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Tonic pain grabs attention, but leaves the processing of facial expressions intact—Evidence from event-related brain potentials

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ABSTRACT

Emotion and attention are key players in the modulation of pain perception. However, much less is known about the reverse influence of pain on attentional and especially emotional processes. To this end, we employed painful vs. non-painful pressure stimulation to examine effects on the processing of simultaneously presented facial expressions (fearful, neutral, happy). Continuous EEG was recorded and participants had to rate each facial expression with regard to valence and arousal. Painful stimulation attenuated visual processing in general, as reduced P100 and late positive potential (LPP) amplitudes revealed, but did not interfere with structural encoding of faces (N170). In addition, early perceptual discrimination and sustained preferential processing of emotional facial expressions as well as affective ratings were not influenced by pain. Thus, tonic pain demonstrates strong attention-demanding properties, but this does not interfere with concurrently ongoing emotion discrimination processes. These effects point at partially independent effects of pain on emotion and attention, respectively.

1. Introduction

Emotion and attention can substantially shape pain perception, which has been shown in a plethora of studies (for reviews, see Villemure and Bushnell, 2009; Wiech and Tracey, 2009). These effects are associated with modulations of brain activity in regions known to be involved in the processing of the sensory and affective dimension of pain (Ploner et al., 2011). In addition, it has been demonstrated that attention and emotion at least partly have different effects on pain processing (e.g., Kenntner-Mabiala et al., 2007, 2008).

With regard to behavioral and (neuro-)physiological correlates of pain processing, it has been demonstrated in many cases that unpleasant stimuli increase and pleasant stimuli decrease pain perception and physiological responses to pain (Kenntner-Mabiala et al., 2008; Kenntner-Mabiala and Pauli, 2005; Rhudy et al., 2005, 2007). These findings are in accordance with the motivational priming theory which assumes facilitated processing of unpleasant and inhibited processing of pleasant information under aversive affect (Lang et al., 1997). Interestingly, most previous studies in pain research focused on the influence of emotional stimuli on pain perception. However, assuming generality of the motivational priming theory one would also expect the reverse, specifically that pain as an aversive state facilitates the processing of unpleasant affective stimuli and inhibits the processing of pleasant affective stimuli. The present study was designed to examine this assumption.

Hints for a possible influence of pain on emotion processing come from a clinical perspective where a high prevalence of mood disturbances, primarily depression, is observed in chronic pain patients (Bair et al., 2003; Campbell et al., 2003) suggesting that their emotional processing may be altered. Indeed, increase in pain causes less differentiated affective states, and chronic pain patients experience their social relationships as less complex than healthy controls (Davis et al., 2004). These findings also point towards a possible interaction of (chronic) pain and the processing of social stimuli. Chronic pain patients show impaired performance on an emotional decision task suggesting that pain interferes with emotional evaluations (Apkarian et al., 2004). Yet, to our knowledge, only one study experimentally induced pain and measured its impact on the processing of emotional pictures (Godinho et al., 2008). In that study pleasant pictures were rated less positive and elicited attenuated visual-evoked responses of the EEG under painful electrical stimulation, however, no facilitated responses to negative stimuli have been found.

In concert with emotion, attention is also a key player in the modulation of pain perception. However, emotion and attentional effects on pain processing are at least partially different, as attention seems to selectively affect sensory aspects while emotion

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seems to affect both sensory and affective aspects of pain processing (Kenntner-Mabiala et al., 2008; Villemure and Bushnell, 2009). Recent findings complement these results by demonstrating that attentional and emotional modulations of pain actually relate to different patterns of functional connectivity (Ploner et al., 2011).

Unlike the effect of pain on emotion processing, the influence of pain on attention is fairly well studied. Pain is known to have attention-grabbing properties, dubbed the "interruptive function of pain" (Eccleston and Crombez, 1999). Several findings using different methodologies support this conclusion: behavioral studies using a variety of cognitive tasks such as numerical interference tasks, memory tasks, or simple discrimination tasks have demonstrated that pain demands attention and thus interferes with ongoing cognitive processes (e.g., Crombez et al., 1997; Eccleston, 1994; Kuhajda et al., 2002), and that increasing levels of heat pain incrementally reduce performance in a working memory task (Buhle and Wager, 2011). An fMRI study revealed that pain interferes with visual object processing in the ventral visual system and that this is paralleled by impaired recognition accuracy for simultaneously presented pictures (Bingel et al., 2007). Using laser- and visual evoked potentials, it was shown that pain processing competes with pain-unrelated cognitive activities for attentional resources and that concomitant painful events diminish attention allocation to ongoing cognitive tasks (Legrain et al., 2002, 2009). Furthermore it was demonstrated that gamma oscillations evoked by painful stimulation influence gamma oscillations evoked by a concurrent visual attention task (Tiemann et al., 2010). Finally, it was shown in a large population-based sample ($N = 1400$) that chronic pain is associated with decreased selective attention abilities (Gijsen et al., 2011). In sum, these studies suggest that painful stimuli involuntary grab attention and as a consequence withdraw capacities from processing other non-painful stimuli as reflected in attenuated brain responses.

As mentioned above, we expect that tonic pain causes dampened responses to simultaneously presented social stimuli. The most powerful social stimulus is the human face, as it conveys information about a person's identity, gender, age, race, intentions and emotions (Erickson and Schulkin, 2003; Smith et al., 2005). However, an experimental test of the influence of pain of facial expression processing is missing up to now. Therefore, the present study aimed at investigating the influence of pain on the processing of social stimuli, i.e. facial expressions.

