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Investigating the affective component of pain: No startle modulation by tonic heat pain in startle responsive individuals

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ABSTRACT

Background: Experimental tonic pain has been assumed to equal clinical pain by triggering sizeable affective responses. A psycho-physiological indicator of defensive affective-motivational responses is the startle reflex. However, earlier studies have not provided unequivocal evidence for a potentiation of the startle reflex during tonic contact heat pain.

Objectives: The demonstration of modulating effects of pain on the startle reflex might require very intense tonic stimulation and investigation of subjects, who are particularly sensitive to startle potentiation by threatening cues.

Method: We investigated a sample of healthy subjects (N = 20), who had shown pronounced startle amplitude potentiation in response to attack pictures. Noxious stimulation was provided by hand immersion into a hot water bath, which is a tonic pain model known for intense and summated stimulation. Modulation of the startle reflex was attempted by use of two stimulation intensities (42 °C, 46 °C) and one control condition (no stimulation).

Results: Even in these favorable conditions, we did not observe startle potentiation under painful stimulation in comparison to non-painful conditions although subjects reported to be experiencing moderate to high pain.

Conclusions: Our findings indicate that tonic heat pain does not trigger defensive affective-motivational responses as measured by the startle reflex when it is applied in a predictable and thus non-threatening fashion. Future research should investigate the effects of manipulations of threat on startle responses to painful stimulation.

1. Introduction

To date it seems to be well established that pain can be described as having two dimensions, which are experienced as distinguishable and which are encoded by two separate neural networks (IASP, 1979; Price and Harkins, 1992; Rainville et al., 1997; Price, 2000). These are the sensory-discriminative dimension, which provides information about stimulus properties like intensity and site, and the affective-motivational dimension, which presents as feeling of unpleasantness associated with the experience of pain and as drive to avoid, escape and overcome noxious stimulations.

This affective-motivational dimension of pain is assumed to arise from the experience of pain as threatening. As pain is mainly identified as an evolutionarily acquired warning signal with the function to protect us from potential tissue damage, the assumption that pain is automatically associated with threat and thereby with affective-motivational responding has not been questioned so far (Eccleston and Crombez, 1999; Auvray et al., 2010; Van Damme et al., 2010).

However, many pain experiences – in everyday life or in the laboratory – may also be perceived as very low in threat and, by that, without major emotional impact. Thus, the question arises whether the affective-motivational component of pain is indeed omnipresent.

In order to answer this question, valid and specific methods of assessing the affective-motivational component are required. Commonly, self-report measures are believed to differentially target the sensory and affective components when two separate rating scales are presented (Price and Harkins, 1992). However, there is some evidence that this differentiation is often an artifact due to experimental instructions (Fernandez and Turk, 1994; Chapman et al., 2001). Additionally, subjective ratings reflect explicit affective processes, which require a certain level of self-awareness and self-verbalization, whereas basal, automatic processes are not indicated by these measures. Therefore, additional parameters, which target these automatic affective processes and capture the level of implicit processing, are important to complement self-report measures; they are also less likely to be distorted by intentional response biases. Such parameters might be found amongst the established psycho-physiological methods for

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assessing affective-motivational reactions. One promising candidate for this purpose is the startle reflex paradigm. The startle reflex is a defensive reflex which is modulated by affective cues in a way that cues signaling threat and thus, activating the motivational defense system, lead to a potentiation of the startle amplitude; whereas cues signaling reward and thus, activating the motivational approach system, lead to reflex attenuation (Lang et al., 1990; Bradley et al., 1999; Grillon and Baas, 2003). Accordingly, one might assume that amplitude potentiation occurs also during painful stimulation given that pain is thought to elicit a defensive affective-motivational reaction by signaling threat to the body (Eccleston and Crombez, 1999; Auvray et al., 2010; Van Damme et al., 2010).

