and even for all six basic emotional expressions (Eimer et al., 2003) compared to neutral facial expressions.

Moreover, ERP research indicates that the N170 may not be the earliest component that is sensitive to faces as compared to other types of objects (Itier & Taylor, 2004). Several studies even showed ERP correlates of emotional expressions preceding N170 and EPN. For instance, Eimer and Holmes (2002) reported a fronto-central positivity at 120 ms after the presentation of fearful faces as compared to neutral faces, and concluded that processing of facial affect starts before face identification. Possibly, this effect corresponds to the EPN component, although it appears with a shorter latency as compared to affective picture processing (see Footnote 1). Batty and Taylor (2003) and Pizzagalli et al. (2002) reported an ERP modulation within the P100 time range in response to faces from the Szondi portrait collection during likeability judgements. Also covering the P100 time range, both emotional positive and negative expressions of schematic line drawings modulated the scalp distribution of an early ERP component at around 85 ms (Eger, Jedynak, Iwaki, & Skrandies, 2003). Taken together, these findings indicate that emotional facial expressions may modulate ERPs as early as or even preceding the N170 component.

Following these early effects, in later time segments ERP modulation by emotional facial expressions have been reported for the LPC. Thus, augmented LPC amplitudes have been reported particularly to faces expressing anger or fear (e.g., Johnston, Stojanov, Devir, & Schall, 2005; Schupp, Öhman, et al., 2004; Schutter et al., 2004; Williams, Palmer, Liddell, Song, & Gordon, 2006). Ashley,

[1] Please, note that differences in the distributions of the reported ERP effects might be due to differences in reference electrode placement (cf. Junghöfer, Peyk, Flaisch, & Schupp, 2006).

Vuilleumier, and Swick (2004) found effects of emotional expressions on LPC amplitudes only for inverted but not upright faces. In addition, the LPC appears to be sensitive also for other affective components in face recognition, such as facial attractiveness (e.g., Schacht, Werheid, & Sommer, 2008; Werheid, Schacht, & Sommer, 2007).

Taken together, there is ample evidence for influences of emotional content of both words and emotional facial expressions. In both domains modulations of the LPC component have been observed but there seem to be earlier effects as well. Based on the evidence of emotion effects with comparable latencies, one might assume that both words and faces activate the same or at least similar affect-sensitive systems in the brain, as recently suggested by Kissler and coworkers (2007). Nevertheless, to the best of our knowledge, as yet there is only one study which has made such a direct comparison of emotional word and face processing (Vanderploeg, Brown, & Marsh, 1987). These authors used a conditioning paradigm and showed emotion effects in the P300 and the subsequent slow wave but only for face stimuli. However, this study suffers from several methodological shortcomings as, for instance, it failed to control for lexical variables and for the size of stimulus sets.

In the present study, a direct comparison will be made between emotion effects in word and face processing. For investigating effects of emotional valence in word processing a lexical decision task on single verbs was required where correct German verbs with positive, negative, or neutral valence had to be distinguished from phonologically legal pseudowords. In contrast to most previous studies of emotion effects on ERPs during word processing, we used verbs rather than nouns or adjectives, as done by Schacht and Sommer (in press). Verbs differ from other word classes by their very direct reference to actions and have been shown to elicit emotional effects in the attentional blink paradigm (Keil & Ihssen, 2004; Keil, Ihssen, & Heim, 2006) as well as lexical decision tasks (Schacht & Sommer, in press). In order to maximize the comparability of emotion effects in the two stimulus domains, we conducted a face decision task where portraits of faces with happy, angry, or neutral expressions ('intact faces') had to be discriminated from portraits where one of the features was smeared by photoediting, but retained the basic facial configuration. Importantly, in both domains the emotion variable was always implicit and not relevant for the task at hand.

2. Method

2.1. Participants

Twenty-four students (16 women) with a mean age of 23.5 years contributed data to the experiment. According to a handedness questionnaire (Oldfield, 1971), all participants were right-handed. Participation was reimbursed with course credits or 8 Euro per hour. All participants were native German speakers with normal or corrected-to-normal vision and without any neurological or neuropsychological disorder according to self-report.

2.2. Stimuli

For the lexical decision task the complete stimulus set consisted of 120 German verbs and 120 pseudowords. Correct words were 40 verbs each of positive, negative, or neutral valence (e.g., kiss, kill, or throw), taken from our previous experiments (Schacht & Sommer, in press). Pronounceable and orthographically correct pseudowords were constructed from verbs other than the correct verbs for the lexical decision task by substituting one letter at a random position, excepting the initial and last positions. Pseudowords were matched to correct words with respect to word length. Correct verbs of different emotional valence were controlled for word frequency and number of orthographic neighbors (CELEX; Baayen, Piepenbrock, & van Rijn, 1995), word length (letters and syllables), all $Fs(2,117) < 1$, as well as for imageability, emotional arousal, and emotional valence as obtained from rating studies[2] in Schacht and Sommer (in press). Descriptive statistics for verbal stimuli are given in Table 1. Pre-experimental ratings of emotional valence revealed significant differences between all three conditions, $F(2,117) = 1960.6$, $p < .001$, all $ts(78) > 32.0$, $ps < .001$. According to these ratings, verbs did not differ in terms of imageability, $F = .18$. Further, statistical comparison of SAM ratings revealed increasing arousal values from neutral over positive to negative verbs, $ts(78) > 6.5$, $ps < .001$. Word stimuli were presented in lower-case dark gray letters (Arial font) on light gray background. Height of the letters was 8 mm; the width of words varied between 35 and 65 mm.

Table 1
Descriptive statistics for control variables and rating results for the word material used in the lexical decision task.

	Positive verbs *M* (*SD*)	Negative verbs *M* (*SD*)	Neutral verbs *M* (*SD*)
Emotional valence (range −3 to +3)	2.0 (0.3)	−2.2 (0.4)	0.1 (0.2)
Arousal (range 1–5)	3.1 (0.6)	4.0 (0.4)	1.8 (0.3)
Imageability (range 0–6)	3.5 (1.3)	3.6 (1.4)	3.5 (1.2)
Word length (number of letters)	9.2 (1.3)	9.1 (0.8)	8.9 (0.7)
Word length (number of syllables)	3.0 (0.6)	3.1 (0.3)	3.1 (0.5)
Word frequency (1/1,000,000, CELEX)	50 (78)	51 (73)	50 (59)
Orthographic neighborhood size	0.9 (1.3)	0.8 (1.1)	1.1 (1.2)

For the face decision task 240 portraits of different persons (half female) were taken from the Purdue University database (Martinez & Benavente, 1998), from the Karolinska database (Lundqvist, Flykt, & Öhman, 1998), and from our own database (Schacht et al., 2008). All portraits were edited to a unitary format, converted to a gray scale with identical light gray backgrounds, and framed within an area of 350×270 pixels (10.4×8 cm). Intact target faces expressed anger, happiness, or no emotion (40 faces per emotion category). Distracter faces were derived from faces with neutral expressions of persons other than the target faces by applying the smearing tool of Adobe Photoshop© to one of the facial features left or right eye, mouth, or nose ($n = 30$ for each smeared feature; see Fig. 1 for examples). Please, note that each portrait used, whether smeared or not, depicted a different facial identity. As for words, each portrait was displayed only once to a given participant.

