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Motivational priming and processing interrupt: Startle reflex modulation during shallow and deep processing of emotional words

Cornelia Herbert [a,b,*], Johanna Kissler [b]

[a] Department of Psychology, University of Wuerzburg, Wuerzburg, Germany
[b] Department of Psychology, University of Konstanz, Konstanz, Germany

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ABSTRACT

Valence-driven modulation of the startle reflex, that is larger eyeblinks during viewing of unpleasant pictures and inhibited blinks while viewing pleasant pictures, is well documented. The current study investigated, whether this motivational priming pattern also occurs during processing of unpleasant and pleasant words, and to what extent it is influenced by shallow vs. deep encoding of verbal stimuli. Emotional and neutral adjectives were presented for 5 s, and the acoustically elicited startle eyeblink response was measured while subjects memorized the words by means of shallow or deep processing strategies. Results showed blink potentiation to unpleasant and blink inhibition to pleasant adjectives in subjects using shallow encoding strategies. In subjects using deep-encoding strategies, blinks were larger for pleasant than unpleasant or neutral adjectives. In line with this, free recall of pleasant words was also better in subjects who engaged in deep processing. The results suggest that motivational priming holds as long as processing is perceptual. However, during deep processing the startle reflex appears to represent a measure of "processing interrupt", facilitating blinks to those stimuli that are more deeply encoded.

Q1 ## 1. Introduction

1.1. Background

The human startle reflex, typically elicited automatically in response to an abrupt aversive noise, is a prominent defensive reflex thought to protect the organism against potential harm and danger. It has been widely studied in both animals and humans as an index reflecting an organisms' basal motivational engagement (Lang, 1995). Startle modulation by emotional foreground stimuli has been demonstrated in a series of affective picture viewing studies (e.g., Bradley et al., 2006; see Bradley and Lang, 2000, Lang et al., 1997 for overviews). These studies show that the magnitude of the acoustically elicited startle eyeblink response varies as a function of picture valence. Eyeblinks are usually enhanced during viewing of unpleasant pictures and reduced during viewing of pleasant compared to neutral pictures. Theoretically, these findings are accounted for by the motivational priming hypothesis (Lang, 1995), according to which emotional responses to unpleasant and pleasant stimuli are controlled and primed by two distinct motivational brain systems — an appetitive and a defensive system. In this view, defensive reflexes such as the startle reflex are automatically primed during confrontation with unpleasant stimuli, which activate the defensive motivational system, and inhibited during encounter of pleasant stimuli that tune the organisms' appetitive motivational system. Empirically, this emotional valence-driven response pattern is most pronounced for highly arousing unpleasant and pleasant pictures and when probes are presented at long lead intervals, that is for startle tones presented later than 1 s after picture presentation (e.g., Bradley et al., 1999, 2006; see Gard et al., 2007 for early and late effects). It is further most clearly seen during external attention focus, that is when attention is directed towards the foreground stimuli and subjects engage in perceptual processing of the foreground stimuli (e.g., Bradley et al., 1990; Cuthbert et al., 1998; Filion et al., 1993).

However, in situations with different processing requirements, such as during affective imagery, the startle reflex is modulated by additional factors besides stimulus valence. Several studies report an increase in the acoustically elicited startle reflex during imagery of both unpleasant and pleasant relative to neutral scenes (Bradley et al., Q2
1995; Miller et al., 2002; Robinson and Vrana, 2000; Vrana, 1994, Q3
1995; Witvliet and Vrana, 1995). The results of these studies suggest that the stimulus' perceived arousal level, its personal relevance, but also more general factors such as attention direction and processing depth modify startle patterns during processing of unpleasant and pleasant emotional stimuli.

Miller et al. (2002) proposed that the discrepancy between startle patterns observed during affective picture viewing and affective imagery can best be accounted for by differences in processing demands such as attention direction and processing depth. Miller

* Corresponding author. Department of Psychology I, Biological Psychology, Clinical Psychology and Psychotherapy, University of Wuerzburg, Marcusstr. 9-11, 97070 Wuerzburg, Germany. Tel.: +49 931 31 81981.
E-mail address: cornelia.herbert@psychologie.uni-wuerzburg.de (C. Herbert).

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et al. (2002) hypothesize that picture viewing is a perceptual task, whereas imagery is a cognitive–mentational task that unlike picture viewing directs attention and processing resources away from the sensory environment towards internal processing of the foregrounds. Under such circumstances of enhanced mental processing, an aversive stimulus such as the startle tone is assumed to act as "processing interrupt", disrupting ongoing internally oriented mental processing for the purpose of rapid reorientation of processing resources to significant changes in the environment (Anthony and Graham, 1985; Miller et al., 2002).

If indeed both "motivational priming" and "processing interrupt" affect startle modulation during processing of emotional stimuli, two general modulatory patterns are expected to arise: First, motivational priming effects should arise especially during a type of processing that is more focused on the environment, that is on physical and external stimulus features. In cognitive terms, this is a shallow type of processing. Second, in line with the processing interrupt view, when attention is directed away from the environment and subjects engage in more internally oriented cognitive–mentational processing of the foreground stimuli, the startle reflex should be increased to those stimuli that receive deeper internal processing. In cognitive terms, this would be associated with deep processing.

Extending findings from affective picture viewing and affective imagery to the processing of verbal foreground stimuli, the current study aimed to validate these assumptions by investigating affective startle modulation in healthy subjects engaged in either shallow or deep processing of emotionally arousing pleasant and unpleasant words.

Concerning visual processing of words and pictures, previous research provides several examples supporting the view that emotional meaning is extracted rapidly from words and pictures alike. During viewing, both elicit similar cortical brain activity patterns (e.g., Fischler and Bradley, 2006; Herbert et al., 2008; Kissler et al., 2006, 2007, 2009; Schapkin et al., 2000) and activate emotional brain structures such as the amygdala, which is implicated in emotion perception and the modulation of approach- and withdrawal-reactions (e.g., Hamann and Q4 Mao, 2002; Herbert et al., 2009; Isenberg et al., 1999; Tabert et al., 2001). Thus, visual processing of emotional words should modulate basal emotional responses such as the startle reflex in a similar manner as has been demonstrated for pictures.

