

The P3 event-related potential as an index of motivational relevance: a conditioning  
experiment

Ingmar H.A. Franken, Jan W. Van Strien, Bruno R. Bocanegra, Jorg Huijding

Institute of Psychology  
Erasmus University Rotterdam, the Netherlands

Corresponding author:

Institute of Psychology, Erasmus University Rotterdam, P.O. Box 1738, 3000 DR

Rotterdam, The Netherlands, E-mail: franken@fsw.eur.nl, Fax: +31-10-4089009

**Acknowledgements**

This work was supported by the Netherlands Organization for Scientific Research  
(NWO).

## **Abstract**

Watching motivationally relevant pictures modulates two types of event-related brain potentials (ERPs), the Early Posterior Negativity (EPN) and the P3. Several studies show that the EPN and P3 to emotional stimuli are enhanced as compared to neutral stimuli. The goal of the present study was to investigate whether experimentally conditioned abstract stimuli (Gabor patches) that predict the occurrence of a subsequent emotional event are able to elicit an enhanced EPN and P3. This would confirm that these ERP components indeed reflect the motivational relevance of a stimulus, rather than other stimulus properties like complexity. In a conditioning paradigm abstract patches (Conditioned Stimuli; CS) were contingently paired with emotional or neutral pictures (Unconditioned Stimuli; UCS). Both EPN and P3 to these CSs were measured in 80 healthy participants. The results demonstrate an enhanced P3 to CSs predicting emotional stimuli as compared to CSs predicting neutral stimuli. The EPN was not modulated by the CSs. These results show that the P3 is a suitable index of acquired motivational relevance and is not, at least not completely, dependent on task-irrelevant stimulus properties such as complexity and contrast. The EPN seems less suitable as an index of recently acquired motivational relevance because, although the CS acquired emotional significance, this did not result in the typical EPN modulation.

## **Introduction**

Several theoretical approaches suggest that emotion is associated with two basic motivational systems, an avoidance (defensive) and an approach (appetitive) mechanism (Bradley, 2009; Gray, 1987; Lang, Bradley, & Cuthbert, 1990).

It is hypothesized that emotional stimuli are motivationally relevant because, evolutionarily, an organism has to be prepared to avoid dangerous stimuli and approach beneficial stimuli (Frijda, 1986; Lang, Bradley, & Cuthbert, 1990; Öhman, 1993).

Therefore, motivationally relevant stimuli are processed preferentially by our brain.

These stimuli tend to capture our attention automatically, and are stored more efficiently in memory (e.g. Beck & Clark, 1997; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). This enhanced processing is reflected in both behavioral and psychophysiological measures. The presentation of arousing stimuli results, among others, in increased skin conductance, enhanced electrophysiological activity, enhanced attention-related reaction times, and modulated eye-blink response (see for an overview Bradley, 2009). These results are in line with theories suggesting that emotional stimuli automatically capture attention (Lang, Bradley, & Cuthbert, 1990; Öhman, 1997; Vuilleumier, 2005).

Event-Related Potential (ERP) studies also show that emotional stimuli are processed preferentially, when compared to non-emotional stimuli (e.g., Ito, Larsen, Smith, & Cacioppo, 1998; Schupp, Stockburger, Codispoti et al., 2007). ERPs are specifically suited to study the temporal characteristics of motivational processing and may reveal differences at various visual processing stages (early versus late) between emotional and neutral stimuli. In addition, several studies have addressed the neural