2.3. Procedure

Participants were seated in a dimly lit, sound-attenuated chamber facing a computer monitor. Word and face stimuli were presented on a dark gray background at the center of the screen placed at a distance of approximately 100 cm from the partici-

[2] These pre-experimental ratings were performed by independent samples. Both emotional valence and imageability judgements were obtained using 7-step rating scales. Perceived arousal values were derived from a computerized version of the Self-Assessment Manikin (SAM; Lang & Cuthbert, 1984).

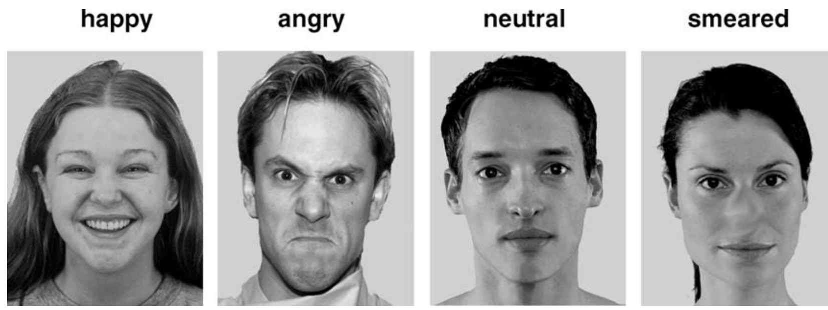

Fig. 1. Examples for faces served as stimuli in the face recognition task.

pant. Each trial started with a fixation cross displayed for 500 ms, followed by the letter string or face picture, which disappeared with the response. After 2700 ms (blank screen) the next trial started. Lexical and face decision tasks were conducted in separate blocks. Within each task stimuli were delivered randomly in four blocks of 60 items each. Between blocks there was a short break. Stimulus presentation and response collection were controlled by the Presentation software (Neurobehavioral Systems©).

Participants were instructed to indicate as fast as possible whether or not the presented letter string was a correct word (lexical decisions) or whether or not the displayed face was intact (face decision) by pressing a button with one of their index fingers. The assignment of word or face type to responding finger as well as the order of tasks was counterbalanced across participants. Prior to the first experimental block of both tasks practice blocks were given, consisting of 12 trials each. Participants were instructed to avoid blinking while a stimulus was visible.

After the lexical and face decision tasks all facial stimuli were presented again in a different random order. Participants had to judge the emotional valence of each face on a 5-point rating scale by pressing buttons labeled from −2 (very unpleasant) to +2 (very pleasant) on a standard PC keyboard. Subjects were instructed to keep their fingers on the response keys (two fingers of each hand on keys labeled with −2 to +2 and one thumb on the space key labeled with 0).[3]

2.4. EEG recording

The electroencephalogram (EEG) was recorded from tin electrodes at 62 sites according to the extended 10–20 system and referenced to the left mastoid. Most of these electrodes were placed in an electrode cap. External electrodes were used for the vertical and horizontal electrooculogram, and left mastoid. Electrode impedance was kept below 5 kΩ; ECI electrode gel (Expressive Constructs Inc., Worcester, MA) was used. Recording was done at a sampling rate of 250 Hz. All signals were amplified with a band pass of 0.032–70 Hz. Offline, the continuous EEG record was segmented into epochs of 1200 ms, starting 200 ms prior to stimulus onset and transformed to average reference. Epochs containing erroneous responses or artifacts were discarded based on visual inspection; the proportion of remaining trials was above 85% for all conditions and did not differ between tasks, $F(1,23) = 1.6$, $p > .21$, or emotional conditions, $F(2,46) = 1.8$, $p > .17$. ERPs were calculated for the edited set of raw data and referred to a 200-ms prestimulus baseline.

2.5. Data analysis

For behavioral data the percentage of wrong classifications and mean reaction times (RTs) for correct responses were first analyzed with overall repeated measures analyses of variance (ANOVAs), involving the factors emotion (positive, negative, neutral) and stimulus domain (words, faces). In case of significant main effects of emotion or an interaction between emotion and stimulus domain, pair-wise comparisons were conducted within each domain and between the different levels of emotion. Here, p-values were Bonferroni-adjusted. An additional domain (2) by correctness (2) ANOVA was conducted for a comparison of RTs and error between correct words or intact faces at the one hand (averaged over all emotion conditions) and distracters on the other hand.

ERP segmentation proceeded according to visual inspection of the global field power (GFP; Lehmann & Skrandies, 1980) and global map dissimilarity (GMD; Brandeis, Naylor, Halliday, Callaway, & Yano, 1992). GFP reflects the overall ERP activity across the scalp at any given moment, that is, the root mean square of averaged voltages at all electrodes. GFP for all emotion conditions is depicted in the upper panels of Fig. 2. GMD reflects the dissimilarity between scalp topographies of adjacent time points. Thus, GMD peaks demarcate the temporal borders between periods of relatively stable topographies and are suggested as borders of ERP components or microstates of the brain (Brandeis & Lehmann, 1986). As can be seen in Fig. 2, the largest peaks in the GMD are framing local maxima of the GFP. During these periods, that is, between two peaks of GMD measures, similar brain areas are continuously active. GMD was calculated in the following steps (see Brandeis et al., 1992): (1) Difference waves were calculated between ERPs to emotional minus neutral items for each electrode site. (2) The topographies of these difference waves at each time point were normalized by dividing the value at each electrode by GFP over all electrodes. (3) These normalized scalp distributions at successive time points were subtracted from each other, that is, the value at each electrode site in the normalized map at time point n was subtracted from the value at the corresponding site at time point $n - 1$, yielding a sequence of difference maps across time. (4) For each of these difference maps the GFP was calculated and plotted as a function of time. As a result of the normalization described above, GMD reflects differences only in distribution, but not in map amplitude. Thus, the GMD between two successive maps "termed as 'sequential dissimilarity' is a measure for topographic instability" (Brandeis et al., 1992, p. 317). Comparing the GFP of the ERP waves for each condition to the GMD as calculated above (Fig. 2), allowed us to identify separate microstates in the ERP with transitions at 92, 128, 144, 172, and 192 ms in the face decision task and at 104, 124, 148, 248, 312, 364, and 388 ms in the lexical decision task (see Fig. 2). These transition times were used as borders

[3] Post-experimental evaluation of emotional valence was restricted to facial stimuli with respect to the overall length of the experimental session. As mentioned above, verbs had been selected from previous studies according to pre-experimental rating values.

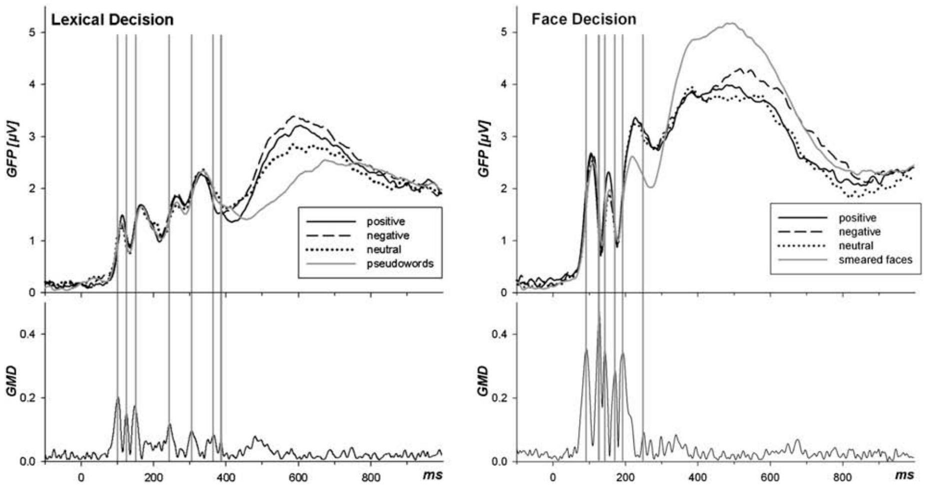

Fig. 2. Effects of emotion on electrophysiological parameters in the Verbal and Face domain (left versus right panel). The upper graphs show global field power (GFP) across all subjects, contrasted for emotionally positive, negative, neutral correct words, and pseudowords, and happy, angry, neutral faces, and blurred faces. The lower graph depicts global map dissimilarity (GMD) across all subjects and averaged across both positive and negative condition. The vertical gray lines mark the segment borders which were defined by GMD peaks. Following the segment border, mean ERP amplitudes were segmented in consecutive time windows of 50 ms duration.