Based on these considerations, we designed an experiment to investigate the modulating effect of noxious stimulation on the startle reflex (Horn et al., 2012). We decided to use a tonic stimulation paradigm because experimental tonic pain is believed to resemble clinical pain more closely than phasic pain and to trigger sizeable affective responses (Chen and Treede, 1985; Price and Harkins, 1987; Rainville et al., 1992; Lautenbacher et al., 1995). Surprisingly, we detected no potentiation of the startle reflex under painful in comparison to non-painful heat stimulation, although unpleasantness ratings for painful heat were rather high. These results provide first evidence that even on-going pain is not necessarily associated with negative affect in the sense of an automatic defensive response.

However, some limitations may have prevented to draw firm conclusions. First, the dosage of tonic pain might have been still too low in our first study. Pain was induced via a thermode, which allows for exact control of intensity but is limited with respect to spatial summation. Since further increases in intensity might have run the risk to produce intolerable levels of pain, we thought it preferable for the present study to produce more nociceptive input by enlarging the degree of spatial summation in using hot water immersion. Hot water immersion belongs to the well-established experimental tonic pain models with proven efficacy (e.g. Staud et al., 2003; Lautenbacher et al., 2002, 2008; Yarnitsky et al., 2008). Second, we might have tapped a sample with individuals, who were generally not very sensitive to activation of the motivational defense system (Cook et al., 1991; Cook, 1999). Therefore, we selected a sample of subjects, who had shown pronounced startle potentiation in response to viewing attack pictures in an affective picture viewing task.

By selecting (i) a noxious stimulation like hot water immersion, which has been shown to be powerful as tonic pain test, and (ii) individuals, who were sensitive to startle potentiation by threatening cues, we optimized the conditions for verifying startle modulation by pain. In other words, if no startle potentiation occurred under these conditions, this would indicate that tonic pain is not necessarily associated with a defensive affective-motivational reaction.

2. Materials and methods

2.1. Subjects

40 healthy volunteers (female: N = 20, male: N = 20; M = 23.62 years; SD = 3.4) were recruited by advertisement at the University of Bamberg; 10 subjects were students of psychology. None suffered from severe acute or chronic illness, mental disorders or facial paralysis. Because contacts are known to enhance blink frequency, persons wearing contacts were asked to wear their glasses instead during the experimental session. None had taken any CNS affecting medication in the last seven days. Prior to the test session, subjects gave written informed consent. After testing, some of the subjects were reimbursed for participation, the others received course credits. The experimental procedure was approved by the local ethics committee.

As our prior studies had failed to show startle potentiation in response to painful stimulation in an unselected sample, we now aimed at investigating subjects who are particularly sensitive to startle potentiation by affective cues signaling threat. Subjects were selected according to their startle reactions in an affective picture viewing task (Lang et al., 1990; Bradley et al., 1999); responses to pictures showing attack scenes (e.g. a gun pointed towards the observer) were compared to responses to neutral pictures (e.g. an umbrella). Attack pictures were chosen because this picture category has been shown to elicit particularly strong startle potentiation, probably because of their directly threatening content (Bernat et al., 2006).

Subjects who showed the highest positive difference in startle amplitude between the two picture categories (i.e. large amplitudes for attack pictures and low amplitudes for neutral pictures) were selected using median split; these 20 subjects (female: N = 14; male: N = 6; M = 23.25 years; SD = 2.92) were included into further statistical analyses for startle modulation by pain.

2.2. Materials and procedures

During the whole session, which lasted for approximately 1 h, subjects sat upright in a comfortable chair. Subjects were familiarized with all the methods to be used before the start of the experiment.

The experiment was divided into two parts: In part "A", we measured the startle reflex during affective picture presentation; this part was designed to identify subjects who are sensitive to startle modulation by affective content (see 1.). In part "B", we assessed the startle reflex during painful thermal stimulation. In both parts, acoustic startle probes were presented to elicit startle blinks. The sequence of the two parts was randomized across subjects; of the 20 subjects selected for further analysis, 9 subjects started with block "B" and the remaining 11 subjects started with block "A".