correlates of ERP components that are associated with emotional processing. In this manner, employment of these components may provide us with new insights on the neurobiological basis of this processing. In previous studies researchers have used visual stimuli, mostly International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) pictures, to investigate the electrophysiology of emotional processing. These studies indicate that the Early Posterior Negativity (EPN) and P3 components of the ERP are modulated by emotional and motivational stimuli (see for a review Schupp, Flaisch, Stockburger, & Junghofer, 2006). Emotional stimuli yield a negative-going potential at posterior regions starting 100-300 ms (EPN) after stimulus onset, which is thought to originate in extra-striate cortex (Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005; Schupp, Stockburger, Bublatzky et al., 2007). The EPN is thought to represent the perceptual encoding phase at which stimuli are selected for enhanced processing (Schupp, Stockburger, Codispoti et al., 2007). Later stages of stimulus processing are measured using the P3 and P3-associated Late Positive Potential (LPP). This P3 index of processing emerges 300-400 ms after stimulus onset and the LPP may last several seconds (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Several studies show that both early and late ERP components can be modulated by attentional demands (Schupp, Stockburger, Codispoti et al., 2007). Research addressing the neural origin of the positive slow wave shows that it represents activity in a network of visual cortical structures such as the lateral occipital, inferotemporal, and parietal visual areas (Sabatinelli, Lang, Keil, & Bradley, 2007). The P3 and the LPP, in particular, are selectively modulated by emotional arousal, regardless of valence properties of the picture

(Franken, Muris, Nijs, & van Strien, 2008; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Stockburger, Codispoti et al., 2007). In addition, several studies indicate that the P3 is modulated by motivational states. Increased motivational states yield larger P3 and LPP amplitudes. For instance, several studies with substance abuse patients show that enhanced motivation for drugs such as cocaine, heroin and nicotine, i.e. increased desire for these substances, results in P3 and associated late wave enhancements (Franken et al., 2008; Franken, Kroon, Wiers, & Jansen, 2000; Littel & Franken, 2007).

There are several reports on the effects of sensory conditioning on ERP responses (Begleiter & Platz, 1969; Sugawara, Kitajima, & Kanoh, 1977). However, these early studies did not use affective pictures such as those indicated in the previous section, making a direct comparison difficult. Further, there are several reports of conditioning effects on ERPs (Wong, Bernat, Snodgrass, & Shevrin, 2004; Wong, Shevrin, & Williams, 1994) using aversive stimuli (electric shock or noise). However, these studies did not employ pleasant stimuli and did not use abstract conditioned stimuli (CS) but rather emotional words. In addition, several studies used anticipatory designs in order to measure late ERP components that are associated with expectancy such as the expectancy negativity and the associated Contingent Negative Variation (CNV; Loveless & Sanford, 1974; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Simons, Macmillan, & Ireland, 1982; Simons, Öhman, & Lang, 1979). In typical expectancy designs, two stimuli (S1 and S2) are displayed contingently. Different stimuli (S1) signal forthcoming neutral or interesting events (S2). High interest events, such as emotional events, prompt an anticipatory ERP response (Simons, Öhman, & Lang, 1979). In contrast to these late (>1

sec) waves representing the expectancy of an interesting event, in the present study we will examine more early ERP components such as the EPN and P3. This should provide further evidence for the interpretation of the EPN and P3 as indices of motivational significance.

Although late positive waves (such as the P3) and EPN are regarded as indices of intrinsic motivational relevance (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Stockburger, Codispoti et al., 2007), there are some issues that remain unclear. One of these issues is the extent to which these emotion-related indices are influenced by stimulus-specific properties, such as color, luminance, contrast, and visual complexity. Although most of the mentioned previous studies control to some degree for stimulus properties, the influence of these properties/characteristics can not be ruled out. In particular the EPN seems to be modulated by stimulus complexity (Bradley, Hamby, Low, & Lang, 2007). As a result it remains somewhat unclear to what extent the findings of previous studies can be attributed to the motivational properties of the stimuli or other, task-irrelevant visual properties of the stimuli. As a first step to clarify this issue, the present study manipulated simple neutral stimuli (Gabor patches) in such a way that they acquired motivational significance by pairing them with emotional stimuli in a conditioning paradigm. This design allowed us to examine the EPN and P3 response to these conditioned motivational relevant stimuli while completely controlling the influence of low-level visual properties of the stimulus.

The main goal of the present study was to investigate whether experimentally conditioned abstract visual stimuli that are predictive for an upcoming emotional event are able to elicit an enhanced P3 and EPN. If this would be confirmed this would suggest that the P3 and the EPN indeed reflect indices of the motivational relevance of a stimulus. As a subsidiary issue, we also investigated whether P3 and EPN responses would be the same for conditioned stimuli that predict pleasant and unpleasant stimuli.