of the time segments for which mean ERPs amplitudes were calculated. Therefore, the peaks in the GMD demarcate separate microstates in the ERP. These microstates were subsequentially used for ERP analysis. Further, clear segment borders, as indicated by GMD peaks (>.01) did not appear any more after 192 and 388 ms, respectively, in the face and word domain. Accordingly, consecutive time periods of 50 ms duration were selected for further analysis of mean amplitudes following these time points.

In order to assess experimental effects within the time windows defined above, the following main strategies were followed. Because the basic ERP waves differ between domains, we first attempted to identify emotion effects in each domain separately. To this aim within each domain ANOVAs including all 62 electrode sites and the emotion factor (3 levels), were calculated for all time segments identified by GFP and GMD measures. By definition, the average reference sets the mean value of the ERP amplitude to zero across all electrodes within a given condition. Therefore, for these ANOVAs, only effects in interaction with electrodes are meaningful.

Interactions between an experimental factor and electrode in these ANOVAs may reflect either differences in overall ERP activity (amplitude) or differences in the scalp distributions between experimental conditions. To assess whether the emotion effects obtained in the ANOVAs within a given domain are distinguishable with regard to their scalp distributions, overall amplitude differences were eliminated by normalization with the vector method (profile analyses; McCarthy & Wood, 1985). This method involves dividing the voltage at each electrode by vector length across all electrodes within each condition. Significant condition by electrode effects in the ANOVA of these data indicate that there are topographical differences independent of overall ERP activity.

In a further step, the domain specificity of apparently corresponding emotion effects was assessed by conducting omnibus ANOVAs across domains with additional factors electrode and emotion. Finally, in order to assess whether the electrode by experimental factor interactions are due to differences in amplitude strengths or scalp topography, ANOVAs on GFP and scaled amplitudes were conducted.

The tasks employed here involved the use of distracter stimuli (pseudowords and smeared faces) that obviously cannot be varied on the factor emotion in a meaningful way. Therefore, amplitude differences between target stimuli and distracters were assessed by averaging correct words and intact faces across all emotion conditions and comparing them with pseudowords and partially smeared faces, respectively, within the time segments defined by GMD.

Huynh–Feldt correction was applied to adjust the degrees of freedom of the *F*-ratios. Please note that all within-subject repeated ANOVA measures will be reported with uncorrected degrees of freedom but corrected *p*-values. In all cases, for post-hoc pair-wise comparisons alpha levels were Bonferroni-corrected.

3. Results

3.1. Effects of emotion

3.1.1. Behavioral data

Descriptive statistics for behavioral data are summarized in Table 2. Emotion effects in *reaction times* differed between face decisions and lexical decisions, as reflected in a two-way interaction, $F(1,23) = 17.5$, $p < .001$, $\eta^2 = .133$: Lexical decisions were significantly faster to positive and negative verbs compared with neutral verbs, $Fs(1,23) > 5.8$, $ps < .05$, $\eta^2s > .203$. In contrast, decisions to angry faces were significantly slower than for both happy and neutral faces, $Fs(1,23) > 25.6$, $ps < .001$, $\eta^2s > .525$. The disproportional slowing for angry faces resulted in a significant main effect of emotion across both domains $F(2,46) = 12.8$, $p < .001$, $\eta^2 = .357$, despite the qualitative differences reflected in the two-way interaction. A main effect of stimulus domain only appeared as a trend, $F(1,23) = 3.5$, $p = .073$, $\eta^2 = .133$, reflecting the slightly shorter RTs in face decisions in general.

Table 2
Reaction times (RTs) in ms and error rates in % (mean values with standard deviations) for both face recognitions and lexical decisions.

Emotional valence	Lexical decision		Face decision	
	RTs	Error rates	RTs	Error rates
Positive	696.5 (157.6)	4.9 (3.9)	601.1 (194.1)	1.8 (2.7)
Negative	690.1 (146.9)	5.4 (7.5)	662.1 (215.2)	4.1 (4.5)
Neutral	716.1 (161.2)	5.2 (4.7)	613.4 (194.1)	2.3 (2.4)
Distracters	820.3 (193.6)	6.0 (5.4)	567.7 (78.0)	4.9 (3.4)

Overall, *error rates* for face decisions were lower than for lexical decisions as reflected in a main effect of stimulus domain, $F(1,23) = 13.2$, $p < .001$, $\eta^2 = .364$. Error rates were not influenced by emotion, $F(2,46) = 2.5$, $p = .1$, $\eta^2 = .099$, nor by any interactions of domain and emotion, $F(2,46) < 1$.

Post-experimental ratings of emotional valence of facial stimuli revealed significant differences between all three emotional expressions, $F(2,117) = 312.5$, $p < .001$, all $ts(78) > 11.2$, $ps < .001$, as rating values increased from angry ($M = 2.1$, $SD = .25$) over neutral ($M = 3.0$, $SD = .47$) to happy expressions ($M = 4.1$, $SD = .30$).

3.1.2. Event-related brain potentials

For *lexical decisions* overall ANOVAs including the factors emotion (positive, negative, neutral) and electrode (62) of mean ERP amplitudes revealed first significant emotion effects within time segments from 388 to 438 ms, $F(122,2806) = 2.1$, $p < .05$, $\varepsilon = .087$, $\eta^2 = .083$, and 438–488 ms, $F(122,2806) = 2.0$, $p < .05$, $\varepsilon = .070$, $\eta^2 = .080$. These main effects of emotion reflect significant differences between positive and neutral verbs in both time segments, $Fs > 2.9$, $ps < .05$, where positive verbs elicited more positive amplitudes at frontal and more negative amplitudes at occipito-temporal electrode sites (see Fig. 3, left panel), whereas ERPs to positive and negative verbs did not differ, $Fs < 1.6$, $p > .05$.

In the following 488–538 ms time segment the emotion effect dropped to a strong trend, $F(122,2806) = 1.7$, $p = .075$, $\varepsilon = .084$, $\eta^2 = .070$, as obtained in the overall emotion (3) by electrode (62) ANOVA.

As depicted in Fig. 4 (upper panel), a second effect of emotion appeared in the two 50-ms segments between 538 and 638 ms, $F(122,2806) = 2.4$, $p < .01$, $\varepsilon = .100$, $\eta^2 = .093$, and, $F(122,2806) = 2.1$, $p < .01$, $\varepsilon = .095$, $\eta^2 = .091$. Pair-wise comparisons revealed significant differences between ERPs to negative as compared to neutral words, $Fs(61,1403) > 3.7$, $ps < .01$, $\varepsilon s = .093$, $\eta^2 s > .137$. Differences between positive and neutral verbs within these time segments were small and confined to the 588–638 ms time segment, $F(61,1403) = 2.4$, $p = .06$, $\varepsilon = .109$, $\eta^2 = .090$.