2.2.1. Affective picture presentation (part "A")

Affective pictures were selected from the IAPS (Lang et al., 2005); we decided to use four categories displaying diverse affective content, which were erotic pictures, attack pictures, pain-related pictures and neutral pictures. It is commonly observed that the startle reflex is potentiated by pictures of negative valence and attenuated by pictures of positive valence, but only when these pictures are highly arousing. Strong modulating effects are commonly observed for attack pictures (negative) and erotic pictures (positive) (Bradley et al., 2001a, 2001b; Bernat et al., 2006). These picture categories display evolutionary relevant content and are rated as highly arousing, thus presumably leading to a strong activation of the motivational defense and approach system, respectively. We also added pain-related negative pictures, i.e. pictures depicting mutilation, to assess whether this special category exerts different effects on the startle reflex in comparison to other negative pictures. For each valence category, we chose six representative pictures, resulting in a total of 24 pictures.[1] Pictures were presented in blocks of the same valence category (four blocks altogether); each picture was shown for 55 s. The sequence of pictures within each category was randomized once and then set for all subjects, while the sequence of categories was randomized across subjects.

After each picture, subjects rated picture valence and arousal as well as the perceived mean intensity of the startle noise. This rating period lasted for 10 s, resulting in a total duration of 6.5 min for each of the four blocks with affective picture viewing.

2.2.2. Tonic heat stimulation (part "B")

To design a condition which provides intense and spatially summated tonic heat stimulation, we used a water bath. Subjects were asked to immerse their right or left hand up to 10 cm above the wrist in the water for 3.25 min. Subjects were informed that they

[1] The IAPS identification numbers were as follows: *Erotic pictures*: 4652, 4659, 4660, 4670, 4687, 4695; *Attack pictures*: 1120, 1300, 1525, 6250.1, 6300, 6510; *Pain-related pictures*: 3010, 3180, 3261, 3350, 9253, 9410; and *Neutral pictures*: 2200, 5120, 5534, 7002, 7031, 7150.

could remove their hand from the water bath at any time as soon as the temperature became intolerable. However, none of the subjects made use of this possibility, so that all subjects completed the full period of heat stimulation. There were three conditions consisting of painful heat stimulation (water temperature: 46 °C), non-painful heat stimulation (water temperature: 42 °C), and no stimulation at all (no immersion). The water temperature was controlled with a thermostat (Variostat, Huber), and the water was stirred with a force and suction pump to avoid regional temperature difference within the water bath.

As we applied both temperature conditions on both arms and there were two control conditions with no immersion of the arm, part "B" consisted of six experimental blocks (each lasting for 3.25 min). The sequence of body sides and temperature blocks was randomized.

2.2.3. Startle noise presentation

To elicit the blink reflex, we applied brief acoustic stimuli (white noise), 50 ms in duration, with an intensity of 105 dB binaurally over headphones. Subjects wore headphones during the whole experimental session, over which they heard a constant white noise of 68 dB as masking background noise. It was pre-set that there should be two to four noise presentations per minute (three on average), resulting in a total of 18 presentations for each 6.5 minute block in part "A" and a total of 9 presentations for each 3.25 minute block in part "B". In each minute, the first noise should be presented after 3 s at earliest and after 15 s at the latest, and the inter-stimulus interval should be at least 12 s to avoid habituation. Furthermore, there should be no noise presentation during the rating period (interval between seconds 55 and 65). In keeping these restrictions startle noise presentations were timed in random intervals to be unpredictable.