## Methods

### Participants

Participants were 80 undergraduate students (57 females) of Erasmus University Rotterdam. The average age was 21.9 years (SD = 3.4). The participants received course credits for their participation.

### *Stimuli and experimental paradigm*

Sixty color pictures (20 neutral, 20 arousing pleasant, and 20 arousing unpleasant slides<sup>1</sup>) that served as Unconditioned Stimulus (UCS)<sup>2</sup> were selected from the IAPS (Lang, Bradley, & Cuthbert, 1999). All UCS were selected on the basis of standardized valence and arousal ratings (Lang, Bradley, & Cuthbert, 1999), see Table 1 for the

---

<sup>1</sup> The IAPS pictures were: Neutral: 2480, 5130, 5390, 7000, 7004, 7006, 7009, 7010, 7025, 7031, 7035, 7040, 7041, 7050, 7055, 7080, 7110, 7140, 7150, 7175; Pleasant: 1710, 2150, 4607, 4608, 4611, 4623, 4643, 4660, 4677, 5621, 5626, 5629, 5833, 8030, 8080, 8180, 8185, 8186, 8190, 8200; Unpleasant: 1050, 1205, 1300, 1525, 2800, 2811, 3051, 3053, 3069, 3130, 3150, 3261, 3400, 6200, 6370, 6550, 6570, 9042, 9253, 9301.

<sup>2</sup> Although we coined the emotional pictures UCS, we are aware that these are not primary unconditioned stimuli, but during life these pictorial stimuli acquired the properties of an UCS. Therefore, our conditioning is in fact a form of second-order conditioning (S1-S2).

characteristics. An ANOVA demonstrated significant differences between the arousal ratings,  $F = 309.8$ ,  $p < .001$ . Bonferroni post-hoc tests indicated that there were no significant differences between the arousal ratings for the pleasant and unpleasant pictures ( $p = 1.0$ ). As expected, both pleasant and unpleasant pictures yielded higher arousal ratings than neutral pictures ( $p < .001$ ). An ANOVA also revealed significant differences between the valence ratings for each category  $F = 499.0$ ,  $p < .001$ . As expected, pleasant pictures had higher valence scores than neutral pictures ( $p < .001$ ), which in turn had higher valence scores than unpleasant pictures ( $p < .001$ ). As CS we employed two sinusoidal luminance gratings (Gabor patches) with a spatial frequency of 1 c/deg and an angle of 90 and 270 deg, respectively (see Figure 1). Stimuli were presented in two blocks. In one block the CSs were coupled with pleasant ( $CS_{plea}$ ) and neutral stimuli ( $CS_{neu}$ ), in the other block the CSs were coupled with unpleasant ( $CS_{unplea}$ ) and neutral stimuli. In total there were 320 trials: 160 CS-neutral trials and 160 CS-emotional trials. First, a CS (the 90 or 270 degree Gabor patch) was presented for 800 ms in the upper half of the screen (see Figure 1 for a graphic representation of the paradigm). After this the UCS was added in the centre of the screen for 400 ms. The inter-trial interval, including the presentation of a fixation cross, was 1000 ms. The presentation of stimuli within each block was randomized. The order of the blocks (pleasant-neutral first or unpleasant-neutral first) and the CS (90 or 270 degrees) that were paired with the emotional or neutral UCS were both counterbalanced across subjects.

### *Procedure*

Upon arrival, participants were instructed about the procedure and signed informed consent. Subsequently, subjects were seated on a comfortable chair in a light- and sound-attenuated room. Stimuli were presented on a 21" monitor 1.5 meters away from the participant. Participants were instructed to pay close attention to the pictures that would be presented (passive viewing without responses). Participants were informed that there would be certain contingencies.

After the conditioning task participants were asked to rate the arousal and valence of the UCS pictures and the arousal of the two Gabor patches that served as CS<sup>3</sup>. Approval of the local ethics committee of the Institute of Psychology was obtained and the experiment was in accordance with international ethical guidelines.

