SOMATOSENSORY ATTENTIONAL MODULATIONS DURING PAIN-RELATED MOVEMENT EXECUTION

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Abstract

Pain serves to protect against bodily threat, and therefore initiates protective responses such as attending towards threat-relevant information. Since pain is often exacerbated by executing movements, these motor actions may serve as cues for pain. Up to date, however, pain-related attention during movement remains largely unexplored. While it has been shown that the preparation of a pain-related movement leads to enhanced processing of somatosensory information, it is unclear how the actual execution of a movement interacts with somatosensory attention. In the current study we examined whether somatosensory processing is enhanced at a moving body part when the movement is expected to be associated with pain. Participants were asked to execute hand movements which were occasionally followed by a pain stimulus. To measure somatosensory attention, a task-irrelevant, innocuous tactile probe was presented on either hand to evoke a somatosensory evoked potential (SEP). The results showed an elevation of the N120 SEP at the hand performing a potentially painful movement, indicating heightened attention towards tactile information at the threatened moving hand compared to the non-threatened hand. Additionally, the P200 SEP also showed enlarged responses when performing a pain-related movement compared to a no-pain-related movement. These results show that not only the anticipation but also the execution of pain-related movements, may modulate the processing of somatosensory input, driven by attentional processes.

Introduction

Pain sends a signal that our body needs protection (Wiech and Tracey 2013). Not only the pain itself, but also cues that predict possible pain can evoke these protective responses (Eccleston and Crombez 1999). When the execution of a certain movement is occasionally followed by the experience of pain, this movement might become a conditioned stimulus signaling pain (Vlaeyen and Linton 2012). It has been proposed that pain-conditioned stimuli can initiate the same cognitive-affective response as pain itself, including increased fear/arousal and increased attending to bodily sensations (Vlaeyen and Linton 2012). Although such anticipatory responses are adaptive in nature because they urge the initiation of protective behavior, excessive and repeated activation in the long term may become maladaptive and disabling, possibly playing a role in the development and maintenance of chronic pain. It is thus crucial to have a clear understanding of these cognitive-affective responses.

Whereas several studies have demonstrated that pain-conditioned movements evoke increased fear (Meulders et al. 2011; 2013), the phenomenon of increased attending to bodily sensations under threat of pain remains indefinite. It has been proposed that pain expectancy may increase attentional processing of somatosensory information at a threatened body location (Durnez and Van Damme 2017; Vanden Bulcke et al. 2013). However, these behavioral measurements that have mainly been used to study this *attentional bias* to the body part under threat of pain are not completely free from alternative explanations such as response strategies (Filbrich et al. 2016). As an alternative to these behavioral measures, event-related potentials may serve as a better option, since it allows to probe somatosensory activity while being completely task-irrelevant. Interestingly, it has been shown that magnitude of somatosensory evoked potentials (SEPs) is susceptible to attentional modulation (Eimer and Forster, 2003; Franz et al. 2015; Garcia-Larrea et al. 1991; Zopf et al. 2004). Recently, it has been shown that this approach is promising to study attentional bias (Clauwaert et al. 2018). Specifically, we assessed SEPs during the anticipation, rather than during the execution, of pain-related and no-pain-related movements. One of the main findings was a larger N120 SEP to tactile stimuli presented on the pain-associated location, and only when preparing the movement associated with pain. This result is supported by the finding that merely the anticipation of pain may lead to cognitive modulations of brain activity (Porro et al., 2002; 2003).

An important question is whether moving a body part, in contrast with a body part that is preparing a movement, affects somatosensory processing, especially if the movement is associated with pain. Several recent studies suggest that task-irrelevant touch is suppressed during movement, but not if it is task relevant (i.e. somatosensory suppression; e.g. Gertz et al. 2017; Voudouris et al., 2019; Juravle et al. 2017). From this

perspective, it is possible that task-irrelevant tactile stimuli are also suppressed during the execution of a pain-associated movement. Additionally, the premotor theory of attention (Rizzolatti et al. 1994) postulates that during movement preparation attention moves to the goal location. This is in contrast with other studies (e.g. Forster and Eimer, 2007) which seem to suggest that attention may move during movement execution from the goal location to the effector. As a result, tactile and visual processing is enhanced (Job et al., 2016; Juravle et al. 2016). Indeed, attending to a moving body part can lift the effect of sensory suppression (Van Hulle et al. 2013; Juravle et al 2011). However, these studies are not in the context of movement being directly associated with pain, a cue that naturally demands attention (Crombez et al. 2013).