2.2.4. Ratings

In part "A", subjects were required to provide valence and arousal ratings using a computerized version of the Self-Assessment Manikin (SAM; Lang, 1980) after each picture. Subjects were advised to choose one of five manikins or a box in between on both of the SAM rating scales (valence and arousal) via mouse click. Thus, ratings ranged from 1 to 9; higher ratings corresponded to positive valence and high arousal, respectively. In addition, subjects rated the intensity of startle noise on a computerized Numerical Rating Scale (NRS) ranging from 0 (labeled as "no noise") to 100 (labeled as "extremely loud noise"), the results of which are not reported here.

In part "B", subjects were asked to use the same NRS to assess the painfulness of the heat stimulation as well as the intensity of startle noise presentations by giving the numbers verbally. Due to hand immersion, the use of the computer mouse was not feasible. Both scales ranged from 0 to 100. For painfulness ratings, 0 was labeled as "no sensation", 50 was labeled as "beginning pain" and 100 was labeled as "most extreme pain". For startle noise ratings, 0 was labeled as "no noise" and 100 was labeled as "extremely loud noise". In the two control blocks without thermal stimulation only startle noise ratings were obtained.

The ratings in parts "A" and "B" were obtained after every 55-second-interval of picture presentation or thermal stimulation and lasted for 10 s.

2.2.5. Questionnaire measures

To assess pain-related emotions and cognitions, we included the German versions of the Pain Catastrophizing Scale (PCS) (Sullivan et al., 1995), the Pain Anxiety Symptom Scale (McCracken, 1997; McCracken et al., 1992) and the Pain Vigilance and Awareness Questionnaire (PVAQ) (McCracken, 1997).

2.2.6. Electromyographic recording and analysis

Startle blinks were measured by recording surface EMG activity on the M. orbicularis oculi beneath the right eye. For that purpose, Ag/AgCl electrodes filled with electrode paste were used. Prior to application of the electrodes, skin was cleaned with an alcoholic skin detergent to reduce electrode resistance.

EMG raw signals were recorded using the device SIGMA Plpro/Type Databox DB 36 including a 16 bit AD-convertor with a dynamic range from 0.5 μV to 2 mV. The recording bandwidth of the EMG signal was between 0.2 Hz and 300 Hz; input resistance was above 20 mΩ. The signal was sampled at 512 Hz. To allow for an event-related signal analysis, trigger signals were set to mark the onset of the startle noise. After recording, the raw signal was analyzed offline using the program "Vision Analyzer" (*Brain Products*, Munich). First, the signal was cut into segments, each containing the responses to the startle probes within one experimental trial. In each segment the raw signal was smoothed, using a 50 Hz notch filter, 20 Hz high-pass filter and 256 Hz low-pass filter, rectified and integrated. The integration procedure was executed over a time interval from 0 to 250 ms after startle noise onset. Finally, exclusion of invalid responses was accomplished first automatically and after that by inspection. The automatic procedure suggested the exclusion of responses if considerable fluctuations in the baseline EMG activity were detected and/or if the peak of activity did not occur in the pre-defined time window (30–100 ms) after stimulus onset. After that, segments were analyzed by inspection and reactions were excluded if they did not match the typical shape of a startle response or if no startle response at all could be detected.

The critical variables were peak latency and amplitude of blink responses. Peak latency was defined as time from startle noise onset to the maximum value of voltage. Amplitude was defined as voltage difference between the averaged baseline and voltage peak within a time frame of 30–100 ms after startle noise onset. Mean values of peak latency and amplitude were calculated for each of the six temperature conditions ("painful heat", "non-painful heat" and "no stimulation", two times each) as well as for each of the four picture valences ("attack", "pain-related", "erotic", "neutral") and then entered into statistical analyses.

2.2.7. Statistical analysis

2.2.7.1. Subjective ratings. To evaluate the effects of the experimental conditions on the SAM ratings of the affective pictures as well as on the NRS ratings of the temperature and the noise, the following ANOVAs with repeated measurements were computed: *effects on SAM ratings*: 4 ("picture valence": erotic, neutral, attack, pain-related) × 6 ("minute of block": 1–6); *effects on pain NRS ratings*: 2 ("thermal stimulation": "46 °C", "42 °C") × 2 ("body side": "right leg", "left leg") × 3 ("minute of block": 1–3).