In comparison to the first frontally positive/occipitally negative emotion effect, the second effect showed a markedly different scalp topography with a central positivity and fronto-temporal negativity (see Fig. 4, top right panel). This impression was verified by ANOVA with repeated measures on emotion (3 levels), electrode site (62 levels), and time segment (2 levels) following normalization. For both emotion effects ERP amplitudes were averaged within the whole intervals of 100 ms duration in which the emotion effect became significant (388–488 ms for the early and 538–638 ms for the late emotion effect). The ANOVA on the normalized early and late emotion effects revealed a significant difference between their scalp distributions, $F(61,1403) = 5.6$, $p < .001$, $\varepsilon = .106$, $\eta^2 = .194$.

In the *face decision task*, first effects of emotional expression by electrode appeared for the 128–144 and 144–172 ms segments, $F(122,2806) = 4.3$ and 3.6, respectively, $ps < .01$, $\varepsilon = .089$ and .080, $\eta^2 s > .136$, and consisted of significant differences between ERPs to happy relative to both angry and neutral faces, $Fs(61,1403) > 4.0$, $ps < .01$, $.084 > \varepsilon < .106$, $\eta^2 s > .146$ (see right panel of Fig. 3). The topographies of the difference waves (happy minus neutral and happy minus angry, respectively) showed an enhanced positivity at fronto-central sites and enhanced negativity at parieto-occipital electrodes. Although the early effect of emotional expression covered the time range of the N170, its scalp topography seemed to differ from that of the N170 component itself. We verified this impression by an additional emotion (3 levels) by electrode (62 levels) ANOVA with normalized amplitudes, which revealed a significant difference between the distribution of the N170 in the neutral condition and the distribution of the difference wave of ERPs to happy minus neutral faces, $F(61,1403) = 5.0$, $p < .001$, $\varepsilon = .106$, $\eta^2 = .180$.

The early emotion effect disappeared in the time segment following 172 ms. However, a second effect of emotional expression started around 450 ms and lasted for the rest of the epoch, all $Fs > 2.0$, $ps < .05$, $.078 < \varepsilon s > 127$, $\eta^2 s > .081$. In contrast to the early effect, where ERPs to happy faces differed from the others, in this late intervals angry faces elicited an enhanced positivity at parietal electrodes (see bottom panel of Fig. 4) as compared to both, neutral, all $Fs(61,1403) > 2.5$, $ps < .05$, $.071 < \varepsilon s > 128$, $\eta^2 s > .103$, and happy faces, $Fs(61,1403) > 2.6$, $ps < 05$, $.083 < \varepsilon s > 146$, $\eta^2 s > .101$. As indicated by a further ANOVA on normalized data, the difference ERP waves of the early (happy minus neutral) and late (angry minus neutral) effects of emotional expression showed distinguishable scalp topographies, $F(61,1403) = 7.8$, $p < .001$, $\varepsilon = .092$, $\eta^2 = .254$.

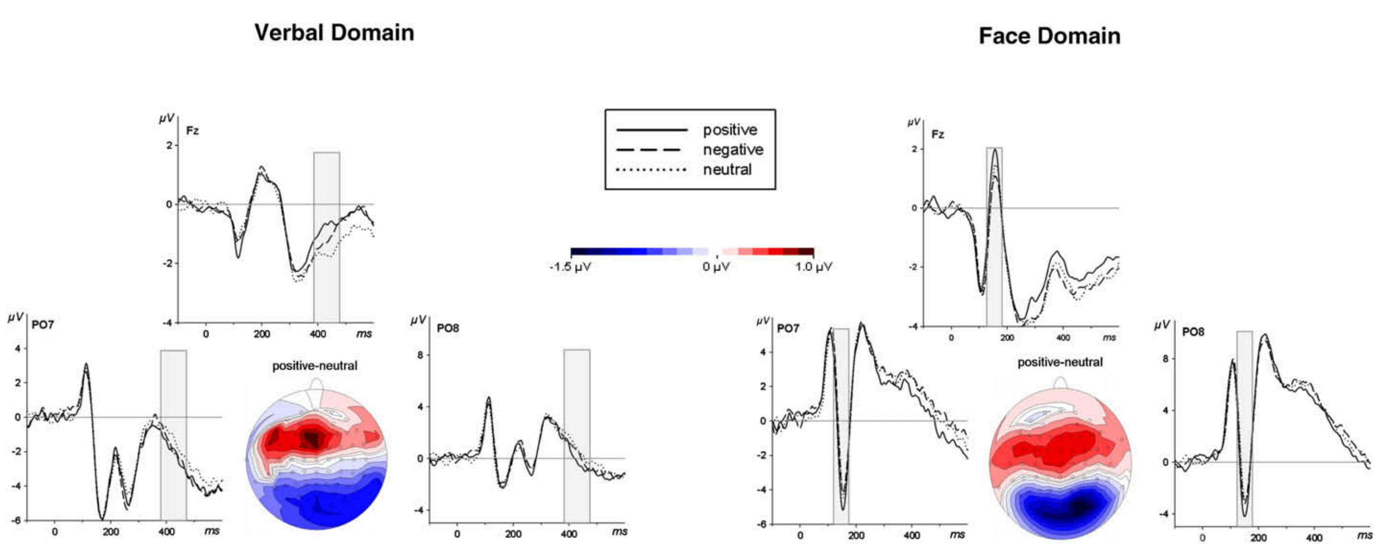

Fig. 3. Early effects of emotion on ERPs in lexical decisions (left panel) and face recognitions (right panel). Grand mean ERP waveforms elicited by emotionally positive, negative, and neutral verbs, and happy, angry, and neutral faces, respectively, are depicted from frontal (Fz) and parieto-occipital (PO7 and PO8) electrodes. Maps show the scalp distributions of the differences between positive and neutral verbs, and angry and neutral faces within the contrasted interval (highlighted in the ERPs by gray-shaded areas).