#### *Electroencephalographic (EEG) Recording and signal processing*

ERPs were recorded using a Biosemi Active-Two amplifier system from 32 scalp sites (10-20 system) using active Ag/AgCl electrodes mounted in an elastic cap. Six additional electrodes were attached: to the left and right mastoids, the two outer canthi of both eyes (HEOG), and the infraorbital and supraorbital regions of the eye (VEOG). Signals were recorded online with a low pass filter of 134 Hz, and digitized with a 512 Hz, 24-bit A/D converter. Data were re-referenced off-line to an average reference. EEG and EOG activity was filtered off-line with a bandpass of 0.01-80 Hz (phase shift-free Butterworth filters; 24dB/octave slope). Both UCS and CS data were segmented in epochs of 600 ms (100 ms before and 500 ms after stimulus onset. Ocular correction (Gratton, Coles, & Donchin, 1983) was applied and epochs containing an EEG signal exceeding  $\pm 75 \mu\text{V}$

---

<sup>3</sup> The valence of the Gabor patches was not measured because the same Gabor patch served as CS<sub>plea</sub> (block 1) and CS<sub>unplea</sub> (block 2; or vice versa) in the same session.

were excluded from the average. The mean 100 ms period before stimulus presentation served as baseline. After baseline correction, average ERP waves were calculated for the neutral, pleasant and unpleasant stimulus conditions (both UCS and CS). All segments, from the start of the conditioning procedure, were included in the average. Separate analyses of the first trials (before conditioning has taken place) and last trials (after conditioning has taken place) was not appropriate because this resulted in too few segments for each average. The resulting ERP-waves were visually inspected and appeared to correspond well with ERP-waves usually reported in response to visual emotional stimuli. Mean activity of the EPN (200-300 ms time window), and the P3 (300-500 ms time window) were used as measures of early and late emotional processing, respectively. We realize that although we label this late wave P3, it is in fact the P3 wave complex, including an extended P3 in the case of the CS (Figure 3). And although the P3 on the UCS (Figure 2) shows the typical emotion-related modulation and is in the P3 time-window, it has an attenuated waveform. This is the result of the fact that we used an average reference (which results in less-pronounced P3 waves), a possible superposition of slow negative waves, and the fact that the UCS was always presented superimposed upon an Gabor patch which was already present on the screen (see Figure 1).

Because the Gabor patches are quite “uninteresting” compared to pictures and probably don’t capture motivated attention for a sustained period of time, we were interested in the first 500 ms. For the EPN, previous studies show that the effects are most pronounced at posterior electrode sites, and for the P3 at parietal electrodes sites

(Schupp, Junghoefer, Weike, & Hamm, 2003, 2004). Consequently, for the EPN analysis we selected O1, Oz, and O2 electrodes for the statistical analysis. Electrodes P3, Pz, and P4 were selected for the statistical analysis of the P3.

### *Data analysis*

#### *Ratings*

Repeated measures ANOVA were employed to examine differences in valence and arousal ratings of the UCS. In addition, self-reported arousal ratings on the CS were compared between Gabor patches that predict a neutral stimulus and Gabor patches that predicted an emotional stimulus using a paired t-test.

#### *ERPs*

First, we examined differences in emotional processing of the UCS, i.e. the IAPS pictures, for the EPN by means of a 3 (Emotion: neutral vs. pleasant vs. unpleasant) x 3 (Location: O1 vs. Oz vs. O2) repeated measures ANOVA. The UCS P3 was analyzed by means of a 3 (Emotion: neutral vs. pleasant vs. unpleasant) x 3 (Location: P3 vs. Pz vs. P4) repeated measures ANOVA.

Second, we examined differences in emotional processing of the CS. For the CS analyses, we analyzed two orthogonal contrasts for the Emotion factor: neutral vs. emotional and pleasant vs. unpleasant. The EPN of the CS was analyzed by means of a 2 (Emotion: neutral vs. emotional) x 3 (Location: O1 vs. Oz vs. O2) repeated measures ANOVA, and a subsequent 2 (Emotion: pleasant vs. unpleasant) x 3 (Location: O1 vs. Oz

vs. O2) repeated measures ANOVA. The P3 of the CS was analyzed by means of a 2 (Emotion: neutral vs. emotional) x 3 (Location: P3 vs. Pz vs. P4) repeated measures ANOVA, and a subsequent 2 (Emotion: pleasant vs. unpleasant) x 3 (Location: P3 vs. Pz vs. P4) repeated measures ANOVA. All significant effects were further analyzed using Bonferroni-corrected post-hoc *t*-tests. In all instances we used Greenhouse-Geisser correction (uncorrected degrees of freedom are reported). Because we were only interested in Emotion-relevant interaction effects (and not for example main effects of location), we only report effects that included this factor.