2.2.7.2. Startle reflex. To evaluate the effects of affective picture viewing and thermal stimulation on startle peak latency and amplitude, we conducted two one-way ANOVAs for repeated measurement: *picture valence*: erotic, attack, pain-related, neutral; *thermal stimulation*: "46 °C", "42 °C", "no stimulation".

Adjusting degrees of freedom with Greenhouse–Geisser correction was necessary when sphericity could not be observed. For F-tests, partial eta squared (η^2) is reported as an estimate of effect size. In case of significant results, post-hoc tests (paired samples t-tests) were computed, for which Cohen's d is reported to describe effect size.

PASW 17.0 was used for all calculations; significant effects were assumed at $\alpha = 0.05$.

3. Results

3.1. Descriptive measures

Table 1 shows demographics and questionnaire scores for those subjects we selected for analysis (modulation-sensitive subjects) and for the non-selected subjects. The two groups did not differ

significantly in terms of age ($T(38)=0.90$; $p=0.929$). However, there was a significant difference in sex ratio ($\chi^2(1, N=40)=1.60$; $p=0.206$), with more female participants in the modulation-sensitive subgroup (female: N = 14; male: N = 6). Additionally, one-way ANOVAs showed no group differences in the questionnaires assessing pain-related vigilance, anxiety and catastrophizing (*PVAQ*: $F(1,38)=0.025$, $p=0.875$; *PASS*: $F(1,38)=0.166$, $p=0.686$; PCS: $F(1,38)=0.178$; $p=0.676$). Accordingly, selected subjects did not differ from non-selected subjects regarding these pain-related self-report measures.

3.2. Effects of affective pictures

3.2.1. Startle reflex

We did not find any effect of "picture valence" on startle reflex peak latency, but there was the expected significant effect on startle reflex amplitude ($F(2.10,39.91)=6.33$; $p=0.001$) with potentiation under negative, i.e. attack and pain-related pictures in comparison to neutral pictures and also in comparison to positive, i.e. erotic pictures (see Fig. 1 and Table 2). These results prove that our selection of modulation-sensitive subjects was successful.

3.2.2. SAM ratings

A first ANOVA yielded a significant main effect of "picture valence" on SAM valence ratings ($F(1.76,33.37)=137.844$; $p<0.001$, $\eta^2=0.879$); erotic pictures were rated as positively valenced ($M=6.88$; $SD=1.18$), while attack pictures ($M=3.31$; $SD=0.77$) as well as pain-related pictures ($M=2.20$; $SD=0.55$) were rated as negatively valenced and neutral pictures ($M=5.18$; $SD=0.51$) scored in between. There was also a significant main effect of "picture valence" on arousal ratings ($F(1.88,35.64)=43.839$; $p<0.001$, $\eta^2=0.698$); erotic ($M=6.06$; $SD=0.85$), attack ($M=6.07$; $SD=0.99$) and pain-related ($M=7.15$; $SD=0.91$) pictures were all rated as more arousing than neutral pictures ($M=3.93$; $SD=1.$).

3.3. Effects of thermal stimulation

3.3.1. Startle reflex

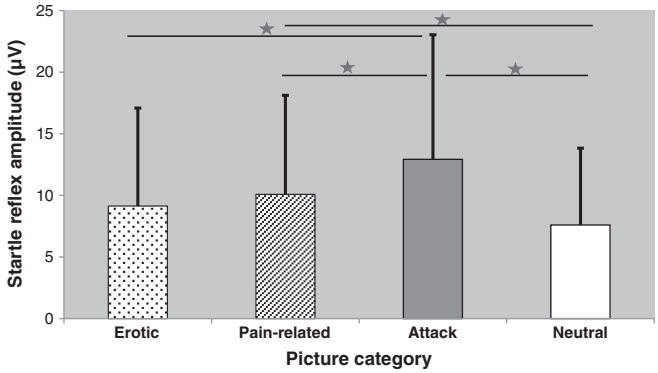
3.3.1.1. Startle reflex peak latency. We found no significant main effect of "thermal stimulation" on startle reflex peak latency ($F(2,38)=0.873$; $p=0.426$, $\eta^2=0.044$).

