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Are the spatial features of bodily threat limited to the exact location where pain is expected?

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ABSTRACT

Previous research has revealed that anticipating pain at a particular location of the body prioritizes somatosensory input presented there. The present study tested whether the spatial features of bodily threat are limited to the exact location of nociception. Participants judged which one of two tactile stimuli, presented to either hand, had been presented first, while occasionally experiencing a painful stimulus. The distance between the pain and tactile locations was manipulated. In Experiment 1, participants expected pain either proximal to one of the tactile stimuli (on the hand; near condition) or more distant on the same body part (arm; far condition). In Experiment 2, the painful stimulus was expected either proximal to one of the tactile stimuli (hand; near) or on a different body-part at the same body side (leg; far). The results revealed that in the near condition of both experiments, participants became aware of tactile stimuli presented to the "threatened" hand more quickly as compared to the "neutral" hand. Of particular interest, the data in the far conditions showed a similar prioritization effect when pain was expected at a different location of the same body part as well as when pain was expected at a different body part at the same body side. In this study, the encoding of spatial features of bodily threat was not limited to the exact location where pain was anticipated but rather generalized to the entire body part and even to different body parts at the same side of the body.

1. Introduction

Imagine a man playing football who suddenly experiences an intense, shooting pain in his leg after a vigorous tackle. There is a high chance that this pain will capture his attention and interrupt his game. In this example, the capture of attention by pain can be thought of as a stimulus-driven or bottom-up effect (Gallace & Spence, 2014; Legrain et al., 2009; McGlone, Lloyd, & Tipper, 1999). Many studies have already demonstrated that attention is unintentionally captured by pain when it is intense, unpredictable, and/or novel (Crombez, Baeyens, & Eelen, 1994; Eccleston & Crombez, 1999; Legrain et al., 2012). However, the bottom-up capture of attention by pain can be modulated by goal-directed or top-down variables, as when pain is the subject of a person's current goals, thoughts, and/or intentions (Crombez, Van Damme, & Eccleston, 2005; Van Damme, Legrain, Vogt, & Crombez, 2010). Imagine another football player who has recently recovered from a serious ankle injury. When starting to play football again, being fearful of re-injury, he may focus his attention on the injured body part and, hence, quickly become aware of any—even innocuous—bodily sensation that may occur there. As such, attention to pain may be the result of the interplay between bottom-up and top-down factors in a similar way to what has also been extensively reported in the context of visual attention (Desimone & Duncan, 1995; Yantis, 2000).

According to the neurocognitive model of attention to pain (Legrain et al., 2009), the top-down modulation of attention to somatosensory information occurs by means of the activation of an attentional set. This is defined as the set of stimulus features that participants keep in working memory to identify goal-relevant information. When a stimulus, even when it is not particularly salient, happens to match one of the features in the attentional set, it is more likely to be selected for further processing (Dowman, 2001; Folk, Remington, & Johnston, 1992; Van Ryckeghem, Crombez, Eccleston, Legrain, & Van Damme, 2013; Yantis, 2000; Zampini et al., 2007). Thus, when one expects pain to occur, a stimulus that shares features with pain, such as its sensory modality or its stimulus location, may also be preferentially attended to (Legrain et al., 2009).

To date, few studies have attempted to investigate this idea. Crombez, Eccleston, Baeyens, and Eelen (1998) investigated the interruptive effect of mild experimental pain stimuli on the performance of a cognitive task. Pain stimuli could be administered to either arm, and participants were led to believe that on one arm a very intense, painful stimulus could sometimes occur. Interestingly, the interruptive effect

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was significantly larger when a pain stimulus arrived at the "threatened" arm in comparison to the other arm, although on both arms only mild stimuli were actually presented. Recently Vanden Bulcke, Van Damme, Durnez, and Crombez (2013) specifically examined whether experimentally induced threat of pain would speed up the processing of innocuous tactile stimuli presented at the bodily location where the painful stimulus was expected, using a Temporal Order Judgment (TOJ) paradigm. Participants indicated which one of two tactile stimuli administered to each hand had been presented first. Crucially, the participants expected that a painful stimulus would occasionally be administered on one of their hands. The results revealed that the participants became aware of tactile stimuli on the "threatened" hand more quickly than on the "neutral" hand.