At present, only few studies investigated affective startle reflex modulation by verbal foreground stimuli using long lead intervals. Hazlett et al. (2007) found significantly enhanced startle responses during viewing of unpleasant relative to neutral words in subjects with borderline personality disorder as compared to normal controls (Hazlett et al., 2007). Two other studies, focusing on the effects of trait anxiety, found a trend towards enhanced startle responses during viewing of unpleasant relative to neutral words in both participants with high and low levels of trait anxiety (Aitken et al., 1999; Waters et al., 2000). Although these studies demonstrate startle modulation by unpleasant verbal foregrounds, it is unclear whether effects are due to motivational priming or to clinically relevant differences in subjective arousal or processing styles. Concerning healthy subjects only few data exist, but the results show an increase in the acoustically elicited startle eyeblink response during encoding of pleasant emotional words, in particular (Herbert et al., 2006).

As detailed above, both the stimulus' emotional valence and its arousal level are critical for affective modulation of the startle response (Bradley et al., 2001, 2006), but emotional imagery studies suggest that startle modulation is also affected by task demands such as attention direction and processing depth (Miller et al., 2002). Interestingly, in healthy student volunteers pleasant words have repeatedly been found to be more deeply encoded and remembered than unpleasant or neutral words (e.g., Ferré, 2003; Herbert et al., 2008, 2009; Kiefer et al., 2007; Monnier and Syssau, 2008; Schapkin et al., 2000; Watson et al., 2007), even when words were matched for arousal, concreteness, and orthographic neighbourhood density (Herbert et al., 2008, 2009). Particularly during encoding of pleasant words, enhanced startle responses have also been observed (Herbert et al., 2006): Notably, in Herbert et al.'s (2006) study, startle magnitude during processing of pleasant words was positively correlated with the late positive event-related brain potential, an index of encoding depth, suggesting that enhancement of the startle eyeblink response during processing of pleasant words was related to deeper encoding of pleasant than of neutral words. This recent finding of larger startle reactivity during encoding of pleasant than of neutral contents is in line with both previous findings of enhanced startle responses during imagery of pleasant stimuli (Bradley et al., 1995; Q5 Miller et al., 2002; Vrana, 1994, 1995; Witvliet and Vrana; Cook et al., Q6 1991; Robinson and Vrana, 2000) and the "processing interrupt Q7,Q8 hypothesis" predicting larger startle responses in processing conditions, where subjects are engaged in non-perceptual, internal mental processing of the foregrounds.

Theoretically, regardless of the type of foreground stimulus (picture or word), affective startle modulation should show the typical motivational priming pattern of blink potentiation to unpleasant and blink inhibition to pleasant content when stimulus processing is predominantly perceptual. This has been shown in many of the above mentioned affective picture studies. However, previous research probing affective startle modulation during mental imagery or memory encoding of emotional words suggests that during deep processing, when attention is not focused on perceptual characteristics of a stimulus, the startle reflex represents a measure of "processing interrupt". Startle modulation by emotion appears to interact with this interrupt function.

On the basis of the above findings, we hypothesized that affective startle patterns vary as a function of the individuals' processing strategies, showing motivational priming during shallow processing, but enhanced blink responses in response to deeply processed emotional words. If the startle eyeblink response was facilitated during deep processing of emotional and particularly pleasant words, results would be in line with previous observations (Herbert et al., 2006). Alternatively, if the startle response was primarily affected by stimulus arousal, startle responses should be generally enhanced during deep processing of both unpleasant and pleasant words. To test these predictions, we measured startle eyeblink magnitude in response to loud startling tones administered while participants processed pleasant, unpleasant, and neutral words, using either shallow or deep-encoding strategies. As a further behavioural measure of processing depth, participants' memory performance was examined in a post-experimental free recall memory test. Moreover, post-experimental ratings of valence and arousal for startled adjectives were obtained to assess potential differences in perceived valence and arousal between the experimental and normative samples.

2. Methods

2.1. Subjects

Thirty-seven native German students of the University of Konstanz (16 males and 21 females, mean age: 26 years) took part in the study. Subjects were paid 10€ in return for participation and gave written informed consent prior to the experiment. Upon interview, all subjects reported normal audition and normal or corrected to normal vision. Subjects were screened for handedness (Oldfield, 1971), drug abuse, chronic bodily, neurological or psychiatric diseases and medication for any of these. None of the subjects had increased scores of state or trait anxiety or depression as revealed by self-report measures of anxiety (STAI, Laux et al., 1981) and depression (BDI, Hautzinger et al., 1994).

Eighteen participants (8 males, 10 females) were assigned to the "shallow encoding group" and nineteen participants (8 males, 11 females) to the "deep-encoding group". A between-group design was implemented

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Table 1
Stimulus material characteristics. Mean valence, arousal and concreteness scores as well as word length (number of letters) and word frequency counts (words per million) of startled pleasant, unpleasant, and neutral adjectives. Note: For valence, arousal and concreteness, ratings ranged from 1 (extremely negative valence, extremely low arousal or concreteness) to 9 (extremely positive valence, extremely high arousal or concreteness). Standard errors are in parentheses. Word frequency counts for written language are based on the standardized word-database CELEX (Baayen et al., 1995).

Startled adjectives — normative sample			
	Pleasant	Unpleasant	Neutral
Valence	7.14 (0.16)	2.47 (0.07)	4.62 (0.06)
Arousal	5.98 (0.13)	6.03 (0.09)	3.50 (0.10)
Concreteness	4.26 (0.23)	3.56 (0.26)	4.09 (0.40)
Word length	8.72 (0.67)	8.0 (0.41)	8.05 (0.37)
Word frequency	33.88 (11.67)	27.67 (12.9)	32.44 (9.43)

to avoid possible sequence effects that could have resulted from a within-design. In particular, assigning participants first to a 'deep-encoding' task might have affected a second 'shallow' encoding task, because it could have drawn attention to certain aspects of the stimuli that might have otherwise gone unnoticed. Such effects could be difficult to undo in a second run. Participants in the shallow and deep processing group did not differ in socio-demographic variables or handedness and scored equally on measures of state anxiety (STAI-state, mean: deep: 34.3, shallow: 36.3, $t(35) = -0.5$, $p > 0.5$) and trait anxiety (STAI-trait, mean: deep: 30.8, shallow: 31.8, $t(35) = -0.3$, $p > 0.7$) and depression (BDI, mean: deep: 3.42, shallow: 3.33, $t(35) = 0.07$, $p > 0.9$).