3.3.1.2. Startle reflex amplitude. The main effect of thermal stimulation on startle reflex amplitude also did not reach significance ($F(1.43,27.24)=0.030$; $p=0.931$, $\eta^2=0.002$); thus, we were not able to find any modulating effect of thermal stimulation on the startle amplitude (Fig. 2).

3.3.2. Pain NRS ratings

An ANOVA yielded significant main effects of "thermal stimulation" ($F(1,19)=214.704$; $p<0.001$, $\eta^2=0.919$) and "minute of block" ($F(1.53,29.13)=9.833$; $p<0.001$, $\eta^2=0.341$) on pain NRS ratings. Besides this significant difference between the two temperature conditions in NRS ratings, the blocks, during which 46 °C hot water was applied, were rated as clearly painful; in these blocks, 85% of the ratings were higher than 50 (the scale value labeled as "beginning pain"). In contrast, the blocks using a stimulation temperature of 42 °C were rated as non-painful; in these blocks, 100% of the ratings were lower than 50. These findings prove that the experimental pain manipulations were successful in this respect.

The interaction between "thermal stimulation" and "minute of block" also reached significance ($F(1.55,29.41)=17.488$; $p<0.001$, $\eta^2=0.479$): NRS ratings showed no change over the 3 min in the blocks with non-painful thermal stimulation but an increase over the same interval in the blocks with painful stimulation (see Table 3), indicating the typical pattern of sensitization only for painful heat stimulation.



Note. Significant differences (p<0.05) between picture categories (paired samples T-test)

Fig. 1. Mean (+SD) of startle reflex amplitudes for the affective picture categories: "erotic", "attack", "pain-related" and "neutral".

4. Discussion

Our aim was to experimentally investigate the affective-motivational reaction to tonic pain, which is generally believed to trigger stronger affective responses than phasic pain (Chen & Treede, 1985; Price and Harkins, 1987; Rainville et al., 1992; Lautenbacher et al., 1995). Given that we were interested in assessing automatic and implicit affective processing in order to complement explicit measures like subjective ratings, we decided to use the startle reflex paradigm for this purpose. The startle reflex amplitude is reliably potentiated by affective cues which are threatening and thus activate the motivational defense system (Lang et al., 1990; Bradley et al., 1999; Grillon and Baas, 2003). As pain is thought to elicit a defensive affective-motivational reaction by signaling threat to the individual in pain (Eccleston and Crombez, 1999; Auvray et al., 2010; Van Damme et al., 2010), one would expect a potentiation of startle amplitude during painful stimulation.

However, in a preceding study, using contact heat stimulation in an unselected sample of individuals, we did not observe any amplitude potentiation of the startle reflex under painful in comparison to non-painful heat (Horn et al., 2012). These findings had suggested that even moderately painful tonic stimulation does not automatically elicit

Table 1
Demographics as well as means and standard deviations for the questionnaire scores of the selected and non-selected subjects.

	Selected subjects (startle sensitive)		Non-selected subjects	
	Mean	SD	Mean	SD
Sex (% male)	30		70	
Age (years)	23.25	2.92	23.15	4.02
PVAQ (sum score)	39.45	9.29	39.90	8.69
PASS (sum score)	112.95	24.47	109.65	26.77
PCS (sum score)	19.70	6.67	20.60	6.82

PVAQ = Pain Vigilance and Awareness Questionnaire, PASS = Pain Anxiety Symptom Scale, PCS = Pain Catastrophizing Scale.