## Results

### *Ratings*

The ANOVAs of the self-reported data concerning valence and arousal showed that there were differences in arousal ratings between the UCS stimuli,  $F(2, 150) = 319.8, p < 0.001$ . Neutral pictures ( $M = 1.7, SD = 1.0$ ) were rated as less arousing than pleasant ( $M = 4.7, SD = 1.7$ ) and unpleasant pictures ( $M = 5.9, SD = 1.3$ ),  $p < 0.001$ . In addition, self-reported valence differences between the stimuli were observed,  $F(2, 150) = 738.0, p < 0.001$ . Pleasant pictures ( $M = 7.1, SD = .9$ ) were rated as more pleasant than neutral ( $M = 5.0, SD = .5$ ) and unpleasant pictures ( $M = 2.3, SD = .9$ ),  $p < 0.001$ . Neutral pictures were rated as more pleasant than unpleasant pictures,  $p < 0.001$ .

After the conditioning task, the CS that predicted an emotional UCS picture ( $CS_{\text{emo}}$ ;  $M = 3.3, SD = 1.7$ ) yielded an enhanced arousal rating as compared to the  $CS_{\text{neu}}$

( $M = 2.2$ ,  $SD = 2.4$ ;  $t = 5.4$ ;  $p < .001$ ), suggesting that the CS acquired emotional/motivational significance during the task.

#### *ERPs to UCS*

For the UCS elicited EPN (see Figure 2), an expected main effect of Emotion was observed,  $F(2, 78) = 78.0$ ,  $p < .001$ . Post-hoc tests revealed that pleasant ( $M = 7.3$ ,  $SD = 3.4$ ) and unpleasant stimuli ( $M = 6.1$ ,  $SD = 3.9$ ) yielded larger, i.e. less positive going, EPN amplitudes as compared to neutral stimuli ( $M = 8.6$ ,  $SD = 3.5$ , both  $ps < .001$ ). In addition, unpleasant stimuli yielded a larger EPN than pleasant stimuli ( $p < .001$ ). A significant interaction effect of Emotion x Electrode was also observed  $F(4, 76) = 13.5$ ,  $p < .001$ . Post-hoc tests showed that this effect was dependent on differences in amplitudes on the three electrodes per emotion category. Overall, the Emotion x Electrode effects resembled the pattern of the Emotion effects; detailed post-hoc analyses fall beyond the scope of this paper.

For the UCS elicited P3, a main effect of Emotion was observed,  $F(2, 78) = 19.0$ ,  $p < .001$ . Post-hoc tests revealed that both pleasant ( $M = 6.3$ ,  $SD = 2.7$ ,  $p < .001$ ) and unpleasant stimuli ( $M = 6.1$ ,  $SD = 3.0$ ) yielded larger, i.e., more positive going, P3 amplitudes than did neutral stimuli ( $M = 5.2$ ,  $SD = 2.2$ ; both  $ps < .001$ ). No significant difference was observed between pleasant and unpleasant stimuli. In addition, an Emotion x Electrode interaction effect was observed  $F(4, 76) = 6.0$ ,  $p < .001$ . Again, post-hoc tests did not reveal a significant effect of Electrode over and above the above-

described effect of Emotion. Accordingly, the Emotion x Electrode effect of the P3 will not be discussed further.