2.2. Apparatus and stimulus material

Experimental stimuli consisted of 228 adjectives describing arousing unpleasant and pleasant affective traits and states as well as less arousing neutral traits and states. Adjectives were taken from a corpus of German words (nouns and adjectives). This corpus of words was previously collected by our research group and provides arousal, valence, and concreteness ratings from 45 adult native speakers of German for a set of about 800 German words. Valence and arousal ratings were obtained on the Self-Assessment Manikin scale (SAM, Bradley and Lang, 1994) in analogy to the ANEW standardized list of affective norms for English words (ANEW, Bradley and Lang, 1999) and the IAPS International Affective Picture System (Lang et al., 2005).

In total, 76 pleasant, 76 unpleasant, and 76 neutral adjectives were presented. Mean valence, arousal, and concreteness scores as well as word length and word frequency counts of startled pleasant, unpleasant, and neutral adjectives are given in Table 1. Pleasant and unpleasant adjectives did not differ significantly in emotional arousal, but were both more emotionally arousing than neutral adjectives. Mean valence differed appropriately (pleasant > neutral > unpleasant). The 18 most unpleasant and the 18 most pleasant adjectives that did not differ in their normative arousal ratings, as well as 18 less arousing neutral words were paired with a startle tone. Neutral 'to-be-startled' adjectives were those 18 valence-neutral words which obtained the lowest arousal ratings. A list of the used startled words and their English translation is given in Appendix A for reference.[1] Emotional and neutral adjectives did not differ in terms of non-emotional aspects, i.e. concreteness, word length or word frequency.

Adjectives were presented in black letters (font = "Times"; size = 40) centred on a white background of a 15 inch computer monitor placed 80 cm away from the participants' eyes. Each word was presented for 5 s and followed by a variable inter-stimulus interval of 1800–2200 ms. Pleasant, unpleasant and neutral adjectives were presented randomly with the constraints that a) no more than two words of the same category (pleasant, unpleasant, and neutral) occurred in sequence and b) startled words were never consecutive. Startle probes were presented acoustically in a time window of 2.5–4.0 s after word onset. Six additional startle tones (two per word category) were delivered at 0–300 ms and 4700–5000 ms. These very early and very late startle probes were not included in the analysis, but served to adapt participants to the startle tones and reduce predictability of startle tone presentation. The acoustic startle probes consisted of 95-dB sound pressure level bursts of white noise with 50 ms duration and instantaneous rise and fall times presented binaurally via stereo headphones.

Experimental runs were generated and controlled by "Presentation" software (Neurobehavioral Systems Inc.).

2.3. Procedure

Upon arrival, subjects were familiarized with the laboratory setting and the experiment was explained to them in general terms. They were questioned about their handedness and health, state- and trait anxiety as well as depression scores were determined and participants signed an informed consent form. Hereafter, participants were seated in a dimly lit, sound attenuated, electrically shielded room, electrodes were attached for electromyographic startle eyeblink measurements, and participants were given more detailed instructions.

Participants were told that they would be shown a set of adjectives that they should process by means of either a shallow or a deep processing strategy. Therefore, participants were provided with examples of shallow and deep processing strategies. In line with Craik and Lockhart's (1972) level of processing framework, shallow processing strategies included passive viewing ($N = 6$), rote stimulus rehearsal ($N = 9$), or lexical categorization ($N = 3$). Deep processing strategies included semantic categorization ($N = 4$), mental imagery ($N = 8$), and thinking about the word's personal relevance ($N = 7$). Participants were asked to choose a processing strategy and then stick to it throughout the entire experiment. Also, they were told that during some words a startling tone would be played via headphones, which they should ignore. They were instructed to keep their eyes open and to fixate the words for the entire viewing period. After completion of the experimental recording session, electrodes were detached and participants were questioned about the strategy they had used during the experiment. Participants' post-experimental self-report of processing strategy served as a manipulation-check to ensure correct assignment of participants' to our a priori defined processing groups (shallow vs. deep). Assignment of participants' to either the shallow or deep processing group was further validated by means of discriminant analysis (see below). Finally, participants were told to recall and write down as many of the presented adjectives as they could and their subjective valence, arousal, and concreteness ratings were assessed for all of the startled adjectives. For these ratings, a nine-point paper–pencil version of the SAM scales (Bradley and Lang, 1994) with the dimensions valence, arousal, and additionally also concreteness, was used. Participants were then debriefed about the purpose of the present experiment.

2.4. Physiological data collection and reduction

2.4.1. Electromyographic recording — startle eyeblink response

The electromyographic (EMG) startle eyeblink response was measured via two miniature Ag/Ag electrodes (5 mm diameter). Electrodes were attached at the left orbicularis oculi muscle beneath the left eye. For all subjects inter-electrode distance was 1 cm. Recording and analysis of startle data followed recommendations by Berg and Balaban (1999) and Blumenthal et al. (2005). EMG signals were recorded continuously, with bandpass from DC to 500 Hz, amplified by 500, and sampled at 2000 Hz. EMG electrodes were connected to ground and impedance was kept below 5 kΩ for all electrodes. EMG activity was recorded with NEUROSCAN SynAmps amplifier and analyzed with BrainVision Analyzer software (BrainProducts GmbH).

[1] The complete list of the words used in this study (original and translation) together with valence and arousal ratings is available from the authors upon request.

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Offline, the EMG signal was bandpass filtered at 28–500 Hz and rectified. Startle eyeblinks were determined in a time window from 20 to 200 ms after the onset of each startle probe from the filtered, rectified, and baseline corrected EMG signal. The 100 ms before word onset was used for startle baseline correction. For each trial and word category, the startle peak amplitude and the onset latency of the startle blink were scored. Blinks were not scored, if a response occurred before 20 ms or later than 200 ms after probe onset or when onset-to-peak latency was greater than 120 ms. For each subject and emotional word category, the average EMG peak amplitude (microvolt), and peak latency (milliseconds) were computed. Trials with no detectable response were scored as zero.

2.5. Statistical data analysis

2.5.1. Startle eyeblink

Modulation of the startle eyeblink component was analyzed in a 3×2 ANOVA design including the factors “Valence” (pleasant, unpleasant, and neutral) as within-subject factor and the factor “Strategy” (shallow vs. deep) as between-subject factor.

Latency of startle peaks was also analyzed, but no effect of stimulus valence was detected, nor did “Strategy” or an interaction between stimulus valence and strategy impact startle peak latency (all $p > 0.2$). Thus, latency is not further reported here.

2.6. Behavioural data

2.6.1. Free recall

Free recall memory performance was analyzed for correctly remembered adjectives and tested with a repeated measurement ANOVA, including the within-subject factor “Valence” (pleasant, unpleasant, and neutral) and the between-subject factor “Strategy” (shallow vs. deep).