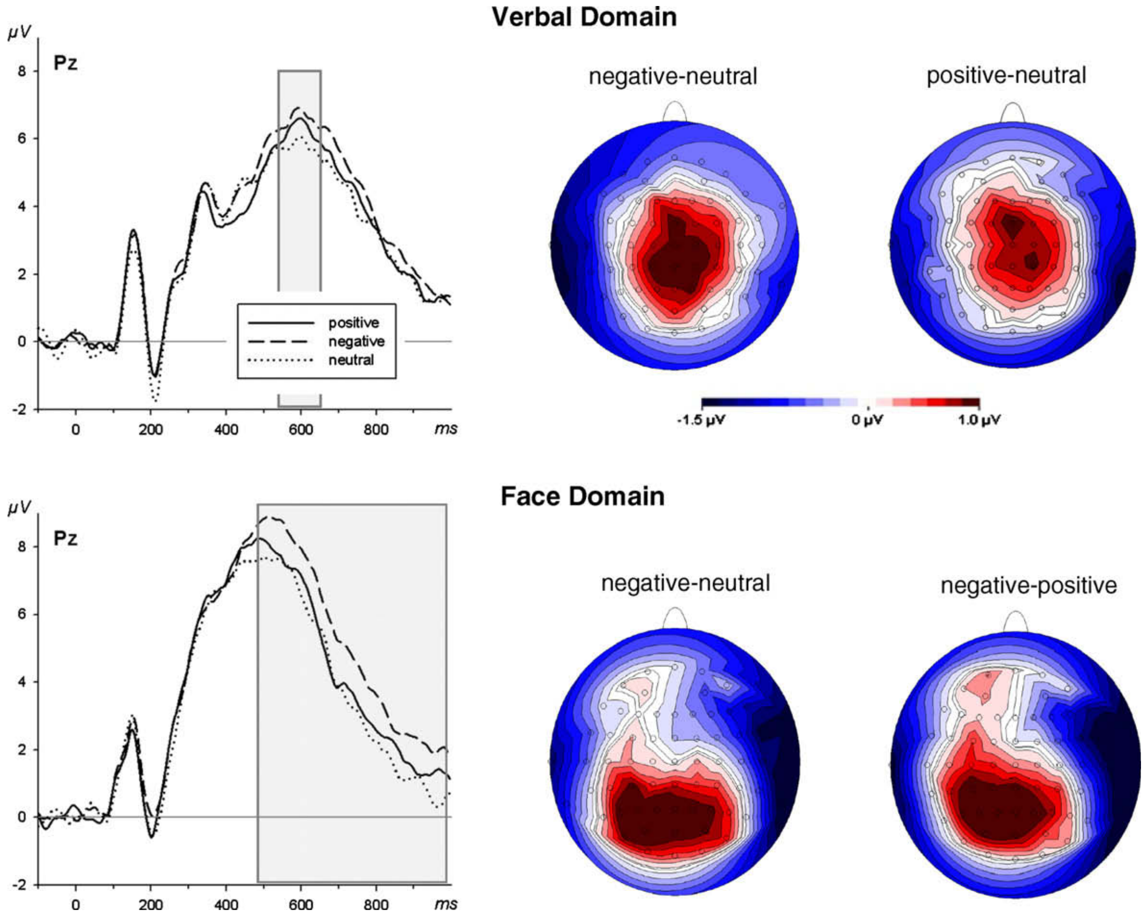

Fig. 4. Late effects of emotion. The left panels depicts grand mean ERP waveforms from Pz electrode, elicited by emotionally positive, negative, and neutral target words during lexical decisions (top), and by happy, angry, and neutral faces during the face recognition task (bottom). At the right side topographies are depicted for difference waves between emotion conditions for both domains within the interval marked by gray-shaded areas in the ERP plot.

As described above, in both the face and word domain two emotion effects appeared which were distinguishable from each other in terms of timing and topography. Interestingly, in both domains the first emotion effects consisted of enhanced posterior negativities and anterior-central positivities to emotionally positive items. However, in the face domain this early effect appeared after around 150 ms, whereas for words the effect appeared about 250 ms later. The late emotion effects appeared at similar latencies in both domains, but a visual inspection of their topographies indicates some differences. In order to investigate the *domain specificity* of the early and late emotion effects, direct comparisons were made between the emotion effects across domains.

In a first step, two separate overall ANOVAs including the factors domain (2 levels), emotion (2), and electrode (62) were conducted. The ANOVA for early emotion effects contrasted ERP mean amplitudes to positive and neutral faces between 128 and 172 ms and positive and neutral words between 388 and 488 ms, respectively. Here, significant main effects of domain, $F(61,1403) = 5.5$, $p < .001$, $\varepsilon = .073$, $\eta^2 = .193$, and emotion, $F(61,1403) = 8.4$, $p < .001$, $\varepsilon = .079$, $\eta^2 = .267$, appeared, but the factors did not interact, $F(61,1403) < 1$. ANOVA on ERP mean amplitudes to negative and neutral faces and words between 442 and 1000 ms and 538 and 638 ms, respectively, revealed a significant effect of emotion, $F(61,1403) = 8.6$, $p < .001$, $\varepsilon = .091$, $\eta^2 = .274$, which interacts with the factor domain, $F(61,1403) = 2.2$, $p < .05$, $\varepsilon = .087$, $\eta^2 = .107$. A main effect of domain appeared as a trend, $F(61,1403) = 2.0$, $p = .087$, $\varepsilon = .083$, $\eta^2 = .079$.

In order to specify whether these effects are due to *amplitude strength* ANOVAs on GFP including the factors domain (2 levels) and emotion (2 levels) were conducted. As expected, strong effects of emotion appeared for both early and late time windows, $Fs(61,1403) > 16.3$, $ps < .01$, $\eta^2 > .415$. Further, for the early effects a trend for an interaction between emotion and domain was obtained, $F(61,1403) = 3.5$, $p = .07$, $\eta^2 = .134$, which reflected a slightly enhanced effect for angry faces compared with negative words. There were neither main effects of domain, $Fs < 1$, nor interaction between emotion and domain for the late effect.

As can be seen in Fig. 3, the *topographies* of the early effects were very similar across the stimulus domains. For a direct comparison of the emotion effects across domains, the topographies of these early and late emotion effects, respectively, were assessed with ANOVAs after normalizing the amplitudes of the ERP difference waves. These comparisons showed no significant differences in the topographies of the early effects of emotion, $F(61,1403) = 1.2$, $p > .05$, $\varepsilon = .122$, $\eta^2 = .051$, but did so for the late effects, $F(61,1403) = 2.2$, $p < .05$, $\varepsilon = .111$, $\eta^2 = .086$. Therefore, scalp topographies of the early emotion effects appeared to be similar across domains, whereas those of the late effects differed.

3.2. Effects of face intactness and lexicality

3.2.1. Performance

An overall 2×2-ANOVA on RTs revealed a significant main effect of domain, $F(1,23) = 25.6$, $p < .001$, $\eta^2 = .527$, and significant differences between intact faces/correct words and distracters, $F(1,23) = 5.1$, $p < .05$, $\eta^2 = .180$. Whereas smeared faces were recognized faster than intact faces, RTs to pseudowords were prolonged compared with correct verbs, as reflected in a significant domain

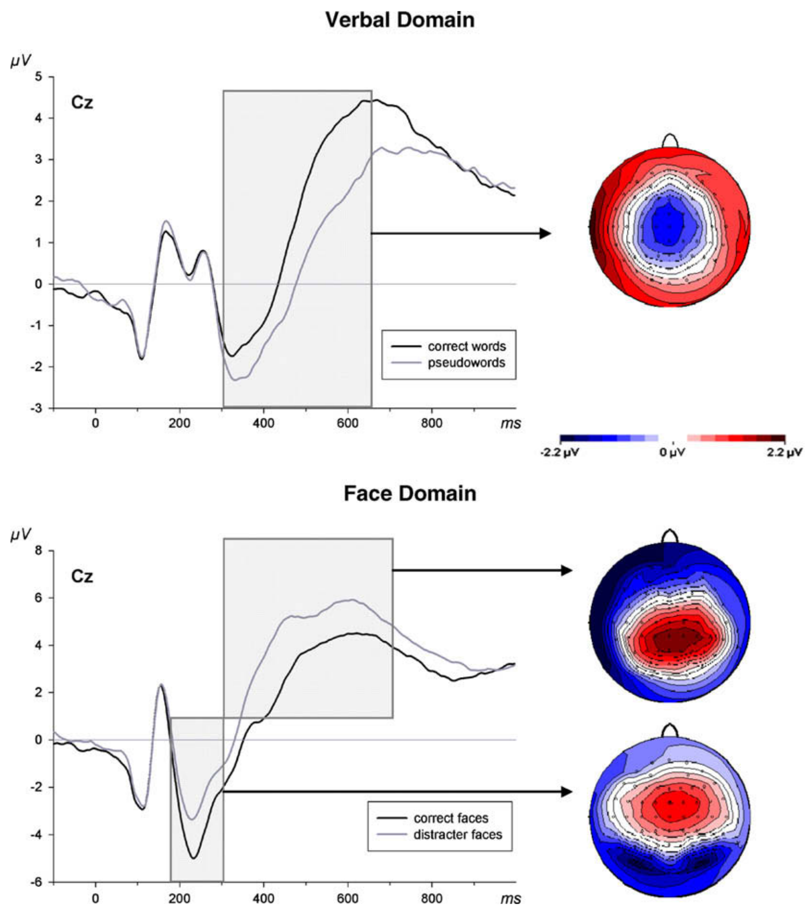

Fig. 5. Scalp distributions of ERP differences between correct words and pseudowords (left panel) and intact faces and distracter faces (right panel) in selected time segments.