Table 2
Descriptive statistics for startle reflex peak latency during stimulation in the hot-water bath and during affective picture viewing.

		Thermal stimulation			Affective picture viewing			
		None	42 °C	46 °C	Neutral	Erotic	Attack	Pain-related
Peak latency (ms)	Mean	93.64	93.84	91.06	92.37	93.55	92.37	94.52
	SD	7.12	6.46	8.10	6.71	7.03	6.34	5.36

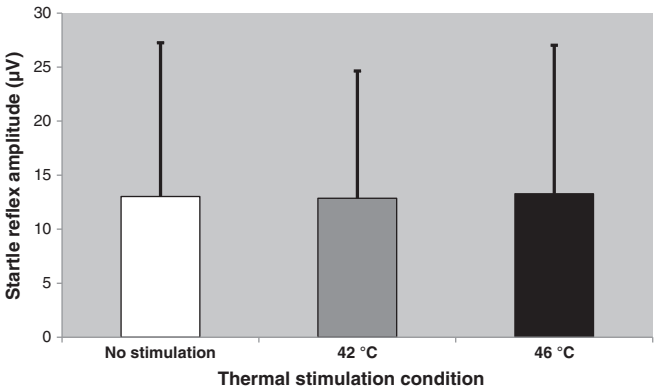


Fig. 2. Mean (+SD) of startle reflex amplitudes for the thermal stimulation conditions.

defensive affective-motivational reactions. However, the demonstration of modulating effects of pain on the startle reflex amplitude might have required even more intense tonic stimulation and investigation of subjects, who are sensitive to activation of the motivational defense system. For this reason, we designed the current experiment, in which we made our paradigm more receptive to startle modulating effects: Nociceptive input was enhanced via enlarged spatial summation by using lower forearm immersion into a hot water bath as an established powerful tonic pain model. A sample of sensitive subjects was selected by only investigating subjects, who had shown pronounced startle amplitude potentiation in response to attack pictures in an affective picture viewing task. However, these modifications did not change the pattern of results: Again, we detected no potentiation of the startle amplitude during painful heat. Similarly to our preceding study, we noticed a discrepancy between startle and subjective ratings: Whereas the startle reflex amplitude was not potentiated by painful vs. non-painful stimulation, subjective ratings clearly distinguished between the painful and non-painful conditions. In the painful condition, ratings ranged above 50 (the scale value, which was labeled as "beginning pain") and increased in the course of 3 min, indicating temporal summation; in contrast, ratings for the non-painful condition ranged below 50 and did not change over the course of 3 min.

These results suggest that both the quantity of nociceptive stimulation and the individual reactivity of the motivational defense system are of little importance when investigating the modulating effects of pain on the startle reflex. Given that Crombez et al. (1997) – in contrast to our studies – did detect startle potentiation by pain using phasic stimuli (which are actually believed to be experienced as less affective than tonic pain stimuli), other parameters must be critical in determining the strength of defensive reactions to pain.

When comparing our stimulation paradigms to the one used by Crombez and colleagues, the main difference lies in the predictability of the painful stimuli. Crombez and colleagues applied short (5 s) phasic heat pulses of different (painful and non-painful) intensities; these stimuli were delivered in random order so that the subjects were not able to predict the painfulness of the upcoming stimulus. In contrast, our tonic heat pain was clearly predictable as regards intensity and course. It has already been shown that unpredictability enhances subjective reports of pain-related unpleasantness as well as activity in brain regions important for affective processing (Price et al., 1980; Carlsson et al., 2006).

Table 3
Descriptive statistics for the pain NRS ratings during thermal stimulation.

Time of thermal stimulation			Minute 1	Minute 2	Minute 3
Pain NRS ratings (0–100), 50 = "beginning pain"	"42 °C"	Mean	26.40	26.48	26.63
		SD	10.87	11.12	10.44
	"46 °C"	Mean	61.20	63.88	68.00
		SD	14.64	14.36	16.10

NRS = Numerical Rating Scale.