2.6.2. Subjective ratings

Participants' post-experimental ratings of emotional valence, arousal and concreteness for startled words were tested with ANOVAs, each containing word category (unpleasant, pleasant, and neutral) as within-subject factor, and strategy use (shallow vs. deep) as between-subject factor.

For all data, significant ANOVA effects containing more than one degree of freedom in the numerator are reported after adjustment for violations of the sphericity assumption using the Greenhouse–Geisser procedure and Greenhouse–Geisser epsilons (G–G ε) smaller than 1.0. Significant main and interaction effects were decomposed using planned comparison tests and linear trend tests.

2.7. Discriminant analysis

The effect of strategy use on startle eyeblink magnitude in the two different groups and the effectiveness of group assignment were validated using discriminant analysis. Methodologically, the goal of discriminant analysis is to predict membership of subjects to two or more a priori defined groups on the basis of a dependent variable (here eyeblink magnitude). Discriminant analysis was performed with the statistical software package SPSS (SPSS Inc.). Participants' startle responses elicited during processing of pleasant, unpleasant, and neutral adjectives were entered as independent variables into the discriminant analysis using the “enter independents together” algorithm and “shallow vs. deep processing” were used as grouping variable. Discriminant analysis provides a summary of number and percent of subjects assigned correctly or incorrectly to either of the two groups. In addition, we report Wilks' Lambda. A small lambda occurs when within-group variability is small compared to the total variability. A small lambda indicates that group means differ. The statistical significance of the difference is reflected in the associated p-value.

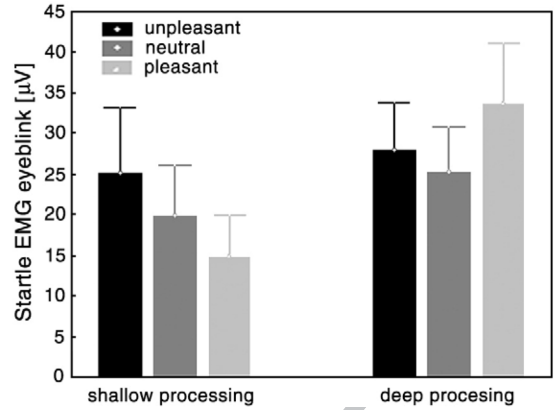

Fig. 1. Modulation of the EMG startle eyeblink response during shallow and deep processing of pleasant, unpleasant, and neutral adjectives. Note: The graphic displays means and standard errors (SEM) of the acoustically elicited startle eyeblink response during shallow and deep processing of pleasant, unpleasant, and neutral adjectives.

3. Results

3.1. Startle eyeblink

The startle eyeblink component showed a significant interaction of the factors “Valence × Strategy” ($F(2,70) = 11.9$; $p_{G–G} < 0.01$; $\varepsilon_{G–G} = 0.68$), revealing a differential impact of processing strategies on startle modulation patterns: Blinks were potentiated by unpleasant and inhibited by pleasant adjectives relative to neutral adjectives in subjects using shallow word encoding strategies (pleasant–neutral: $F(1,35) = 5.4$, $p < 0.05$; pleasant–unpleasant: $F(1,35) = 9.6$, $p < 0.01$; unpleasant–neutral: $F(1,35) = 6.9$, $p < 0.01$). Moreover, linear trend tests indicated a highly significant linear relationship between stimulus valence and startle amplitude in the shallow processing group (unpleasant > neutral > pleasant: $F(1,35) = 9.48$; $p < 0.001$). By contrast, in subjects using deep word encoding strategies, blinks were facilitated specifically to pleasant adjectives (pleasant–neutral: $F(1,35) = 18.14$, $p < 0.01$; pleasant–unpleasant: $F(1,35) = 3.4$ $p = 0.07$; unpleasant–neutral: $F(1,25) = 2.1$, $p > 0.1$). The main factors “Valence” ($F(2,70) = 2.67$; $p > 0.1$) and “Strategy” ($F(1,35) = 0.76$; $p > 0.3$) were not significant.

Affective modulation patterns of the startle eyeblink response during shallow and deep word processing are shown in Fig. 1.

3.2. Memory — free recall

Analysis of memory data showed significant effects for the main factors “Valence” ($F(2,70) = 14.4$, $p < 0.001$) and “Strategy” ($F(1,35) = 8.63$, $p < 0.005$) as well as the interaction of the main factors “Valence” and “Strategy” ($F(2,70) = 5.34$, $p_{G–G} < 0.01$; $\varepsilon_{G–G} = 0.89$). Thus, adjectives were better remembered when encoded deeply at study. Pleasant adjectives were significantly better remembered than unpleasant or neutral adjectives (pleasant–neutral: $F(1,35) = 20.1$, $p < 0.01$; pleasant–unpleasant: $F(1,35) = 15.8$, $p < 0.01$), in subjects using deep processing strategies (deep: pleasant–neutral: $F(1,35) = 25.47$, $p < 0.01$; pleasant–unpleasant: $F(1,35) = 23.8$, $p < 0.01$). Unpleasant adjectives were not remembered better than neutral adjectives regardless of processing strategy (shallow: unpleasant–neutral: $F(1,35) = 0.67$, $p > 0.4$, deep: unpleasant–neutral: $F(1,35) = 1.32$, $p > 0.25$). Comparisons within the shallow processing group were not significant. Memory performance of correctly remembered adjectives is displayed in Fig. 2.

3.3. Post-experimental subjective ratings

Post-experimental ratings of emotional valence, arousal and concreteness of startled adjectives showed that participants evaluated startled pleasant adjectives as more emotionally pleasant and startled

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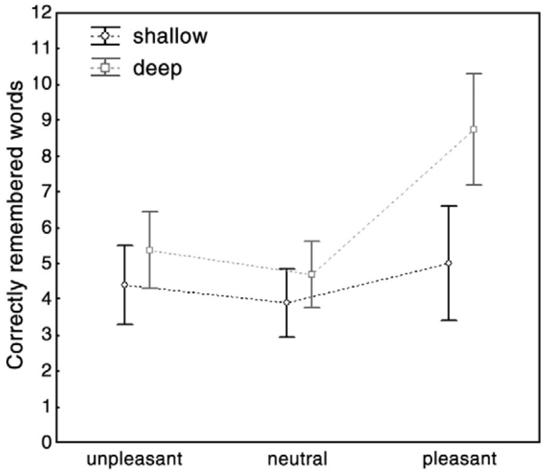

