Capture of lexical but not visual resources by task-irrelevant emotional words: A combined ERP and steady-state visual evoked potential study

Sophie M. Trauer [a], Søren K. Andersen [a,b], Sonja A. Kotz [c], Matthias M. Müller [a,*]

[a] Institute of Psychology, University of Leipzig, Leipzig, Germany
[b] Department of Neurosciences, University of California at San Diego, La Jolla, CA, USA
[c] Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

ARTICLE INFO

ABSTRACT

Numerous studies have found that emotionally arousing faces or scenes capture visual processing resources. Here we investigated whether emotional distractor words capture attention in an analogous way. Participants detected brief intervals of coherent motion in an array of otherwise randomly moving squares superimposed on words of positive, neutral or negative valence. Processing of the foreground task was assessed by behavioural responses and steady-state visual evoked potentials (SSVEPs) elicited by the squares flickering at 15 Hz. Although words were task-irrelevant, P2 and N400 deflections to negative words were enhanced, indicating that emotionally negative word content modulated lexico-semantic processing and that emotional significance was detected. In contrast, the time course of behavioural data and SSVEP amplitudes revealed no interference with the task regardless of the emotional connotation of distractor words. This dissociation of emotion effects on early perceptual versus lexical stages of processing suggests that written emotional words do not inevitably lead to attentional modulation in early visual areas. Prior studies have shown a distraction effect of emotional pictures on a similar task. Thus, our results indicate the specificity of emotion effects on sensory processing and semantic encoding dependent on the information channel that emotional significance is derived from.

© 2011 Elsevier Inc. All rights reserved.

Introduction

Emotional words and visual attention

It is of evolutionary advantage when our attentional focus not only follows perceptually striking items or current intentions. Objects that are dangerous or desirable and thus potentially relevant for an organism's survival should be detected and processed rapidly and prioritised over present task goals in many situations. Accordingly, emotionally significant signals are favoured in perception and memory as reflected in behavioural performance and corresponding cortical activity (for reviews, see Lang and Bradley, 2009; Vuilleumier, 2005). Arousing stimuli are detected quickly amongst other objects (Hodsoll et al., 2011; Öhman et al., 2001), are less prone to be missed when processing capacities are limited (e.g. Maratos et al., 2008), are more likely to be remembered (Versace et al., 2010), and boost perceptual processing as indicated by enhanced cortical activation along the ventral visual path (Sabatinelli et al., 2005). In spite of empirical evidence that affective stimuli are prioritised, it is still a matter of debate how invariably sensory processes are shaped by emotionally arousing signals (Vuilleumier and Huang, 2009). Here we examined how symbolic stimuli such as written words, whose meaning is not necessarily linked to their physical features, influence early visual processing.

Written words are acquired rather late in life. They can be ambiguous when presented out of sentence context (Fischler and Bradley, 2006) suggesting that the emotional arousal of words may be variable, if not too weak to capture attention. However, words still assert emotion effects on brain activity when presented subliminally (Bernat et al., 2001; Ortigue et al., 2004) and their valence can be guessed above chance even without awareness of the word (Nasrallah et al., 2009). Arousing verbal stimuli can lead to amygdala activation similar to that induced by emotional faces, pictures, or conditioned stimuli (Baas et al., 2004). Some studies found emotion effects on the ERP to written words as early as 100 ms (Begleiter and Platz, 1969; Landis, 2006; Scott et al., 2009; Skrandies, 1998; for a review see Kissler et al., 2006).

Thus emotional word content can be detected rapidly, but how does this influence further processing? Attentional effects of words have been investigated with a variety of paradigms: For example, Attentional Blink (AB) studies repeatedly reported identification advantages for emotional compared to neutral words. Keil and Ihssen (2004) presented verbs in Rapid Serial Visual Presentation (RSVP) streams containing one or two colour target words. Whilst

* Corresponding author at: Institute of Psychology, University of Leipzig, Seeburg-strasse. 14–20, 04103 Leipzig, Germany. Fax: +49 341 973 5969.
E-mail address: m.mueller@rz.uni-leipzig.de (M.M. Müller).

after the first target (T1) identification rates for a second target (T2) decreased for a short time (i.e. an AB was observed), T2 words of high arousal were identified more often than low arousing ones. Vice versa emotional words, even as irrelevant distractors, increase the AB in subsequent target identification (Arnell et al., 2007; Mathewson et al., 2008) indicating the enhanced capture of processing resources by emotional words. As another example, in emotional Stroop Tasks the meaning of a word serves as distractor whilst its ink colour has to be named. Several studies showed that arousing word content interferes more with colour naming as indicated by decelerated response latencies (McKenna and Sharma, 1995; Pratto and John, 1991; Williams et al., 1996). These findings support the assumption that arousing word content captures attention.

Note that in these studies the task was word identification or naming a colour. Therefore, it remains unclear whether emotional words are prioritised at perceptual or lexical stages of processing. However, there is evidence that affective words also compete with non-lexical stimuli and tasks. Dot-probe experiments require reactions towards neutral stimuli after task-irrelevant words are presented at possible target locations. Low-anxious participants have been shown to react slower to targets at locations where negative compared to neutral words were presented before, whereas anxiety correlates with accelerated detection of targets replacing threat words (Amir et al., 2003; MacLeod et al., 1986; Mogg et al., 1997). These findings demonstrate the influence of emotional words on visuospatial attention, but they also emphasise that behavioural effects of emotional words, being the result of a number of processing steps, can be strongly mediated by cognitive-motivational biases.