The question can therefore be asked if expectation of pain during movement guides attention towards the effector of the movement. Moreover, it is unclear whether the pre-movement attentional modulation of task-irrelevant tactile stimuli, as shown by Clauwaert and colleagues (2018) also persists through movement. To test this hypothesis, healthy volunteers were cued to perform a left- or right-hand movement, and one of these movements was occasionally followed by a painful stimulus to the moving hand. SEPs to a task-irrelevant vibrotactile stimulus were measured *during* movement execution. Importantly, this paradigm allows dissociating whether pain motivates location-specific attending (i.e. if attention is only focused towards the body part under threat of pain). We hypothesized that, similar as during movement preparation, participants would attend more towards somatosensory information at the pain-related hand compared to the neutral hand when performing the pain-conditioned movement, as reflected by an enhanced N120.

Method

Participants

A group of forty healthy volunteers (9 males) was recruited through the online recruiting system for research participants of Ghent University. Only right-handed (mean score on the Edinburgh Handedness Inventory was 80.58 (*SD*=16.61)) and healthy participants without any neurological disorders were allowed to participate in the study. Due to a technical error, the data of one participant was not recorded properly. The mean age of the remaining participants was 22.22 (*SD*=2.98, range 18 – 30). The participants took part in the experiment in exchange for a monetary reward and were not informed about the goals of this study before the start of the experiment. Instead, participants were informed that the experiment consisted of a simple behavioral task in which

harmless sensory stimuli would be administered. To avoid that only individuals without fear of pain would be recruited for the experiment, the use of painful stimuli in the study was not explicitly mentioned in the announcement of the study. However, all stimuli were described when the participants arrived at the experiment. Participants were told that they were free to terminate the experiment at any time should they so desire. All participants agreed to continue with the experiment and provided informed consent. The study protocol was approved by the local ethical committee and was performed according to the ethical standards laid down in the declaration of Helsinki.

Materials

The experiment was programmed using the Tscope 5 library package, in the programming language C (Stevens et al. 2006). Two resonant-type tactile probes (C-2 TACTOR, Engineering Acoustics, Inc., Florida; see Van Hulle et al. 2013) were used to administer vibrotactile stimuli with a duration of 200 ms and a frequency of 300 Hz to the metacarpals of both hands. Both the amplitude and the frequency were controlled by means of a self-developed software program. The tactile probes were attached directly to the skin surface using double-sided tape rings and were driven by a custom-built device. To prevent any interference from environmental noise, participants were asked to wear earplugs during the experiment. Prior to the start of the experiment, the perceived stimulus intensities at each probe location were individually matched. In order to accomplish this, a standardized matching procedure was used for each participant (Clauwaert et al. 2018; Van Hulle et al. 2013). First, a tactile reference stimulus (Power = 0.04 watts) was presented on the left hand, followed by a tactile stimulus at the other hand. Participants then had to verbally report whether the intensity was lower than, higher than, or equal to the intensity of the reference. The intensity of the tactile probe on the right hand was varied until it was reported that the subjective intensity of each stimulus was perceived as being equal to the subjective intensity of the stimulus on the left hand.

The painful electrocutaneous stimuli (ES, bipolar; 50Hz; 200 ms; instantaneous rise and fall time) were delivered by means of a Constant Current Stimulator (DS5, Digitimer Ltd, Hertfordshire, UK) with two lubricated Medcat surface electrodes with a diameter of 1 cm. These electrodes were placed in the middle of the base of metacarpal 2. Participants were first presented with an ES of low amplitude (0.5 mA) to prevent the initial surprise effect to affect the evaluation of the stimulus. After this, the same stimulus was presented, and the participants were motivated to choose an intensity that they evaluated as unpleasant as possible but that they were still willing

to endure during the experiment. Each time the participant pressed a key to increase the intensity, the amplitude was elevated in steps of 0.5 mA. It was not possible to go back to a lower intensity. An optical sensor box was used to record the start of the movement.