Fig. 2. Free recall memory performance. Memory for correctly remembered emotional and neutral adjectives as obtained from a free recall test after shallow and deep processing of pleasant, unpleasant, and neutral adjectives.

unpleasant adjectives as more emotionally unpleasant than startled neutral adjectives (Valence$_{participants}$: $F(2,70)=683.78$, $p<0.001$). Moreover, both startled pleasant and startled unpleasant adjectives were judged as more arousing than startled neutral adjectives (Arousal$_{participants}$: $F(2,70)=164.10$, $p<0.001$). Surprisingly, startled pleasant adjectives were rated as more arousing than startled unpleasant adjectives (pleasant–unpleasant: $F(1,35)=30.9$, $p<0.01$). Concerning stimulus concreteness, emotional and neutral to be startled adjectives were evaluated as equally concrete (Concreteness$_{participants}$: $F(2,70)=2.68$, $p>0.1$). Comparisons of participants of the two processing groups (shallow vs. deep) showed no significant group differences in valence, arousal and concreteness ratings of startled words (all $p>0.3$). Participants mean valence, arousal and concreteness ratings are summarized in Table 2.

3.4. Discriminant analysis

Results showed that based on the measured startle data, 89.2% of our participants were assigned correctly to either the shallow or the deep processing group (shallow: $N=17$ out of 18, deep: $N=16$ out of 19). Wilks' Lambda was 0.667 ($p<0.001$), indicating that startle patterns differed significantly between the two processing groups.

4. Discussion

The current study aimed at determining the factors and potential mechanisms that drive startle modulation during shallow and deep processing of emotional words. First, we investigated whether for emotional words as foregrounds, motivational priming, that is reflex potentiation by unpleasant words and reflex inhibition by pleasant words occurs at all. Second, we studied to what extent the startle eyeblink pattern during processing of emotional words is modulated by the way words are processed (shallow vs. deep processing). Therefore, affective startle modulation was examined in two groups of healthy participants who processed the words by means of either shallow or deep processing strategies. Results showed a significant interaction of processing mode (shallow vs. deep) with affective startle modulation patterns.

In the shallow word processing group, startle responses varied as a function of stimulus valence. Eyeblinks were larger during processing of unpleasant than during processing of both neutral and pleasant adjectives, blinks during processing of pleasant adjectives also being significantly smaller than during processing of neutral ones. This startle response modulation by emotional valence has been proposed to reflect a general principle of motivational response organization, priming and preparing the mobilization of defensive responses during confrontation with aversive stimuli and inhibiting defensive reactions to stimuli signalling approach and reward (Lang, 1995; Lang et al., 1997). In line with this assumption, motivational priming of the startle reflex has been replicated many times during viewing of emotionally evocative picture stimuli (Bradley and Lang, 2000, and Lang et al., 1997 for an overview) and blink potentiation during viewing of threat-related and disorder-relevant words has been demonstrated in three recent-studies (Aitken et al., 1999; Hazlett et al., 2007; Waters et al., 2000). Nevertheless, the full pattern of emotional priming during word processing, including blink inhibition during viewing of pleasant words, has not been demonstrated before.

Second, and in line with previous studies probing startle modulation during viewing of emotional pictures and unpleasant words (e.g., Bradley et al., 2006; Aitken et al., 1999; Waters et al., 2000), motivational priming effects occurred during shallow processing only. Given that picture viewing and shallow processing of words are perceptual tasks, our findings support the notion that motivational priming accounts for modulation of the startle during perceptual processing of affective stimuli (e.g., Bradley et al., 1990, 2001; Cuthbert et al., 1998; Filion et al., 1993), that is when attention is captured automatically by emotional stimuli (e.g., Herbert et al., 2008; Kissler et al., 2007; Schupp et al., 2004, 2006). Under such conditions, activation of emotional brain structures implicated in emotion perception and approach- and withdrawal-reactions has also reliably been demonstrated (e.g., Bradley et al., 2003; Sabatinelli et al., 2009; Smith et al., 2006).

Third, by probing startle modulation under different conditions of shallow and deep processing of emotional words, we were able to elucidate under which overall processing conditions the startle reflex is modulated primarily by effect or by additional factors. The Q9 processing instructions chosen, corresponded to instances of shallow (e.g., passive viewing, rote stimulus rehearsal, and lexical categorization) vs. deep processing (e.g., semantic processing, mental imagery, and relevance evaluation) as suggested by Craik and Lockhart (1972). Discriminant analysis confirms that the shallow and deep processing instructions differed in their effect on startle modulation, although each individual strategy within the deep or shallow distinction is likely to have its own characteristic processing demands which may have slightly different effects on physiological reactivity that should be analyzed in future studies.

Earlier studies, which investigated startle modulation during emotional imagery (Bradley et al., 1995; Miller et al., 2002; Vrana, Q10 1994, 1995; Witvliet and Vrana, 1995; Robinson and Vrana, 2000) and Q11 encoding of emotional words (Herbert et al., 2006) suggest that under conditions of enhanced mental engagement and internally focused attention, ongoing cognitive processes affect startle modulation during processing of emotional stimuli. Specifically, it has been proposed that when processing resources are directed away from perceptual processing of the environment and allocated toward internal, memory-based processing, the startle interrupts ongoing cognitive processes for the purpose of rapid reorientation of processing resources to changes in the environment. As pointed out by Miller et al. (2002) and Graham (1979),

Table 2
Rating data (participants). Mean valence, arousal and concreteness ratings of startled pleasant, startled neutral, and startled unpleasant adjectives according to ratings of the participants. Note: Valence, arousal and concreteness ratings ranged from 1 (extremely negative valence, extremely low arousal or concreteness) to 9 (extremely positive valence, extremely high arousal or concreteness). Standard errors are in parentheses.

Startled adjectives — participants			
	Pleasant	Unpleasant	Neutral
Valence	7.32 (0.08)	2.44 (0.11)	4.55 (0.05)
Arousal	6.11 (0.24)	5.30 (0.20)	2.45 (0.16)
Concreteness	4.50 (0.17)	3.98 (0.15)	4.27 (0.15)

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without such an interrupt mechanism, the organism would be highly vulnerable to environmental threat when subjects engage in internal processing. As a consequence of this processing interrupt function, blinks will be facilitated in particular to those stimuli that are more deeply processed.