These observations suggest that pain is not necessarily associated with high levels of threat; this is in line with findings obtained by other researchers, who have already shown that threat and pain can change independently (Jackson et al., 2005; Van Damme et al., 2008; Hubbard et al., 2011). However, we were – to our knowledge – the first ones to show that predictable, constant pain can be experienced as so low in threat that it does no longer elicit a traceable defensive affective-motivational response.

Another consideration, which might be of relevance in this context, is the distinction between phasic and tonic pain. When confronted with phasic pain, rapid flight is presumably the best strategy to provide immediate escape from the threatening stimulus. Thus, it makes sense that defensive reflexes like the startle reflex are augmented by phasic pain. In contrast, tonic pain as ongoing challenge of bodily functioning can better be coped with by lasting stress responses accompanied by an inconspicuous lowering of mood.

One might argue that a lack of defensive responding (as suggested by our results) must not always coincide with a lack of affective responding. We acknowledge that there might be circumstances leading to dissociation between motivational and affective responding. Accordingly, a subjective feeling of unpleasantness might be associated with a low level of defensive motivation. However, given that merely the passive viewing of unpleasant pictures without any response demands has repeatedly proven to elicit sufficient defensiveness to enhance the startle reflex (Lang and Bradley, 2010), our experimental protocol does very likely also not induce a strong dissociation between defensive and affective responding.

4.1. Limitations

Several features of our study might result into limitations, worth being mentioned.

First, one might argue that our results are simply attributable to attentional interference effects, with noxious stimulation distracting participants from the startle noise presentations and thus, blocking startle modulation. However, this seems rather unlikely, as pain is a very effective distractor when it is unfamiliar and unpredictable (Crombez et al., 1994), but not when it is applied in a stable and predictable manner as in our paradigm. In the latter form, it lacks a critical feature of powerful distractors, which is novelty.

Second, it might be regarded as problematic that only pain intensity but not pain unpleasantness ratings were assessed. We decided to collect only intensity ratings mainly for two reasons: (i) The time for ratings was very limited and we were more interested in guaranteeing the subjective painfulness of the 46 °C condition compared to the non-painfulness of the 42 °C condition. (ii) Asking the subjects to rate pain unpleasantness, might have implied a suggestion, which induced affective responding not due to the pain stimulus but due to the instruction. Furthermore, intensity and unpleasantness ratings are highly correlated when experimental pain is applied. Finally, tonic pain is known to elicit even higher unpleasantness compared to intensity ratings (ratio unpleasantness/intensity) (Rainville et al., 1992, Hofbauer et al., 2001, Kunz et al., 2012).

Third, the startle amplitude was overall higher in the blocks with thermal stimulation than in the blocks with picture presentations. Since order effects were controlled for, this might have occurred due to stronger anticipatory anxiety as regards the physical stressor compared to the psychological stressor. However, the startle amplitude did not reach ceiling in the blocks with thermal stimulation, because the standard deviations appeared to be particularly high and not constricted in these blocks.

Fourth, another shortcoming of our study might have been the significant difference in sex ratio between selected and non-selected subjects, with more female participants in the modulation-sensitive

subgroup. However, this observation is consistent with research proving that women show stronger defensive reactions to aversive pictures (Bradley et al., 2001b) and is therefore difficult to avoid when selecting subjects highly sensitive to startle potentiation by threatening cues.

5. Conclusions

Taken together, our results show that stable and predictable tonic pain stimulation does not elicit defensive affective-motivational reactions as measured by the startle reflex paradigm. Accordingly, defensive affective-motivational reactions do not always occur in the context of pain, but seem to depend on the circumstances of pain stimulation. A critical factor might be the experience of pain as threatening, which was likely not induced by our pain induction protocol. Future research should clarify the impact of varying degrees of threat on startle modulation by pain.

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