The time course of facial expression processing is best examined with event-related brain potentials (ERPs) due to their excellent time resolution. Recent ERP studies have demonstrated that facial expressions (particularly of negative content) involuntarily capture attention and are selectively processed in visual brain areas (e.g., Mühlberger et al., 2009; Schupp et al., 2004; Wieser et al., 2010). Here, early emotion discrimination is likely reflected in a relative negative shift of the ERP over occipital areas (early posterior negativity, EPN) developing about 200 ms after picture onset (Schupp et al., 2003a). Of note, the EPN is a relative negativity for emotional compared to neutral stimuli, and has been dubbed negativity due to its resemblance to the selection negativity with a similar latency known from attention research (see Schupp et al., 2006). Moreover, at later stages of stimulus processing affective faces were observed to elicit enhanced late positive potentials (LPP), which is likely to index sustained preferential processing (Schupp et al., 2004; Wieser et al., 2010, in press). To investigate early attention effects of pain on face processing, the P100 and the face-specific N170 components of the ERPs are also of interest: the P100 was found to be amplified by selective spatial attention (Hillyard et al., 1998) and to be modulated by facial expressions (Pourtois et al., 2004). The N170 reflects the structural encoding of faces (Bentin et al., 1996). Research on the affective modulation of the N170 has yielded inconsistent results so far with previous studies reporting differences in the amplitude of the N170 between emotional and neutral faces (Batty and Taylor, 2003; Blau et al., 2007; Wieser et al., 2010; Wronka and Walentowska, 2011), but also zero-findings (Schupp et al., 2004). Recently, it has been suggested that modulations of the N170 are observed only when participants attend to the facial expressions (Wronka and Walentowska, 2011). However, to the best of our knowledge no study has been conducted on how pain influences these early attentional and structural encoding of faces.

Based on the literature discussed above, we expected attentional and emotional effects such that painful compared to non-painful stimulations cause a generally diminished processing of visually presented faces most likely reflected in reduced P100 amplitudes. Since we were especially interested how tonic pain modulates responses to emotional faces, we also examined the EPN and the LPP, as these were consistently found to vary with emotional facial expressions (Mühlberger et al., 2009; Schupp et al., 2004; Wieser et al., 2010, in press). If pain, as suggested by the emotional priming hypothesis, facilitates the processing of unpleasant stimuli (i.e., negative facial expressions like fearful faces) and inhibits the processing of pleasant stimuli (i.e., positive facial expressions like happy faces), the elicited EPN and LPP should be enhanced and reduced, respectively. In order to test for pain effects on the structural encoding of faces, the N170 was also examined, however, without clear predictions.

Table 1
Sociodemographic characteristics (means and SDs) of participants in the painful and non-painful pressure condition.

	Pain		No pain		*t*	*p*
	M	*SD*	*M*	*SD*		
Age	24.0	3.5	22.2	2.1	1.947	.066
PCS	19.7	9.6	19.4	9.1	0.091	.928
STAI state	36.7	8.0	38.6	6.1	0.797	.430
STAI trait	35.7	9.9	39.4	9.4	1.18	.246
BDI II	5.6	4.5	8.8	5.5	1.943	.056
PANAS PA	30.3	6.2	28.7	6.7	0.789	.435
PANAS NA	12.5	2.7	14.7	5.1	1.652	.107
Fear of pain	2.2	1.3	2.4	1.3	0.384	.703

Note. PCS: Pain Catastrophizing Scale; STAI: State-Trait-Anxiety Inventory; BDI: Beck Depression Inventory; PANAS: Positive and Negative Affect Scales.

2. Materials and methods

2.1. Participants

Forty healthy female participants (18–32 years) took part in this study. They were randomly assigned to either the experimental group (painful pressure stimulation) or the control group (non-painful pressure stimulation). Due to hardware failure, 2 participants of the control group had to be excluded from the analysis, resulting in a sample of 20 participants in the experimental and 18 participants in the control group. Exclusion criteria were self-report of acute or chronic pain, analgesic or psychoactive medication, as well as any history of neurological or mental disorder. All participants reported normal or corrected-to-normal vision and were right-handed. All participants gave informed consent before completing the study, which was ethically approved by the Faculty of Medicine Institutional Review Board of the University of Würzburg.

Participants of both groups were comparable in sociodemographic variables such as educational level (i.e., years of basic schooling: 9 or 10 years: qualification for apprenticeship or trade-school; 13 years: qualification for University studies), $\chi^2(1, N = 38) = 1.4$, $p = .29$, and age (experimental group: $M = 24.0$ years, $SD = 3.48$; control group: $M = 22.2$ years, $SD = 2.07$, $t(37) = 1.95$, $p = .066$). In addition, participants in both groups completed the following set of questionnaires: the German version of the revised Beck Depression Inventory (BDI-II, Hautzinger et al., 2006), the German version of the Pain Catastrophizing Scale (PCS, Meyer et al., 2008), the German version of the Positive and Negative Affect Schedule (PANAS, Krohne et al., 1996), and the German version of the State-Trait-Anxiety Inventory (Laux et al., 1981). In addition, participants were asked to indicate their fear of pain (1 = not at all–9 = very strong). As shown in Table 1, both groups did not differ significantly in any of these measures.