#### *ERPs to CS*

Concerning the EPN (see Figure 3), no significant main effects of Emotion or interaction effects of Electrode x Emotion were observed,  $ps > .44$ . Most importantly, a main effect of Emotion was observed on the P3 elicited by the CS,  $F(1, 79) = 7.0, p < .01$  ( $\eta_p^2 = .08$ ). A post-hoc test revealed that the CS<sub>emo</sub> resulted in larger P3 amplitudes ( $M = 1.8, SD = 1.0$ ) than the CS<sub>neu</sub> ( $M = 1.6, SD = 1.1; p < .01$ ). A more detailed analysis that differentiated between CS<sub>plea</sub> and CS<sub>unplea</sub> showed a similar effect main effect of Emotion,  $F(2, 78) = 3.6, p < .05$ . Post-hoc tests demonstrated that the CS<sub>plea</sub> ( $M = 1.8, SD = 1.2$ ) yielded larger P3 amplitudes than the CS<sub>neu</sub> ( $M = 1.6, SD = 1.1; p < .05$ ). No statistical differences between the CS<sub>neu</sub> and CS<sub>unplea</sub> ( $M = 1.7, SD = 1.2$ ) were observed ( $p = .18$ ). In addition, no Emotion x Electrode interaction effects were observed for the P3.

#### Discussion

The P3 and EPN components of ERP responses to emotional stimuli are regarded as indices of intrinsic motivational relevance (Olofsson, Nordin, Sequeira, & Polich, 2008). At the same time, it has been suggested that these emotion related waves may be influenced by stimulus properties, such as color intensity, contrast, and complexity (Bradley, Hamby, Low, & Lang, 2007). To rule out that the P3 and EPN findings could be attributed to stimulus properties only, the present study examined the EPN and P3

response to conditioned motivational relevant stimuli while completely controlling the influence of stimulus visual properties.

The results show an enhanced P3 to CS that predicted emotional stimuli as compared to CS that predicted neutral stimuli. This indicates that the P3 is a suitable index of motivational relevance and is not, at least not completely, dependent on task-irrelevant stimulus properties such as complexity and contrast. An interesting next step would be to try to disentangle the impact of motivational relevance and other stimulus properties, for instance by systematically manipulating both motivational relevance in combination with different stimulus attributes, like complexity and contrast.

In contrast to the P3, the EPN seems less suitable as an index of motivational relevance. That is, although the CS that predicted emotional stimuli acquired emotional significance (as indicated by the differences with neutral CSs on the P3 and self-reports), this did not result in the typical EPN modulation. The finding that the EPN was not modulated by conditioned emotional stimuli may indicate that the EPN is mainly modulated by the perceptual organization of the stimuli. For instance, a recent study of Bradley et al. (2007) shows that the EPN is modulation by the perceptual organization of a visual stimulus. Importantly, the typical EPN did emerge in response to the UCS stimuli. However, it could be that more trials (i.e. UCS-CS pairings) are needed in order to modulate these fast processes. Indeed, it has been suggested in many information processing models that fast processes need time and repetition to ingrain. In addition, it is important to notice that the IAPS stimuli used in this study did not have extremely high arousal ratings. It might be that the use of more arousing stimuli would result in the modulation of CS-related EPN. Furthermore, it might be that the EPN is selectively modulated by

the actual perception of biologically relevant stimuli (UCS) than by a symbolic or abstract representation (CS) of this relevant stimulus. These issues could be examined in future research.

Although the present results seem relatively straightforward it should be acknowledged that the effects size of the effect of emotion was quite small. Nevertheless, we believe the results are robust and reliable for several reasons. First, we anticipated a small effect because ERP responses were measured to otherwise completely meaningless abstract gratings. In addition, we only employed a modest level of conditioning, with limited trials in one session. Larger effects could be possible in more lengthy conditioning paradigms. In addition, we used very abstract CSs (Gabor patches), this is likely to reduce the conscious CS-UCS pairing. If less abstract figures were to be used, it would be likely that the effect size increases.