In line with this, we found the acoustically elicited startle eyeblink response to be facilitated during deep processing of specifically pleasant adjectives. In the deep processing group startle amplitudes were also somewhat larger for unpleasant than for neutral adjectives, but, like in an earlier study (Herbert et al., 2006) that showed larger EMG startle responses during covert evaluation and encoding of pleasant than unpleasant or neutral adjectives, the unpleasant–neutral difference was not significant.

Moreover, in the present study pleasant adjectives were better remembered than unpleasant and neutral adjectives when encoded deeply at study, providing further support for the view that larger EMG startle responses during deep processing may be the product of the interruptive impact of the startle. Better memory for deeply encoded pleasant adjectives also agrees with previous reports (e.g., Schapkin et al., 2000; Watson et al., 2007) of more enhanced processing of pleasant than unpleasant or neutral words in tasks requiring enhanced internal memory-based, evaluative, or self-referential processing. Elucidating the mechanisms of this advantage for pleasant stimuli is beyond the scope of the present study. Nevertheless, it has been theoretically suggested and empirically demonstrated repeatedly that healthy subjects hold profound biases towards pleasant in contrast to unpleasant and neutral stimuli (e.g., Deldin et al., 2001; Ferré, 2003; Herbert et al., 2008, 2009; Kiefer et al., 2007; Kissler and Hauswald, 2008; Koenig and Mecklinger, 2008; Monnier and Syssau, 2008; Schapkin et al., 2000; Watson et al., 2007). Thus, a processing bias in favour of pleasant stimuli may, at least during deep processing conditions, bias participants' evaluations and bodily emotional responses towards words with pleasant content. Although theoretically the present results could be specific to pleasant stimuli per se, we suggest that the results are more likely due to pleasant words having been more deeply processed in this experiment.

Our observations corroborate the idea of "processing interrupt" as a functional mechanism underlying startle modulation during deep processing of emotional stimuli, but there are limitations: In between-group designs differences in startle modulation patterns observed during shallow and deep processing may be influenced by differences other than processing interrupt. Previous studies have shown that startle is modulated by individual differences in negative or positive affect as well as subjective arousal (e.g., Hazlett et al., 2007; Waters et al., 2000). We assessed a number of such potential factors and found that subjects using shallow vs. deep processing strategies differed neither in self-report measures of anxiety and mood, nor in valence and arousal ratings. Participants' post-experimental ratings showed that startled pleasant adjectives were experienced as significantly more arousing than startled unpleasant adjectives, but this effect did not differ between the groups and the numerical differences were small. Still, this result is somewhat surprising given that on pre-experimental normative ratings pleasant and unpleasant words did not differ in arousal. The effect may be a consequence of the experimental treatment. Perhaps pairing words with startling tones alters arousal perception and possibly attenuates arousal for the affectively more congruent pairings of startle and unpleasant words and enhances it for the incongruent pairings of pleasant words with startle. Post-experimental arousal ratings for startled unpleasant words are indeed somewhat lower and arousal ratings for pleasant startled words somewhat higher than the normative ratings (see Tables 1 and 2). On the other hand, unknown accidental differences between the normative and the experimental population may account for this finding. In the absence of both pre- and post-experimental ratings for the stimuli there is no firm answer to this question.

Since previous studies demonstrate that both the stimulus' emotional valence and its arousal level modulate the startle response during processing of emotional stimuli (e.g., Bradley et al., 2001, 2006; Witvliet and Vrana, 1995), we need to address the possibility that the present larger eyeblink response for pleasant foregrounds in the deep processing group is due to differences in arousal. In order to follow up on this possibility, participants' arousal ratings were used as covariates. After removal of variance associated with arousal, the same processing patterns as reported above were found and the interaction effect between the factors "Valence" and "Strategy" remained highly significant ($F(2,64) = 11.2$, $p < 0.001$). Therefore, an arousal difference alone cannot explain why for the shallow processing group the startle eyeblink response was facilitated during processing of unpleasant words and inhibited during pleasant words, whereas in the deep processing group startle eyeblink responses were facilitated only during deep processing of pleasant words. Thus, effects appear to be a consequence of the experimental treatment verifying motivational priming and processing interrupt as two functional mechanisms for startle modulation during shallow and deep emotional stimulus processing. Future research along these lines may provide further tests of this hypothesis. To this end, comparing startle modulation during specific shallow and/or deep processing strategies in a within-subject design could prove useful. Although theoretically preferable, the realization of within designs in experiments like the present one is not trivial because of possible confounding sequence effects. While it is most likely unproblematic to first assign participants to a shallow processing strategy and then switch to deep processing, the reverse may introduce carry-over effects, because a deep processing strategy often alerts participants to aspects like self-reference or emotional significance that may not be easily undone, even with a second, parallel, set of stimuli.

Startle facilitation as a function of processing depth was demonstrated previously (Herbert et al., 2006). In this study, encoding of pleasant adjectives enhanced both amplitudes of late cortical potentials (LPP) and the acoustically elicited startle eyeblink, and both measures were positively correlated. In the current study blink facilitation by pleasant adjectives was found in deep-encoding subjects, providing further support for the view that processing depth enhances the startle during deep processing.

Concerning attention direction, previous studies have mainly focused on modality-specific effects, directing attention either to the modality of the foregrounds or the startle probe. These studies show that allocating attentional resources to the foregrounds decreases the magnitude of the startle response compared to when attention is directed to the startle probe itself (for comprehensive reviews see Filion et al., 1998; Putnam and Vanman, 1999, but see Böhmelt et al., 1999; Lipp et al., 2003a,b for attention-potentiated effects). In the present study, only the type of processing of the foreground stimuli was varied and effects of levels of processing were demonstrated. Attention was never directed to the startle probe itself and such a manipulation may, like in previous studies, still result in larger overall startle responses. This issue could be addressed in future studies.

In sum, the present study gives important insights into the modulation of basal reflexes by emotional stimuli during cognitively different processing conditions. It is the first study that demonstrates motivational priming of the startle reflex during processing of verbal material and it elucidates some boundary conditions of this effect. Our observations corroborate the idea that motivational priming and processing interrupt are two functional mechanisms that drive startle modulation during shallow and deep processing of emotional stimuli. Although further validation using a within-subject rather than a between-group design and an extension to other types of emotional stimuli are needed, the current findings are noteworthy and important. They can provide a basis for further systematic research regarding the impact of cognitive strategies on emotion processing and particularly the regulation of basic physiologic bodily responses.