Design and procedure

Participants were asked to take place in front of a computer screen and to place their hands on the sensor box in front of them. The study consisted of 2 similar phases. In the first part of the experiment, the *learning phase,* the participants were familiarized with the experiment and learned that moving one hand was associated with a painful stimulus and moving the other hand was associated with a non-painful stimulus during movement execution.

In the learning phase each trial started with the presentation of a fixation cross (500 ms), followed by the presentation of a cue (the Dutch words for "LEFT", "RIGHT" or "STOP") in the middle of the screen. This cue was presented on a screen for 1000 ms. As soon as the cue disappeared, participants were required to perform either a left- or right-hand movement, or to do nothing, according to the cue. If participants answered before the cue had disappeared, the Dutch words for "TOO FAST" were presented in red in the middle of the screen for 1000 ms, followed by the next trial. The movement consisted of releasing the corresponding hand from the detector of the sensor box and to press a button placed 20 centimeters away in front of the body. Importantly, participants learned that the execution of either the left- or the right-hand movement was combined with the administration of a painful ES in 25% of the cases during movement, while the other hand movement received an innocuous tactile probe in 25% of the cases during movement. In the other 75% of the cases of the learning phase, no stimulation occurred. The hand that received the ES stimulus was counterbalanced across participants, and this association was made clear both by verbal instructions and experience (Field and Storksen-Coulson 2007). The stimuli were presented immediately between 25 and 50 ms after releasing the sensorbox. The next trial started 1500 ms after pressing the button. In total, this learning phase consisted of 24 trials.

The *experimental phase* was very similar to the learning phase. However, in every trial of the experimental phase, also a vibrotactile probe was presented between 25 and 50 ms after initiation of the movement on one of the two hands for a duration of 200 ms, and the SEPs evoked by this stimulation were recorded. Participants were instructed to ignore this stimulation, since it was irrelevant for the task. There were in total 864 trials, divided into 6 blocks, with 144 trials in total for each condition. In order to maintain the association which hand-movement is

associated with pain, the ES was presented on the pain-related hand instead of the vibrotactile probe in 25% of the trials during the movement. These trials were left out of the analyses. Nonmovement trials (i.e., "stop" trials) were only included in the design to check whether movement may contribute to the SEP amplitudes. These trials were excluded from the main analysis. The design of the study was thus a 2 (type of cue: pain-related vs safe movement) x 2 (stimulation location: pain-related vs safe location) design, with the ERP amplitudes evoked by the tactile stimulus during movement execution as the dependent variable.

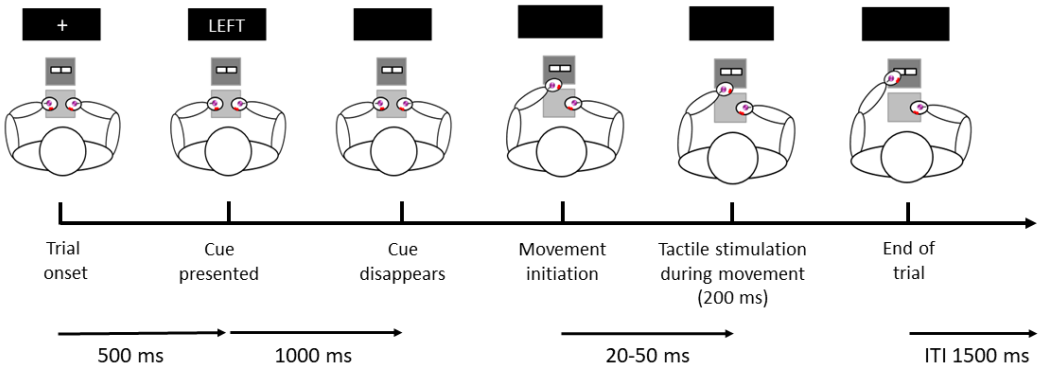

Figure 1. overview of an experimental trial.