by correctness interaction, $F(1,23) = 24.8$, $p < .001$, $\eta^2 = .519$ (see Table 2). Overall, error rates were higher in lexical decisions, $F(1,23) = 6.7$, $p < .05$, $\eta^2 = .225$, compared with face decisions, as well as for distracter stimuli in both domains, $F(1,23) = 9.0$, $p < .01$, $\eta^2 = .281$. The interaction between both factors appeared as a trend, $F(1,23) = 3.3$, $p = .081$, $\eta^2 = .127$.

3.2.2. ERP data

Differences between ERPs to correct words and pseudowords (lexicality effect) appeared between 312 and 638 ms after stimulus onset, $Fs(61,1403) > 9.0$, $ps < .001$, $.055 < \varepsilon > .080$, η^2s > .283, as obtained in the lexicality (2) by electrode (62) ANOVA. As depicted in Fig. 5 (upper panel), this effect of lexical correctness consisted in an enhanced negativity to pseudowords with a maximum over the vertex.

Further, we assessed the effect of *face intactness*. The intactness (2) by electrode (62) ANOVA revealed significant differences in ERPs to intact and distracter faces starting at 172 ms and lasting until 692 ms after stimulus onset, $Fs(61,1403) > 3.1$, $ps < .01$, $.057 < \varepsilon > .107$, η^2s > .120. Visual inspection of GFP measures (see Fig. 2) indicates effects of facial intactness varying over time. Whereas distracter faces elicited enhanced posterior-occipital negativities between about 170 and 300 ms, in the following time windows this difference showed a distribution similar to the emotional LPC effect described above (see Fig. 5, bottom).

To assess whether the emotional LPC effects may relate to any differences in RTs, we conducted bivariate correlation analyses of amplitude and RT differences to negative minus neutral stimuli in each domain. None of these correlations were significant, all $rs < .24$, $ps > .26$.

4. Discussion

The present study compared effects of emotion in word and face processing using tasks in which the emotional connotation of these stimuli was irrelevant for successful performance. As a main result, two qualitatively different effects of emotion were found in the ERPs of each domain. A *first emotion effect* appeared after around 380 ms to emotionally positive verbs and around 130 ms to happy faces. Importantly, these first emotion effects appearing at different latencies in the two domains showed very similar scalp distributions consisting of enhanced negativities at parieto-occipital electrode sites. A *second emotion effect*, starting at about 540 (words) and 450 ms (faces), respectively, consisted in enhanced amplitudes of the LPC component to negative verbs and angry faces, and showed a domain-specific scalp topography.

4.1. Early effects of emotion

In the *verbal domain*, the first effect of emotion differentiated between positive and neutral verbs and started approximately 50 ms after the initial dissociation between correct verbs and pseudowords. This lexicality effect consisted in a greater negativity at vertex to pseudowords as compared to correct words starting around 320 ms (cf., Braun et al., 2006; Chwilla, Brown, & Hagoort, 1995; Schacht & Sommer, in press). Importantly, the head start of lexicality over emotion effects is in line with our previous findings (Schacht & Sommer, in press) and, provides more direct evidence for the assumption that the emotional content of a written word is activated at a post-lexical level (see also Kissler et al., 2007).

Importantly, the emotion effect observed here showed a bilateral occipito-temporal negativity and—as its electrical counterpart—a fronto-central positivity. This scalp distribution is typical for the EPN (e.g., Schupp, Junghöfer, Weike, & Hamm, 2003), which has been observed during the perception of emotional scenes (e.g., Junghöfer et al., 2001), faces (e.g., Schupp, Öhman, et al., 2004), and words (e.g., Kissler et al., 2007; Schacht & Sommer, in press).

In the *face domain*, the present ERPs displayed an enhanced posterior negativity for happy faces around 150 ms after stimulus onset. Considering its latency in the N170 time range, this effect might be interpreted as resulting from emotion-related differences in facial configurations. On the other hand, as depicted in Fig. 2, the distribution of the difference waves to happy versus neutral faces showed a markedly different scalp topography as compared to the N170 reported in the literature (cf., Bentin et al., 1996; Deffke et al., 2007). Moreover, our profile analyses revealed significant differences between this emotion effect and the distribution of the current N170 to neutral faces. These findings indicate that emotional expression does not affect the N170 amplitude itself. Therefore, we suggest an independent emotion process coinciding with and superimposing on the structural encoding of the face in view. These findings indicate that the analysis of facial expression is not contingent upon structural analysis of faces; instead, they are in line with the notion of independent systems for emotion recognition and analysis of invariant structural features of faces (e.g., Bruce & Young, 1986; Calder & Young, 2005).

Importantly, both the early effect of happy relative to neutral facial expressions and of positive relative to neutral verbs observed here showed EPN-like scalp distributions. Stronger effects of positive than negative emotions have been reported also for the EPN in affective picture processing (Schupp, Junghöfer, Weike, & Hamm, 2004; Schupp et al., 2003, 2007). However, it is noteworthy, that the 'positive advantage' found here, is partially at variance with our previous results of enhanced EPN effects not only to positive but also to negative verbs[4] as well as to stronger early ERP responses to negative than positive facial expressions (e.g., Schupp, Öhman, et al., 2004). Future research should specify to which extent the EPN is sensitive to different valences or whether it is triggered by arousal differences.

Because the scalp distributions of the present EPN effects for positive words and happy faces relative to neutral ones did not show significant differences between domains, the underlying neural systems appear to be similar within the spatial resolution power of ERPs in the setup used here. An important task for future research with will be to scrutinize the overlap of emotion processing systems in the word and face domain with techniques that complement the high temporal resolution obtained here with high spatial resolution. Such research is currently under way.

EPN effects in affective picture processing have been related to attention capture by emotionally salient stimuli (e.g., Schupp et al., 2007). Attention to distinct stimulus features is associated with a broadly distributed negative ERP difference over temporo-occipital regions occurring around 150–350 ms after stimulus onset. This occipital negativity reflects a transitory processing period during which task-relevant stimuli are presumably selected for elaborate processing (cf., Kissler et al., 2007; Potts & Tucker, 2001). It was therefore suggested that emotionally salient stimuli spontaneously catch attention (e.g., Kissler et al., 2007; Schupp et al., 2007). Vuilleumier and Driver (2007) proposed that both attentional and emotional effects on visual perception are due to top-down influences upon visual cortex from brain regions further up-stream. Although the up-stream networks may differ, their effects upon processing in peri-striate cortex may consist in similar activation patterns. As recently proposed by Kissler and colleagues (2007), bidirectional connections between limbic structures and extrastriate regions might amplify the ERP responses to emotional words. Possibly, these mechanisms underlie the first step of emotion detection—independent of the stimulus domain.