While the results of these previous studies (Crombez et al., 1998; Vanden Bulcke et al., 2013) are consistent with the idea of top-down prioritization of the pain-related bodily location, it is as yet unclear how specific the spatial features of bodily threat are encoded in the attentional set. If only the *exact* location of the pain is encoded, top-down prioritization should be limited to those somatosensory inputs that are in close proximity to the specific bodily location where the painful stimulus is expected. However, it is also possible that the spatial features of bodily threat are encoded in a more general manner, for instance, in terms of the body part where the painful stimulus is anticipated or in terms of the side of the body where the pain is expected. The aim of the present study was to investigate the specificity of the spatial features of pain in the attentional set. We report two experiments in which a tactile TOJ task was used for stimuli presented to the hands. In the first experiment, a painful stimulus was occasionally administered, either proximal to one of the tactile stimuli, i.e., the hand (near condition), or more distant on the same body part, i.e., the arm (far condition). In the second experiment, a painful stimulus was occasionally administered either proximal to one of the tactile stimuli, i.e., the hand (near condition) or on a different body part at the same body side, i.e., the leg (far condition). With regard to the "near" condition, we hypothesized that in both experiments, tactile stimuli would be perceived more rapidly on the "threatened" hand than on the "neutral" hand (see also Van Damme, Gallace, Spence, Crombez, & Moseley, 2009; Vanden Bulcke et al., 2013). With regard to the "far" condition, we examined whether tactile stimuli would be perceived more rapidly on the hand of the "threatened" arm (Experiment 1) or the hand ipsilateral to the threatened leg (Experiment 2) than on the other hand.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Thirty-four undergraduate students (25 females, 9 males; mean age = 20.4 years; all white Caucasian) participated to fulfill course requirements. All of the participants had normal or corrected-to-normal vision and normal hearing. All but three of the participants reported being right-handed. The participants rated their general health on average as "good" and none of the participants reported having a current medical condition or mental disorder. Although a student group is often described as healthy, pain can be a prevalent symptom among this group and is therefore best documented. Twenty-eight of the participants reported having experienced pain during the last six months (average of 24.3 days in 6 months). Thirteen of these participants reported feeling pain at the time of testing, but the average rating of the intensity of this pain was low (M = 2.91; ranging from 1 to 6, SD = 1.44) on a Likert scale where 0 indicated "no pain" and 10 the "worst pain ever." All of the participants gave their informed consent and were free to terminate the experiment at any time should they so desire. The study protocol was approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of Ghent University. The experimental session lasted for approximately 1 hour.

2.1.2. Apparatus and materials

Tactile stimuli (10 ms duration; 200Hz) were presented by means of two resonant-type tactors (C-2 TACTOR, Engineering Acoustics, Inc., Florida, http://www.eaiinfo.com/) consisting of a housing of 3.05 cm diameter and 0.79 cm high, with a skin contactor of 0.76 cm diameter. Prior to the start of the experiment, the perceived stimulus intensities at both tactor locations were individually matched (Weinstein, 1968). This was done by means of a double random staircase procedure, based on the "simple up-down method" of Levitt (1971). In a first phase, 24 stimuli presented on the left hand were judged relative to a reference stimulus, which was defined as the maximum intensity (power = 0.21 Watt) on a 5-point Likert scale ranging from 1 ("no sensation") to 5 ("maximum intensity"). The intensity that elicited an average rating of 3 was used as the stimulus intensity for the left hand and was the reference stimulus for the second phase. In the second phase, 24 stimuli on the right hand were judged relative to the reference stimulus on the left hand, once again using a 5-point Likert scale (1 = "much weaker," 2 = "weaker," 3 = "equally strong," 4 = "stronger," 5 = "much stronger"). The stimulus intensity that elicited an average rating of 3 was used as the intensity of the stimulus at the right hand.

Painful stimuli were delivered by means of two constant current stimulators (Digitimer DS5 2000, Digitimer Ltd, England, http://www.digitimer.com/index.htm). Each stimulator consisted of trains of 20 ms sinusoid pulses with a frequency of 50 Hz and a duration of 200 ms. Painful stimuli were delivered via two pairs of lubricated Fukuda standard Ag/AgCl electrodes, each pair consisting of an anode and cathode (1 cm diameter). One pair of electrodes was attached on the forearm, the other pair of electrodes on the hand. The intensity of the electrocutaneous stimuli was determined for each participant individually by means of a random staircase procedure. For each hand, 20 electrocutaneous stimuli were presented to participants (starting intensity between 0 and 1.5 mA) and self-reports were collected on an 11-point Likert scale (0 = "no sensation"; 10 = "unbearable pain"). The pain intensity that elicited an average rating of 7 was selected as the pain stimulus for the main experiment (Arntz, Dreessen, & De Jong, 1994; Vanden Bulcke et al., 2013).

The task was programmed and controlled by the INQUISIT Millisecond software package (Inquisit 3.0, Millisecond Software LLC, Seattle, WA, http://www.millisecond.com//) on a laptop (HP Compaq nc 6120).

2.1.3. TOJ paradigm

In the TOJ task (Piéron, 1952), two tactile stimuli were administered, one on either hand, separated by one of 10 randomly assigned stimulus onset asynchronies (SOAs) ranging from −120 to +120 ms (−120, −60, −30, −15, −5, +5, +15, +30, +60, +120 ms; negative values indicate that the left hand was stimulated first) (see also Vanden Bulcke et al., 2013). The participants were instructed to report aloud the hand on which the first tactile stimulus was presented, and the experimenter registered the answers using a keyboard. A trial started with the presentation of a fixation cross (1000 ms) in the middle of the screen, followed by a colored cue (either blue or yellow, of 1000 ms duration), indicating whether or not a painful stimulus could follow on one specific location (threat and control trial, respectively). Which color of cue was associated with threat was counterbalanced across the participants. Before the start of each block of trials, the participants were told on which location (hand or forearm) they should expect the painful stimulation to be delivered. In 10% of the threat trials, the pain stimulus was actually delivered instead of the two tactile stimuli (pain trials), but the participants were not informed about this contingency. The