Self-reports

After the experimental task, participants were asked to report about their pain experience ('How painful did you find the electrocutaneous stimuli?'), how unpleasant they rated the stimulus ('How unpleasant did you find the electrocutaneous stimuli?'), and their expectations and fear ('To what extent did you expect that the right/left hand movement cue would be followed by a painful stimulus?' and 'To what extent were you afraid that the right/left hand movement cue would be followed by a painful stimulus?') on an eleven-point numerical rating scale (anchored 0 = not at all and 10 = very strongly; Vanden Bulcke et al. 2013). Also, they were asked to fill out a Dutch version of the Pain Vigilance and Awareness Questionnaire (PVAQ), a scale that consists of 16 items in which participants are asked to report on their vigilance for pain sensations on a Likert scale from 1 ("never") to 5 ("always"). The PVAQ consists of two subscales: the attention subscale (e.g. 'I focus on sensations of pain'), and the attention to changes in pain subscale (e.g. 'I am quickly to notice changes in pain intensity'). High scores on the PVAQ reflect increased levels of hypervigilance to pain sensations. The Dutch version of this questionnaire

has been shown to be valid and reliable in both healthy populations and chronic pain patients (Roelofs et al. 2002; Roelofs et al. 2003).

EEG recording and analyses

EEG was recorded continuously using a Biosemi ActiveTwo recording system at a sampling rate of 2,048 Hz from 64 active electrodes, placed according to the international 10/20 setting. EEG signals were referenced online to the active Common Mode Sense (CMS) and passive Driven Right Leg (DRL) ground electrodes. Bipolar electrodes were placed respectively above and below the left eye and next to the outer left and right canthi to record eye movements. Electrode contact was checked by the offset values (i.e. running average of voltage at each electrode), which were kept between -50 and 50 μV at all electrodes.

EEG data were analyzed off-line using Brainvision Analyzer 2.1 (Brain Products GmbH, Munich, Germany). First, signals were re-referenced to the right and left mastoids, band-pass filtered between 5 and 30 Hz and epoched from -50 ms to 2500 ms from the onset of cue one. A baseline was selected from -200 ms to 0 ms before the disappearance of cue 1. This timeframe was selected in order to avoid motor interference evoked by the motor command (i.e. the disappearance of cue 1, Luck, 2005) and used for a baseline correction. Next, signals were re-epoched from -200 ms to 500 ms to the onset of the tactile stimulation. Prior to averaging, artifacts due to eye blinks were automatically corrected by means of the Gratton et al. algorithm (Gratton et al. 1983). Next, an automatic artifact rejection was applied including a gradient check (maximum allowed voltage step: 50 μV/ms within 200 ms before and after the locked event), a minimum/maximum amplitude check (-75 μV and 75 μV respectively), and a low activity check (0.5 μV within an interval length of 100 ms). Since we were not interested in left/right hand differences, SEPs were averaged together according to their relative location to the tactile probe (i.e. ipsi- and contralateral to the tactile probe), regardless of which hand was stimulated (i.e. left or right). Next, four waveforms were obtained, elicited by stimuli applied onto: (i) the pain location when the movement had to be performed with the safe hand (Safe cue-Pain location), (ii) the safe location when the movement had to be performed with the safe hand (Safe cue-Safe Location), (iii) the pain location when the movement had to be performed with the pain hand (Pain Cue-Pain Location), (iv) the safe location when the movement had to be performed with the pain hand (Pain Cue-Safe Location). A collapsed localizer (i.e. an average across the four different conditions, Luck and Gaspelin 2017) was created and ERP data were visually inspected. Two components, similar to the study by Clauwaert and colleagues (2018) (the N120 and P200 SEPs) were selected.

The collapsed localizer showed a negative peak at 121 ms (N120) at electrodes Fz and FCz and a positive peak at 186 ms (P200) at electrodes Cz and FCz. Mean amplitudes for the first component were exported from electrodes Fz and FCz in a time window between 96 and 146 ms. For the second component, data was exported from electrodes FCz and Cz in a time window between 136 and 236 ms (see Figure 2).