The EPN-like component to emotional words appeared about 150 ms later than commonly described in reports about affective picture processing (e.g., Schupp et al., 2007) and about 250 ms later than in the present face recognition condition. This implies that—under the given experimental conditions—the activation of emotional contents at initial stages takes more time when positive verbs rather than happy facial expressions are processed. Both face recognition and visual word comprehension consists of several processing stages from the retinal input to the access or activation of identity or meaning. Nevertheless, they obviously require different kinds of perceptual lead-in processes *preceding* the activation of emotional content. A basic difference between emotional face and word processing is related to the source of emotional content. Emotional expressions of faces can be recognized by changes in single facial features and their specific arrangement (configuration). In contrast, the emotional meaning of written words can not be extracted from superficial/structural features since single parts as letters or syllables do not differ in terms of emotional valence. The extraction of emotional significance of verbs may require not only processes of grapheme analysis and lexical retrieval but also the activation of semantic/conceptual representations (cf., Azizian, Watson, Parvaz, & Squires, 2006). Therefore, the comparatively late effects of emotional verb-content as compared to affective faces or pictures may not be surprising.

Interestingly, the initial emotion effect in the verbal domain found here appeared at a longer latency than emotion effects with similar scalp distribution in the verbal domain, as recently reported by others (Herbert et al., 2006; Inaba et al., 2005; Kissler et al., 2007, 2008).[5] This discrepancy may relate to differences in task requirements since several imaging and ERP studies have shown modulations of emotion effects by task requirements in different domains and experimental settings (e.g., Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003; Cunningham, Raye, & Johnson, 2004; Hariri, Bookheimer, & Mazziotta, 2000; Schacht et al., 2008; Schupp et al., 2007). However, in our previous study we have shown that different task requirements in word recognition influence only later stages of processing as reflected in LPC modulations, while the EPN is unaffected by the task to be performed on the verbs. Therefore, we consider it unlikely that the relatively late onset of initial emotion effects in words might be due to the specific processing requirements during lexical decisions (see also Kissler et al., 2008).

Instead, the relative delay in the onset of emotion effects might relate to word class. Whereas the studies of Herbert et al. (2006), Inaba et al. (2005) and Kissler et al. (2007, 2008) used emotional nouns or adjectives, in the present study verbs served as stimuli.

[4] Please, note that in the present study no significant differences between EPN effects to positive and negative verbs have been observed. Because this early emotion effect is rather small, the non-significance of differences between EPNs to negative versus neutral verbs might result from less power (see also Fig. 3 for slight differences between grand mean ERPs).

[5] To make sure that the absence of any earlier emotion effects is not due to the particular type of ERP analysis, additional regional analyses were conducted in analogy to the study of Kissler et al. (2007). The averaged activity of two groups of six occipito-temporal electrodes each were calculated, one in the left hemisphere (O1, PO3, PO7, P7, P5, P3) and one in the right hemisphere (O2, PO4, PO8, P8, P6, P4). Repeated measures ANOVAs with factors emotion (3 levels) and hemisphere (left, right) was also unable to uncover any effects of these factors prior to 388 ms after stimulus onset, all $Fs < 1.0$.

At least for the word classes verbs and nouns, there are several indications for differences in processing. For instance, nouns are acquired earlier during language development (e.g., Nelson, 1973) and are remembered more easily than verbs (e.g., Reynolds & Flagg, 1976), possibly caused by several syntactic and semantic differences (cf., Federmeier, Segal, Lombrozo, & Kutas, 2000). Studies of visual word processing have shown such a noun advantage in a wide range of different tasks (e.g., Kauschke & Stenneken, 2008; Sereno, 1999; Tyler, Russel, Fadili, & Moss, 2001), which appears to interact with emotional valence as shown by Dietrich and coworkers in a word recognition task (Dietrich et al., 2001). This idea is also supported by most recent results of Scott and coworkers (Scott, O'Donnell, Leuthold, & Sereno, 2008) who used a similar LDT as in the present experiment and found an EPN for emotional nouns and adjectives at similar latencies as in silent reading paradigms (e.g., Kissler et al., 2007). Future research should assess the time course of accessing emotional meaning in different word classes when crucial linguistic factors such as word frequency or word length are controlled for.

It should be noted that in comparison to the word material of other studies the verbs used here were comparable in mean frequency but appear to be of greater word length (e.g., Kissler et al., 2008; Scott, O'Donnell, Leuthold, & Sereno, 2008). This could explain in the present study why the RTs in the LDT were about 150 ms longer in the same task reported by Scott and coworkers.

4.2. Late effects of emotion

Angry faces and both positive and negative verbs augmented the LPC. This finding is in line with previous studies on affective picture processing (e.g., Cuthbert et al., 2000; Schupp et al., 2000), emotional word processing (Fischler & Bradley, 2006; Naumann et al., 1997; Schacht & Sommer, in press), and also with studies focusing on effects of emotional expressions in face recognition (e.g., Schupp, Öhman, et al., 2004; Schutter et al., 2004). Such LPC augmentations are commonly interpreted as an increase in the P300 component. For non-emotional stimuli enhanced P300 amplitudes are found when the ERP eliciting stimulus is attended (e.g., Johnson, 1988), infrequent, or task-relevant (e.g., Picton & Hillyard, 1988). Thus, the P300 is considered as an ERP component elicited by active cognitive processes of stimulus analysis caused by enhanced stimulus relevance (cf., Bashore & van der Molen, 1991, for a review). In terms of emotional processing, LPC effects may therefore be attributed to the emotional stimuli's increased motivational significance and arousal value (see Eimer & Holmes, 2002; Kayser et al., 1997; Schupp et al., 2000) and to reflect a continued perceptual analysis (cf., Kok, 2000) because of the high intrinsic relevance of emotional stimuli.

In emotional picture and word processing, several studies have shown the effect of positive emotional valence on LPC amplitudes to be similar—and sometimes even larger—as compared to negative valence (e.g., Cuthbert et al., 2000; Herbert et al., 2006; Kissler et al., 2008; Schacht & Sommer, in press; Schupp, Junghöfer, et al., 2004), whereas in the face domain usually negative expressions elicit increased LPC amplitudes (e.g., Schupp, Öhman, et al., 2004). This is in line with the present face decision task, where significantly larger LPC amplitudes were found to faces depicting negative as compared to both neutral and positive expressions. Also RTs and error rates were increased for angry faces, which might imply that anger expressions signal higher intrinsic relevance and involve a more elaborate processing at *later* stages. Possibly, this elaborate processing of negative expressions results in a depletion of resources for the task-relevant processes during visual scanning of faces for intactness, resulting in increased RTs. Alternatively, one might argue that both the augmentation of LPC amplitudes and the increased RTs to angry faces are the result of the difficulty of perceptually discriminating angry faces from smeared faces. On the other hand, enhanced LPC amplitudes to angry faces can not solely be related to effects of task since distracter faces elicited larger LPC amplitudes (see Fig. 5), but were discriminated much faster than intact faces of all emotion condition.

Whereas these LPC findings conform to those of others, our increased EPNs to happy faces are at variance with the increased EPN to angry faces reported by Schupp, Öhman, et al. (2004). It is difficult to explain this discrepancy in findings. One might speculate that they may be related to procedural difference such as stimulus size or luminance, the repeated presentation from different viewpoints or the absence of a task in the study of Schupp, Öhman, et al. (2004). Clearly, this discrepancy should be the subject of future investigations.