Importantly, and as expected, analysis of the UCS showed that the emotional pictures were rated as more arousing than neutral pictures. Also as expected, the emotional pictures yielded larger EPN and P3 amplitudes as compared to neutral pictures. These data indicate that we employed adequate stimuli, making it less likely that the responses to the CSs are the result of other factors than the consistent pairing with the emotional or neutral UCSs. One limitation of the present study should be mentioned, however. The present paradigm yielded too few data segments to analyze the conditioning over time. That is, in calculating the effects of the conditioning procedure on the CS-related ERPs all segments had to be included in the average, excluding the possibility to run separate analyses of the first trials (before conditioning has taken place) and last trials (after conditioning has taken place). It is possible that this may have attenuated the effects in the present study, and may (partially) explain the absence of a significant modulation of the CS-related EPN. This hypothesis could be tested in future studies by increasing the number of trials included in the conditioning paradigm. It is important to note that the present results can only have been due to the conditioning procedure. However, we

don't know whether this is some kind of conditioned voluntary cognitive appraisal of the stimuli or an automatic conditioning effect. In addition, we don't want to suggest that anticipation effects are not involved. The fact that an effect on the slow P3 wave is observed and not on the early EPN wave is suggestive of a voluntary appraisal effect which might be the result of conscious S1-S2 anticipation.

Another limitation of the present study is that the same grating was presented with pleasant pictures in the first block and then with unpleasant pictures in the second block. Learning effects could have occurred already by the time the second set of emotional pictures was presented. Although this does not affect our main conclusion about the effect of emotional conditioning on the CSs, it might explain why we did not observe differences between pleasant and unpleasant CSs.

In sum, these present results show that the P3 is a suitable index of acquired motivational relevance and is not, at least not completely, dependent on task-irrelevant stimulus properties such as complexity and contrast. The EPN seems less suitable as an index of recently acquired motivational relevance because, although the CS acquired emotional significance, this did not result in the typical EPN modulation.

## References

- Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research & Therapy, 35*(1), 49-58.
- Begleiter, H., & Platz, A. (1969). Evoked potentials: modifications by classical conditioning. *Science, 166*(906), 769-771.
- Bradley, M., M. (2009). Natural selective attention: Orienting and emotion. *Psychophysiology, 46*(1), 1-11.
- Bradley, M. M., Hamby, S., Low, A., & Lang, P. J. (2007). Brain potentials in perception: picture complexity and emotional arousal. *Psychophysiology, 44*(3), 364-373.
- Canli, T., Zhao, Z., Brewer, J., Gabrieli, J. D., & Cahill, L. (2000). Event-related activation in the human amygdala associates with later memory for individual emotional experience. *Journal of Neuroscience, 20*(19), RC99.
- Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biological Psychology, 52*(2), 95 - 111.
- Franken, I. H. A., Dietvorst, R. C., Hesselmann, M., Franzek, E. J., van de Wetering, B. J. M., & van Strien, J. W. (2008). Cocaine craving is associated with electrophysiological brain responses to cocaine-related stimuli. *Addiction Biology, 13*, 386-392.
- Franken, I. H. A., Kroon, L. Y., Wiers, R. W., & Jansen, A. (2000). Selective cognitive processing of drug cues in heroin dependence. *Journal of Psychopharmacology, 14*(4), 395-400.

- Franken, I. H. A., Muris, P., Nijs, I., & van Strien, J. W. (2008). Processing of pleasant information can be as fast and strong as unpleasant information: implications for the Negativity Bias. *Netherlands Journal of Psychology, 64*(4), 168-176.
- Frijda, N. H. (1986). *The emotions*. Cambridge, England UK: Cambridge University Press.
- Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55*, 468-484.
- Gray, J. A. (1987). *The psychology of fear and stress*. Cambridge: Cambridge University Press.
- Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: the negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75*(4), 887-900.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97*, 377-395.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International affective picture system (IAPS): Instruction Manual and Affective Ratings*. Gainesville, FL: The Center for Research in Psychophysiology, University of Florida.
- Littel, M., & Franken, I. H. A. (2007). The effects of prolonged abstinence on the processing of smoking cues: an ERP study among smokers, ex-smokers and never-smokers. *Journal of Psychopharmacology, 21*(8), 873-882.
- Loveless, N. E., & Sanford, A. J. (1974). Slow potential correlates of preparatory set. *Biological Psychology, 1*(4), 303-314.