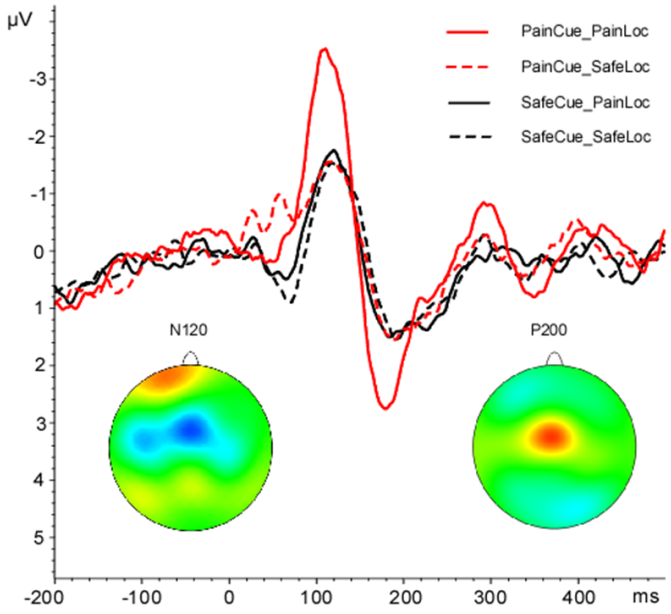

Figure 2. Grand average wave of both the N120 and P200 SEP, recorded at electrode FCz for the 4 different conditions. Current source densities (CSD) for the PainCue_PainStim condition are presented under the waveform for both the N120 SEP (left) at 121 ms after stimulus onset and P200 (right) at 186 ms after stimulus offset.

Statistical analyses were conducted with JASP 0.10.2.0 on the exported mean area amplitudes. To check the influence of movement on SEP amplitudes, nonmovement trials (i.e. "STOP" trials) were compared with the averaged movement trials (both threatened and safe) using a t-test. A 2 (type of cue: Pain Cue vs Safe Cue) x2 (stimulation location: Pain Location vs Safe Location) repeated measures analysis of variance (ANOVA) was conducted to analyze the data. Post-hoc testings, adjusted with Holm's correction for multiple comparisons, were run to clarify significant interactions.

Bayes Factors (BFs) were calculated in JAPS (2019) with default priors to further quantify the evidence. BFs allows to quantify the support for a model (e.g. an alternative hypothesis H1) relative to another (e.g. the null hypothesis H0). A BF of 2.00 can be interpreted as evidence that the data is twice more likely under H1 than under H0. In contrast, a BF of 0.5 indicates that the data is twice more likely under H0 than under H1. Cut-offs are based

on Jeffreys (1961), with a BF between 1 and 3 indicating anecdotal evidence, between 3 and 10 moderate evidence, and larger than 10 strong evidence.

To evaluate the relationship between the SEP-responses and the self-report ratings and PVAQ scores, the indexes of the interactions were calculated as the differences of the mean amplitudes ($M_{SafeCue\_PainLoc} - M_{PainCue\_PainLoc}$) − ($M_{SafeCue\_SafeLoc} - M_{PainCue\_safeLoc}$) and correlated with the participants' reported amounts of fear, pain expectations, and scores on the PVAQ.

Results

Self-report data

The ratings from 4 participants were not recorded completely and were therefore not included in the analyses. Participants selected an average intensity of 1.78 mA (*SD*=1.18, ranging between 0.5 and 5.5 mA) for the ES and rated these stimuli as painful (*M*=6.03, *SD*=1.99) and unpleasant (*M*=7.05, *SD*=1.85). Furthermore, when asked to what extent they expected that a movement cue would be followed by a painful stimulus, the participants reported that they had higher expectations to feel pain before performing a pain-related movement (M=7.60, SD=1.35), compared to the safe movement (*M*=0.97, SD=1.65, $t(34) = 17.85$, $p<0.001$, $d= 3.02$). Similarly, the participants also reported to experience more fear when they had to perform a pain-related movement (*M*=7.31, *SD*=1.51), compared to the safe movement (*M*=1.29, *SD*=1.67, $t(34) = 16.91$, $p<0.001$, $d= 2.74$, indicating a successful manipulation. Finally, the mean score on the PVAQ was 39.97 (*SD*=9.90), which is a representative score for a non-clinical population (Roelofs et al. 2002; Vanden Bulcke et al. 2013; 2015).