Interestingly, the late emotion-related ERP modulations showed some domain specificity. Relative to the neutral condition only angry but not happy faces elicited enhanced LPC amplitudes, whereas this was the case for both negative and positive words. The topographies of negative and positive emotions effects in the verbal domain were similar with maxima over the vertex. However, although appearing at a similar latency as the emotion effects in words, the emotion effect in the LPC to angry faces showed a more posterior distribution which was confirmed by significant domain effects in our profile analysis. These domain-specific results indicate that late emotion effects in the LPC reflect the involvement of at least partially different brain systems. Although it is possible that these effects truly reflect domain specificity of the emotion effects in terms of brain anatomy and—possibly—function, one should point out that there is a confound of the angry expression condition in faces with task difficulty in terms of reaction times and error rates. It appears that it was more difficult to distinguish this condition from smeared faces than it was for happy and neutral faces, possibly causing both the LPC increase and the distinct scalp distribution of this effect. Although the non-significant correlations between ERP and RT effects of the negative emotional expressions do not support this explanation, future research might assess this question in more detail.

Taken together, the present study directly compared—for the first time—emotional effects in word and face processing revealing two distinguishable effects of emotion. Most importantly, in both domains a first ERP difference that appeared between positive and neutral stimuli showed similar scalp distributions but emerged considerably earlier for faces than for words. This suggests shared neural brain systems involved in emotional processing in both stimulus domains. A second effect of emotion consisting of enhanced LPC amplitudes to both positive and negative verbs and to angry faces appeared at a similar latency in both domains but with notably different scalp topographies. Future work should clarify to which extent the domain specificity of the LPC distribution relates to emotional processes or to task difficulty, which was increased in this conditions.

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Appendix A

Target stimuli for lexical decision task.

Positive		Negative		Neutral	
anlachen	to smile at	ausbeuten	*to exploit*	abonnieren	*to subscribe*
aufblühen	*to flourish*	ausnutzen	*to advantage of so*	ausfüllen	*to fill in*
beglücken	*to favor with*	beleidigen	*to insult*	bedrucken	*to print on*
beköstigen	*to feed*	berauben	*to despoil*	befestigen	*to fix*
beschenken	*to give*	betrügen	*to defraud*	dünsten	*to steam*
bewundern	*to adore*	einsperren	*to imprison*	einfügen	*to insert*
bezaubern	*to enchant*	erhängen	*to hang*	einlagern	*to store*
einladen	*to invite*	erpressen	*to blackmail*	einordnen	*to range*
erfreuen	*to delight*	ertrinken	*to drown*	markieren	*to brand*
erheitern	*to amuse*	erwürgen	*to strangle*	nachmessen	*to remeasure*
erstrahlen	*to gleam*	röcheln	*to breathe stertorously*	panieren	*to crumb*
frühstücken	*to breakfast*	ruinieren	*to ruin*	polstern	*to pad*
musizieren	*to make music*	überfallen	*to hijack*	sortieren	*to sort*
schmunzeln	*to smile benignly*	verarmen	*to impoverish*	umrechnen	*to convert*
sonnenbaden	*to sunbath*	verenden	*to perish*	verdünnen	*to thin down*
spazieren	*to promenade*	verhungern	*to starve*	vermieten	*to lease*
streicheln	*to pet*	vermodern	*to molder*	verwalten	*to administer*
tanzen	*to dance*	vernichten	*to destroy*	zusenden	*to send*
überleben	*to survive*	verrecken	*to peg out*	abstempeln	*to postmark*
umschwärmen	*to idolize*	verseuchen	*to contaminate*	abwiegen	*to weigh*
verreisen	*to travel*	abstürzen	*to crash*	abwischen	*to wipe*
versüssen	*to sweeten*	anbrüllen	*to roar at so*	anfertigen	*to fabricate*
verwöhnen	*to coddle*	anspucken	*to split at*	anmelden	*to register*
ausschlafen	*to sleep in*	belästigen	*to annoy*	aufpumpen	*to pump up*
belohnen	*to reward*	bestrafen	*to punish*	aufzählen	*to enumerate*
beschützen	*to protect*	blamieren	*to embarrass*	beantragen	*to apply*
bezirzen	*to bewitch*	erbrechen	*to vomit*	besticken	*to embroider*
entspannen	*to relax*	erdrosseln	*to strangle*	einfädeln	*to thread*
erholen	*to recover*	erschlagen	*to slay*	einräumen	*to place in*
faszinieren	*to fascinate*	ersticken	*to suffocate*	erfragen	*to ask for*
geniessen	*to enjoy*	hinrichten	*to execute*	justieren	*to adjust*
harmonieren	*to accord*	verbluten	*to bleed to death*	kopieren	*to copy*
küssen	*to kiss*	verdammen	*to damn*	numerieren	*to number*
schlemmen	*to feast*	verfaulen	*to rot*	radieren	*to erase*
schmusen	*to smooch*	vergiften	*to poison*	schleifen	*to grint*
turteln	*to flirt*	verletzen	*to insure*	signieren	*to sign*
verführen	*to seduce*	verleugnen	*to disclaim*	speichern	*to save*
vernaschen	*to lay/love so up*	verprügeln	*to bash*	überdachen	*to roof*
verzücken	*to ecstasize*	verraten	*to betray*	umdrehen	*to turn around*
zuzwinkern	*to wink at so*	verwunden	*to wound*	umschulen	*to retrain*

Appendix B

B.1. Regional analyses

B.1.1. Lexical decision task

According to our previous findings (Schacht & Sommer, in press), early effects of emotion in the verbal domain are expected as enhanced negativity at occipito-temporal electrode sites, whereas late effects have been consistently shown as enhanced positivities at centro-parietal electrodes. Therefore, regional activity was assessed for early emotional effects at electrodes O1, Oz, O2, PO7, PO3, POz, PO4, PO8, P7, P5, P3, Pz, P4, P6, and P8, and for emotional LPC modulations at Cz, FCz, CPz, C1, and C3 electrode.

Additional regional analyses on activity of 15 occipito-temporal electrodes confirmed a main effect of emotion (3 levels) between 388 and 438 ms, $F(2,46) = 5.7$, $p < .01$, $\eta^2 = .168$, and between 438 and 488 ms, $F(2,46) = 3.0$, $p < .05$, $\eta^2 = .114$.

Further, regional analysis on mean LPC amplitudes of a cluster of five central electrodes (Cz, FCz, CPz, C1, and C3) confirmed a main effect of emotion between 538 and 588 ms, $F(2,46) = 4.5$, $p < .05$, $\eta^2 = .163$, and 588 and 638 ms, $F(2,46) = 4.5$, $p < .05$, $\eta^2 = .163$.

B.1.2. Face decision task

Due to the absence of homogeneous evidence for effects of emotional expression in the literature, a selection of electrodes for regional analysis was based on visual inspection of the scalp topography. For the EPN effect, a regional analysis of mean amplitudes on the same parieto-occipital electrodes as for the EPN in lexical decisions (see above) confirmed the main effect of emotion, between 128 and 144 ms, $F(2,46) = 12.7$, $p < .001$, $\eta^2 = .357$, and between 144 and 172 ms, $F(2,46) = 9.9$, $p < .001$, $\eta^2 = .301$.

In contrast to the late emotion effect in lexical decisions, the maximal LPC amplitudes are located more posteriorly (see Fig. 5). Therefore, regional analysis of mean ERP amplitudes of five posterior electrodes (Pz, CPz, POz, P1, and P2) averaged over the whole segment between 488 and 1000 ms, confirmed the main effect of emotional expression, $F(2,46) = 11.6$, $p < .001$, $\eta^2 = .336$.

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