- Öhman, A. (1993). Fear and anxiety as emotional phenomena: clinical phenomenology, evolutionary perspectives, and information processing mechanisms. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions*. New York: Guilford.
- Öhman, A. (1997). As fast as the blink of an eye: Evolutionary preparedness for preattentive processing of threat. In P. J. Lang, R. F. Simons & M. Balaban (Eds.), *Attention and orienting: sensory and motivational processes* (pp. 477). New Jersey: Lawrence Erlbaum Associates Inc.
- Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology, 77*, 247-265.
- Poli, S., Sarlo, M., Bortoletto, M., Buodo, G., & Palomba, D. (2007). Stimulus-Preceding Negativity and heart rate changes in anticipation of affective pictures. *International Journal of Psychophysiology, 65*(1), 32-39.
- Pourtois, G., Thut, G., Grave de Peralta, R., Michel, C., & Vuilleumier, P. (2005). Two electrophysiological stages of spatial orienting towards fearful faces: early temporo-parietal activation preceding gain control in extrastriate visual cortex. *NeuroImage, 26*(1), 149-163.
- Sabatinelli, D., Lang, P. J., Keil, A., & Bradley, M. M. (2007). Emotional perception: correlation of functional MRI and event-related potentials. *Cerebral Cortex, 17*(5), 1085-1091.
- Schupp, H. T., Flaisch, T., Stockburger, J., & Junghofer, M. (2006). Emotion and attention: event-related brain potential studies. *Progress in Brain Research, 156*, 31-51.

- Schupp, H. T., Junghoefer, M., Weike, A. I., & Hamm, A. O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science, 14*(1), 7-13.
- Schupp, H. T., Junghoefer, 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., Stockburger, J., Bublatzky, F., Junghofer, M., Weike, A. I., & Hamm, A. O. (2007). Explicit attention interferes with selective emotion processing in human extrastriate cortex. *BMC Neuroscience, 8*, 16.
- Schupp, H. T., Stockburger, J., Codispoti, M., Junghofer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *Journal of Neuroscience, 27*(5), 1082-1089.
- Simons, R. F., Macmillan, F. W., & Ireland, F. B. (1982). Anticipatory pleasure deficit in subjects reporting physical anhedonia: slow cortical evidence. *Biological Psychology, 14*(3-4), 297-310.
- Simons, R. F., Öhman, A., & Lang, P. J. (1979). Anticipation and Response Set: Cortical, Cardiac, and Electrodermal Correlates. *Psychophysiology, 16*(3), 222-233.
- Sugawara, M., Kitajima, S., & Kanoh, M. (1977). Enhancement and diminution of the evoked responses to conditioned stimuli during discrimination conditioning. *Neuropsychologia, 15*(2), 243-248.
- Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Science, 9*(12), 585-594.

Wong, P. S., Bernat, E., Snodgrass, M., & Shevrin, H. (2004). Event-related brain correlates of associative learning without awareness. *Int J Psychophysiol*, 53(3), 217-231.

Wong, P. S., Shevrin, H., & Williams, W. J. (1994). Conscious and nonconscious processes: an ERP index of an anticipatory response in a conditioning paradigm using visually masked stimuli. *Psychophysiology*, 31(1), 87-101.

Table 1. Characteristics of the pictorial stimuli.

	<b>Neutral</b>		<b>Pleasant</b>		<b>Unpleasant</b>	
	M	SD	M	SD	M	SD
<b>Arousal Ratings*</b>	2.5	.38	6.3	.64	6.3	.58
<b>Valence Ratings*</b>	4.9	.30	7.3	.53	2.4	.68

\* Note. Valence and arousal ratings were based on normative data (Lang, Bradley, & Cuthbert, 1999).

## Figure captures

Figure 1. Schematic representation of the experimental paradigm.

Figure 2. ERP to UCS (IAPS pictures). Lines represent response to neutral (black lines), pleasant (solid gray lines) and unpleasant pictures (dashed gray lines) at Pz (P3) and Oz (EPN).

Figure 3. ERP to CS (Gabor patches). Lines represent response to Gabor patches that predict neutral (black lines) and emotional (gray lines) pictures at Pz (to evaluate the P3) and Oz (to evaluate the EPN).