ERP data

N120. The N120 was larger for the collapsed movement trials ($M = -1.57$, SD=1.38) than for nonmovement trials ($M = -1.73$, SD=1.68, t38 = .90, $P = .376$, d = .15). A 2x2 (cue type x stimulus location) repeated-measures ANOVA revealed a significant main effect of cue, $F(1, 38) = 7.72$, $p=0.008$, BF10 = 4.747, $d= .45$, and a significant main effect of stimulus location, $F(1, 38) = 4.62$, $p=0.038$, BF10 = 1.349, $d= .34$. Moreover, there was a significant interaction between location and cue, $F(1,38)=16.97$, $p<0.001$, BF10 = 131.746, $d=.66$, indicating a difference in amplitudes between stimuli at the pain-related hand and safe hand when performing a

pain-related movement ($t(38)$=-3.74, p_{holm}=.002). Amplitudes were larger at the pain-related hand compared to the safe hand, but not between stimuli at the pain-related and safe hand when performing a safe movement ($t(38)$=-.12, p_{holm}= 1) (See table 1 for all means and standard deviations).

P200. A t-test comparing no-movement trials (M = 1.89, SD=1.06) and collapsed painful and pain-free movement trials (M = .94, SD=.80) showed an effect of movement (t38 = −7.46, P < .001, d = 1.21). A 2x2 (cue type x stimulus location) repeated-measures ANOVA revealed a significant main effect of cue, F (1, 38) =5.45, p=0.025, BF10 = 1.903, d= 0.37, with larger SEPs when anticipating a pain-related movement relative to a safe movement. There was also a significant main effect of stimulus location, F (1, 38) =4.86, p=0.034, BF10 = 1.491, d= 0.35, with larger SEPs when stimulating at the threatened location. No significant interaction was found (F (1, 38) =0.45, p=0.508, BF10 = 0.213, d= 0.11).

Table 1. mean amplitudes and standard deviations for both components.

	N120		**P200**	
	Pain Cue	Safe Cue	Pain Cue	Safe Cue
Pain Loc	-2.43 (1.92)	-1.30 (1.79)	1.34 (1.31)	0.89 (.97)
Safe Loc	-1.26 (1.55)	-1.27 (1.92)	.91(1.21)	0.63(1.01)

Correlations. The correlations between the SEP-amplitudes and the participants' rates of pain and unpleasantness did not reach significance (all p>.05). Similarly, there were no significant correlations between the PVAS scores and both the N120 and P200 amplitudes (all p>.05)

Discussion

The current study aimed to investigate whether attending to somatosensory information at a moving body part is enhanced when the movement is expected to induce pain. The analysis of the N120 component showed a significant interaction between the type of cue (threatened or not threatened) and the location of the vibrotactile stimulus. Only when performing a movement that was cued to be accompanied with pain, amplitudes were larger when stimulating at the pain location compared to the location without pain.

The N120 SEP has been shown to be larger for attended compared to unattended stimuli (García-Larrea et al. 1995), indicating that participants attended more towards the threatened hand during the execution of a

movement with that hand. As a result, N120 amplitudes to somatosensory information were elevated at the hand under threat of pain. These results resemble those of an earlier study which showed with a similar setup to the current study that participants showed that during the anticipation of a painful movement execution, N120 amplitudes in response to somatosensory information were larger at the hand associated with pain (compared to the safe hand) (Clauwaert et al. 2018). The current results therefore extend the previous findings by showing that the expectancy of pain increases attention towards the pain-related location, and especially, that this is also present during the execution of a pain-threatened movement. Since the anticipation of pain has shown to elicit different neural activation patterns compared to the experience of pain (Ploghaus et al. 1999), it is not evident to expect similar attentional effects both during a pain-related movement anticipation or execution. For example, during movement execution, other motor processes such as proprioception may interfere. On the other hand, it can be argued that the anticipation of pain may elicit more affective preparatory responses, resulting in perhaps more attention towards the body part under potential threat of pain. Therefore, the results of the current study suggest that the attentional response to pain is similar both during the anticipation and execution of a pain-threatened movement.