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Q13 5. Uncited references

Cuthbert et al., 1996

Vrana and Lang, 1990

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Appendix A

Unpleasant	Pleasant	Neutral
Ängstlich	Ausgelassen	Neutral
Anxious	Jolly	Neutral
Blutig	Begeistert	Irrelevant
Bloody	Thrilled	Irrelevant
Korrupt	Entusiastisch	Breit
Corrupt	Enthusiastic	Broad
Lügnerisch	Erotisch	Bürgerlich
Dishonest	Erotic	Civilian
Neidisch	Euphorisch	Chemisch
Envious	Euphoric	Chemical
Rabiat	Frei	Eckig
Rude	Free	Square
Giftig	Fröhlich	Eigenartig
Toxic	Cheerful	Idiosyncratic
Grausam	Heldenhaft	Flach
Cruel	Heroic	Flat
Sarkastisch	Interessant	Gewöhnlich
Sarcastic	Interesting	Usual
Illoyal	Vergnügt	Lautlos
Disloyal	Merry	Silent
Infiziert	Verliebt	Mechanisch
Infected	In love	Mechanical
Zerstört	Verführerisch	Psychisch
Ruined	Alluring	Mental
Wütend	Sexy	Trocken
Furious	Sexy	Dry
Teuflisch	Rebellisch	Typisch
Diabolic	Rebellious	Typical
Speiübel	Fantastisch	Subjektiv
Queasy	Amazing	Subjective
Sorgenvoll	Nackt	Speziell
Sorrowful	Naked	Particular
Sexistisch	Mutig	Unbewusst
Sexist	Brave	Unconscious
Schuldig	Lustvoll	Schläfrig
Guilty	With relish	Drowsy

References

Aitken, C.J., Siddle, D.A., Lipp, O.V., 1999. The effects of threat and non threat word lead stimuli on blink modification. Psychophysiology 36, 699–705.

Anthony, B.J., Graham, F.K., 1985. Blink reflex modification by selective attention: evidence for the modulation of 'automatic' processing. Biol. Psychol. 21, 43–59.

Baayen, R.H., Piepenbrock, R., Gulikers, L., 1995. The CELEX Lexical Database (CD-ROM). Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Berg, W.K., Balaban, M.T., 1999. Startle elicitation: stimulus parameters, recording techniques, and quantification. In: Dawson, M.E., Schell, A.M., Bohmelt, A.H. (Eds.), Startle Modification: Implications for Neuroscience, Cognitive Science, and Clinical Science. New York, Cambridge University Press, pp. 157–183.

Blumenthal, T.D., Cuthbert, B.N., Filion, D.L., Hackley, S., Lipp, O.V., van Boxtel, A., 2005. Committee report: guidelines for human startle eyeblink electromyographic studies. Psychophysiology 42, 1–15.

Böhmelt, A.H., Schell, A.M., Dawson, M.E., 1999. Attentional modulation of short and long-lead-interval modification of the acoustic startle eyeblink response: comparing auditory and visual prestimuli. Int. J. Psychophysiol. 32, 239–250.

Bradley, M.M., Lang, P.J., 1994. Measuring emotion: the self-assessment manikin and the semantic differential. J. Behav. Ther. Exp. Psychiatry 25, 49–59.

Bradley, M.M., Lang, P.J., 1999. Affective norms for English words (ANEW): stimuli, instruction manual and affective ratings. Technical report C-1. The Center for Research in Psychophysiology, University of Florida.

Bradley, M.M., Lang, P.J., 2000. Measuring emotion: behavior, feeling, and physiology. In: Lane, R., Nadel, L. (Eds.), Cognitive Neuroscience of Emotion. New York, Oxford University Press, pp. 242–276.

Bradley, M.M., Cuthbert, B.N., Lang, P.J., 1990. Startle reflex modification: emotion or attention? Psychophysiology 27, 513–522.

Bradley, M.M., Cuthbert, B.N., Lang, P.J., 1999. Affect and the startle reflex. In: Dawson, M.E., Schell, A.E., Bohmelt, A.H. (Eds.), Startle Modification: Implications for Neuroscience, Cognitive Science, and Clinical Science. University Press, Cambridge, England, pp. 157–183.

Bradley, M.M., Codispoti, M., Cuthbert, B.N., Lang, P.J., 2001. Emotion and motivation I: defensive and appetitive reactions in picture processing. Emotion 1, 276–298.

Bradley, M.M., Sabatinelli, D., Lang, P.J., Fitzsimmons, J.R., King, W., Desai, P., 2003. Activation of the visual cortex in motivated attention. Behav. Neurosci. 117, 369–380.

Bradley, M.M., Codispoti, M., Lang, P.J., 2006. A multi-process account of startle modulation during affective perception. Psychophysiology 43, 486–497.

Craik, F.I.M., Lockhart, R.S., 1972. Levels of processing: a framework for memory research. J Verbal Learn. Verbal Behav. 11, 671–684. Q14

Cuthbert, B.N., Bradley, M.M., Lang, P.J., 1996. Probing picture perception: activation and emotion. Psychophysiology 33, 103–111.

Cuthbert, B.N., Schupp, H.T., Bradley, M., McManis, M., Lang, P.J., 1998. Probing affective pictures: attended startle and tone probes. Psychophysiology 35, 344–347.

Deldin, P.A., Keller, J., Gergen, J.A., Miller, G., 2001. Cognitive bias and emotion in neuropsychological models of depression. Cogn. Emot. 15, 787–802.

Ferré, P., 2003. Effects of level of processing on memory for affectively valenced words. Cogn. Emot. 17, 859–880.

Filion, D.L., Dawson, M.E., Schell, A.M., 1993. Modification of the acoustic startle-reflex eyeblink: a tool for investigating early and late attentional processes. Biol. Psychol. 35, 185–200.

Fischler, I.S., Bradley, M.M., 2006. Event-related potential studies of language and emotion: words, phrases and task effects. Prog. Brain Res. 156, 185–204.

Gard, D.E., Gard, M.G., Mehta, N., Kring, A.M., Patrick, C.J., 2007. Impact of motivational salience on affect modulated startle at early and late probe times. Int. J. Psychophysiol. 66, 266–270.

Graham, F.K., 1979. Distinguishing among orienting, defense, and startle reflexes. In: Kimmel, H.D., van Olst, E.H., Orlebeke, J.F. (Eds.), The Orienting Reflex in Humans. Erlbaum, Hillsdale, NJ, pp. 137–167.

Hamann, S., Mao, H., 2002. Positive and negative emotional verbal stimuli elicit activity in the left amygdala. NeuroReport 13, 15–19.