Imaging studies, which offer a more direct approach to study the influence of emotional words on activity in visual areas, have not yet drawn a consistent picture. During silent reading of emotionally positive compared to neutral and negative adjectives, an enhanced BOLD response in left extrastriate regions was found that was positively correlated with left amygdala activation (Herbert et al., 2009). However, using a lexical decision task, Kuchinke et al. (2005) observed no stronger activation for emotional as compared to neutral nouns in occipital regions. Thus, it remains unclear whether emotional words capture attention in terms of enhanced early visual processing or interfere with concurring tasks only at later stages of attentional selection.

The present study

Ongoing amplification of visual responses to emotional pictures and faces compared to neutral ones has been demonstrated by frequency-tagging the sensory processing of those stimuli using steady-state visual evoked potentials (SSVEPs; Bakardjian et al., 2011; Keil et al., 2003, 2010; McTeague et al., 2011). In a distraction paradigm, Müller et al. (2008; Hindi Attar et al., 2010a) presented neutral and emotional background pictures whilst participants performed a motion detection task on an array of randomly moving squares superimposed on the pictures. The onset of any recognisable picture led to decreased target detection rates and SSVEP amplitudes. This decrease was stronger for positive and negative pictures between 400 and 1000 ms after picture onset, indicating that emotional arousal of stimuli additionally biases competition for visual processing resources. This notion was supported further by an imaging study where activity in the motion-sensitive area V5, induced by the task array of moving dots, was reduced when emotional as compared to neutral background faces were presented (Hindi Attar et al., 2010b).

Here we investigated whether task-irrelevant emotional words capture visual processing resources as has been observed for emotional pictures and faces (Hindi Attar et al., 2010a,b; Müller et al., 2008). On the one hand, words are not very complex visual stimuli. On the other hand, their emotional connotation may be derived later than that of faces or scenes as indicated by early ERP

effects for emotional pictorial stimuli but not for words in studies that compared both stimulus types (Frühholz et al., 2011; Hinojosa et al., 2009). Therefore, previous results do not allow for more specific hypotheses about the timing and direction of effects. Thus, we examined the time course of emotion effects on ongoing visual processing by means of the SSVEP to a foreground task.

To our knowledge, only two previous studies have investigated the processing of emotional words with steady-state potentials. In an RSVP study emotional verbs led to a transient early increase of the SSVEP amplitude elicited by the presentation rate of 8.6 Hz (Keil et al., 2006). This facilitation correlated with more accurate word identification. The authors concluded that the SSVEP effect reflected a facilitation of early stages of visual word processing by affective content, especially so in situations of limited resources as during the attentional blink. In contrast, Koban et al. (2010) presented neutral and emotional nouns flickering at 7.5 Hz in a passive viewing paradigm and found a late and ongoing decrease in SSVEP amplitudes following positive words. Given that words are symbolic and perceptually simple stimuli the finding was interpreted as a potential "shift of attention to internal processes rather than external stimulation" [p. 10]. The authors argued that associative rather than perceptual encoding may be amplified by word affect, resulting in decreased sensory processes as indicated by decreased SSVEP amplitudes.

Both studies did not provide behavioural measures of selective attention. We therefore used a visual foreground task to investigate distraction effects of emotional words on steady-state and behavioural responses to the task. To simultaneously examine encoding of the task-irrelevant words we chose a higher flicker frequency (15 Hz) allowing for the concurrent analysis of ERPs elicited by word onset (see Müller and Hillyard, 2000). We hypothesised that the emotional meaning of background words, even though they were task-irrelevant, may modulate early stages of lexico-semantic analysis (i.e. ERP effects in the P2 time window, see e.g. Kanske and Kotz, 2007; Kissler et al., 2009) and later on during the N400 time window that reflects lexico-semantic integration (for a review, see Kutas and Federmeier, 2011). Furthermore, effects on the Late Positive Complex (LPC) were reported in most studies manipulating emotional word content (e.g. Fischler and Bradley, 2006; Herbert et al., 2008; Hinojosa et al., 2009).

Methods

Participants

23 right-handed subjects (12 female) with reported normal or corrected-to-normal visual acuity and a mean age of 23.4 years (SD: 2.8 years) took part in the experiment after giving written consent. All were native speakers of German and reported no prior difficulties in reading or orthography. Participants received course credit or monetary compensation. The experiment was conducted under the ethic provisions of the Declaration of Helsinki.

Stimuli

The task array (see Fig. 1) consisted of 180 randomly moving yellow squares (subtending approximately 0.3°×0.3° of visual angle each) superimposed on a grey rectangle (15°×7.5°) containing black background letter strings (10°×2°). A yellow fixation cross was presented at the centre of the screen throughout each trial.

60 neutral, 60 negative, and 60 positive German nouns were selected from a word pool rated in a prior study (Kanske and Kotz, 2010). Words differed significantly in terms of valence and arousal (see Table 1) but were matched for print frequency, word length in letters and syllables as well as concreteness as the latter factor has been shown to interact with emotion effects (Kanske and Kotz, 2007). 120 additional words served as filler items in training and