It is important to note, however, that during movement execution there is always one hand performing the movement while the other hand lays still, which may have led to different effects on the SEPs for tactile stimuli at the moving hand versus the non-moving hand. However, if this difference would have impacted the results, the interaction should have looked differently. For example, if movements would have suppressed or enhanced somatosensory processing, this would result in smaller or larger SEPs at the 'congruent' trials (stimulation at the safe hand when executing a safe movement and stimulation at the pain-related hand when executing a pain-related movement) in comparison with incongruent ones. Since this was not the case, we may therefore conclude that movement in itself in this study did not impact N120 amplitudes.

Additionally, the P200 SEP results in the current study also show that during movement execution, the tactile stimuli elicited larger responses compared to movements without the threat of pain. In contrast with the N120 SEP, the effects of this component appeared to be independent of the hand at which the tactile stimulus was presented. These results also resemble the effects for this component found in the study by Clauwaert and colleagues (2018) which showed that the responses to the tactile stimuli were larger when anticipating a pain-related movement compared to a safe movement, regardless of the location at which the tactile stimulus was presented. Similar to the N120 SEP, the P200 SEP is also typically shown to be modulated by attention (Fiorio et al. 2012; Forster and Gillmeister 2011; Kida et al. 2006). Moreover, threat-cues typically induce a larger positive

component around 200 ms (i.e. P2) compared to no-threat cues (Zopf et al. 2004). Therefore, due to its independence of stimulus location, it may be argued that the current P200 results can be interpreted as a general arousal effect, elicited by the threat of the ES stimulus (Zopf et al. 2004). In contrast with our earlier study, the current results indicate larger P200 SEP amplitudes on the pain-related hand compared with the non-threatened hand, independent on which type of movement is being executed. This finding adds to the interpretation that the P200 might indicate a general state of arousal, elicited by the use of painful stimuli in the experiment.

Interestingly, the current findings suggest increased attending towards the body when performing a potentially painful movement. This somatosensory attending is location specific for the N120 SEP, and generalized for the P200 component. In line with the observation that instructed attention to a moving body part can lift the effect of sensory suppression (e.g. Van Hulle et al. 2013), the current findings illustrate that that the threat of pain served as a natural cue for the participants to attend to the body under threat. As a result, SEP amplitudes were increased, a finding that corresponds with previous findings in the literature (Job et al. 2016; Juravle et al. 2016). In addition, the current findings go against the premotor theory of attention and confirm that, at least for the case of pain-threatened movements, attention is focused towards the effector rather than the goal location during movement execution. Indeed, if attention was focused on the goal, no attentional effects on the body would have been registered at all. In addition, at first sight, the current results seem to contrast the results reported in Rossi et al. (2003) in which the amplitudes of early SEP components were reduced during the execution of movements with tonic pain. The authors put forward the explanation that attention towards the non-painful stimulus needed to be gated in order to avoid a reduction in attention to the pain, which was in that situation more relevant information. However, in the current study the tactile stimulus might have been interpreted as a cue for pain, and would therefore needed more attention.

It is well known that individuals who expect or fear receiving pain tend to scan their body for threats (Leeuw, Goossens, Linton, Crombez, Boersma, & Vlaeyen, 2006). However, the current results do not support this since there were no significant correlations between the SEP amplitudes and the self-reported fear and expectations, nor dispositional vigilance or awareness for pain. Similarly, no significant correlations were found in the Clauwaert et al. (2018). A possible explanation for this lack of result might be that the measures used in this study were not sufficiently specific or sensitive to evaluate individual differences in this specific context. Alternatively, assessing the participants' expectations and fears before each trial might be a more appropriate measure (Raes, De Houwer, De Schryver, Brass, & Kalisch, 2014).

In sum, the current study supports the hypothesis that during movement execution, participants attend more towards the pain-related location when performing a movement under threat of pain, compared to the execution of a movement without this association. The results thereby show that the same attentional processes elicited by the anticipation of pain-related movements continue during movement execution as well, affecting the processing of somatosensory inputs.

Conflict of interest

The authors declare no conflicts of interest.

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