Hautzinger, M., Bailer, M., Worall, H., Keller, F., 1994. Beck-Depressions-Inventar (BDI). Huber, Bern, Switzerland.

Hazlett, E.A., Speiser, L.J., Goodman, M., Roy, M., Carrizal, M., Wynn, J.K., Williams, W.C., Romero, M., Minzenberg, M.J., Siever, L.J., New, A.S., 2007. Exaggerated affect-modulated startle during unpleasant stimuli in borderline personality disorder. Biol. Psychiatry 62, 250–255.

Herbert, C., Kissler, J., Junghofer, M., Peyk, P., Rockstroh, B., 2006. Processing of emotional adjectives: evidence from startle EMG and ERPs. Psychophysiology 43, 197–206.

Herbert, C., Junghofer, M., Kissler, J., 2008. Event related potentials to emotional adjectives during reading. Psychophysiology 45, 487–498.

Herbert, C., Ethofer, T., Anders, S., Junghofer, M., Wildgruber, D., Grodd, W., Kissler, J., 2009. Amygdala activation during reading of emotional adjectives—an advantage for pleasant content. Soc. Cogn. Affect. Neurosci. 4, 35–49.

Isenberg, N., Silbersweig, D., Engelien, A., Emmerich, S., Malavade, K., Beattie, B., Leon, A.C., Stern, E., 1999. Linguistic threat activates the human amygdala. Proc. Natl. Acad. Sci. U. S. A. 96, 10456–10459.

Kiefer, M., Schuch, S., Schenck, W., Fiedler, K., 2007. Mood states modulate activity in semantic brain areas during emotional word encoding. Cereb. Cortex 17, 1516–1530. Q15

Kissler, J., Hauswald, A., 2008. Neuromagnetic activity during recognition of emotional pictures. Brain Topogr. 20, 192–204.

Kissler, J., Assadollahi, R., Herbert, C., 2006. Emotional and semantic networks in visual word processing: insights from ERP studies. Prog. Brain Res. 156, 147–183.

Kissler, J., Herbert, C., Peyk, P., Junghofer, M., 2007. Buzzwords: early cortical responses to emotional words during reading. Psychol. Sci. 18, 475–480.

Kissler, J., Herbert, C., Winkler, I., Junghofer, M., 2009. Emotion and attention in visual word processing—an ERP study. Biol. Psychol. 80, 75–83.

Koenig, S., Mecklinger, A., 2008. Electrophysiological correlates of encoding and retrieving emotional events. Emotion 8, 162–173.

Lang, P.J., 1995. The emotion probe. Am. Pychol. 50, 372–385. Q16

Lang, P.J., Bradley, M.M., Cuthbert, B.N., 1997. Motivated attention: affect, activation, and action. In: Lang, P.J., Simons, R.F., Balaban, M. (Eds.), Attention and Emotion: Sensory and Motivational Processes. Erlbaum, Mahwah, NJ, pp. 97–135.

Lang, P.J., Bradley, M.M., Cuthbert, B.N., 2005. International affective picture system (IAPS): affective ratings of pictures and instruction manual. Technical Report A-6. University of Florida, Gainesville, FL.

Laux, L., Glanzmann, P., Schaffner, P., Spielberger, C.D., 1981. Das State-Trait-Angstinventar (STAI). Weinheim, Beltz.

Lipp, O.V., Neumann, D.L., McHugh, M.J., 2003a. Lead stimulus modality change and the attentional modulation of the acoustic and electrical blink reflex. Biol. Psychol. 62, 27–48.

Lipp, O.V., Neumann, D.L., Pretorius, N.R., McHugh, M.J., 2003b. Attentional blink modulation during sustained and after discrete lead stimuli presented in three sensory modalities. Psychophysiology 40, 285–290.

Miller, M.W., Patrick, C.J., Levenston, G.K., 2002. Affective imagery and the startle response: probing mechanisms of modulation during pleasant scenes, personal experiences, and discrete negative emotions. Psychophysiology 39, 519–529. Q17

Monnier, C., Syssau, A., 2008. Semantic contribution to verbal short-term memory: are pleasant words easier to remember than neutral words in serial recall and serial recognition? Mem. Cogn. 36, 35–42.

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Oldfield, R.C., 1971. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia 9, 97–113.

Putnam, L.E., Vanman, E.J., 1999. Long lead interval startle modification. In: Dawson, M.E., Schell, A.M., Boehmelt, A.H. (Eds.), Startle Modification: Implications for Neuroscience, Cognitive Science, and Clinical Science. Cambridge University Press, Cambridge, UK, pp. 72–92.

Robinson, J.D., Vrana, S.R., 2000. The time course of emotional and attentional modulation of the startle eyeblink reflex during imagery. Int. J. Psychophysiol. 37, 275–289.

Sabatinelli, D., Lang, P.J., Bradley, M.M., Costa, V.D., Keil, A., 2009. The timing of emotional discrimination in human amygdala and ventral visual cortex. J Neurosci 29, 14864–14868.

Schapkin, S.A., Gusev, A.N., Kuhl, J., 2000. Categorization of unilaterally presented emotional words: an ERP analysis. Acta Neurobiol. Exp. (Wars.) 60, 17–28.

Schupp, H.T., Junghofer, M., Weike, A.I., Hamm, A.O., 2004. The selective processing of briefly presented affective pictures: an ERP analysis. Psychophysiology 41, 441–449.

Schupp, H.T., Flaisch, T., Stockburger, J., Junghofer, M., 2006. Emotion and attention: event-related brain potential studies. Prog. Brain Res. 156, 31–51.

Smith, J.C., Low, A., Bradley, M.M., Lang, P.J., 2006. Rapid picture presentation and affective engagement. Emotion 6, 208–214.

Vrana, S.R., Lang, P.J., 1990. Fear imagery and the startle-probe reflex. J. Abnorm. Psychol. 99, 189–197.

Waters, A.M., Lipp, O.V., Cobham, V.E., 2000. Investigation of threat-related attentional bias in anxious children using the startle eyeblink modification paradigm. J. Psychophysiol. 14, 142–150. **Q18**

Watson, L.A., Dritschel, B., Obonsawin, M.C., Jentzsch, I., 2007. Seeing yourself in a positive light: brain correlates of the self-positivity bias. Brain Res. 1152, 106–110.

Witvliet, C.V., Vrana, S.R., 1995. Psychophysiological responses as indices of affective dimensions. Psychophysiology 32, 436–443.