Consciousness and Cognition 36 (2015) 246–255

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Is attentional prioritization on a location where pain is expected modality-specific or multisensory?

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ARTICLE INFO

Article history:
Received 19 May 2015
Revised 8 July 2015
Accepted 9 July 2015
Available online 13 July 2015

Keywords:
Attention
Temporal Order Judgment
Experimental pain
Bodily threat
Multisensory integration

ABSTRACT

Previous research suggests that anticipating pain at a particular body location prioritizes somatosensory input at that location. The present study tested whether this prioritization effect is limited to somatosensory information (modality-specific hypothesis) or generalizes to other sensory modalities (multisensory hypothesis). Thirty-four students performed tactile and visual Temporal Order Judgment (TOJ) tasks while either expecting a painful stimulus on one of the hands (threat), or expecting no pain stimulus (control). Participants judged the order of either two visual stimuli (visual condition) or two tactile stimuli (tactile condition), one on each hand. Analyses revealed that only in threat trials, participants became aware of stimuli on the threatened hand more quickly as compared to the neutral hand, replicating the prioritization effect. Of particular interest, this effect was not different between the tactile and visual conditions. This suggests that the anticipation of pain results in multisensory prioritization of information at the threatened body location.

1. Introduction

Pain fulfills an important protective function, as it is an archetypal warning of danger to an organism. Rapidly detecting and responding to bodily threats is undoubtedly necessary to prevent us from physical injury (Crombez, Van Damme, & Eccleston, 2005; Dowman, 2011). Attention has been put forward as a central component in the adequate detection of bodily threats. Pain may be captured by attention in an involuntary, bottom-up way. As a result, ongoing behavior is interrupted, which allows dealing efficiently with a potentially dangerous situation (Eccleston & Crombez, 1999; Legrain et al., 2009). Many studies have already demonstrated that pain is indeed prioritized over competing information (Crombez, Baeyens, & Eelen, 1994; Eccleston, 1995; Tiemann et al., 2012; Vangronsveld et al., 2007).

Successful adaptation is, however, also supported by the ability to anticipate pain. By gathering knowledge about the association between cues and the occurrence of pain, the organism can prepare itself to act appropriately (Bolles & Fanselow, 1980; Ohman, 1980; Vlaeyen & Linton, 2012). When pain is expected or anticipated, attention may be directed in a top-down manner, resulting in prioritization of pain-relevant information (Van Damme, Crombez, & Eccleston, 2004a). It has been proposed that individuals adopt 'attentional control settings,' which consist of certain stimulus features or characteristics that are relevant for their actions. These stimulus features will receive more attention if they are present in the environment (Corbetta & Shulman, 2002; Folk, Remington, & Johnston, 1992; Yantis, 2000). Accordingly, if pain is

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http://dx.doi.org/10.1016/j.concog.2015.07.003
1053-8100/

expected, attention may be preferentially allocated to stimuli that match pain-related features highlighted in the attentional set (Legrain et al., 2009; Van Damme, Legrain, Vogt, & Crombez, 2010). The location where one expects pain to occur may be an important feature. Imagine a person who is experiencing low back pain. He or she may be worried about a potential injury and anticipate changes in pain in certain situations. This may activate the spatial stimulus representation 'location' (i.e. lower back) in working memory. As a result, this person may become more quickly aware of bodily sensations in the back, as these sensations match location features that are present in the attentional set.

There is some empirical evidence for this idea. Crombez, Eccleston, Baeyens, and Eelen (1998) investigated the interruptive effect of mild experimental pain stimuli on the performance on a tone discrimination task. Pain stimuli could be administered to either arm. Participants were told that on one arm a very intense, painful stimulus could sometimes occur, although in reality, the same mild stimuli were presented on both arms. Interestingly, the interruptive effect of the pain stimuli was larger when they were administered to the "threatened" arm in comparison with the "neutral" arm. More recently Vanden Bulcke, Van Damme, Durnez, and Crombez (2013) examined whether experimentally induced threat of pain would speed up the processing of innocuous tactile stimuli in a region of the body where pain is expected. Participants made judgments regarding which of two tactile stimuli, one administered to each hand, had been presented first. Crucially, expectation of a painful stimulus on one of the hands was experimentally induced. It was demonstrated that the expectation of pain resulted in faster awareness of tactile stimuli to the threatened hand compared with the neutral hand.

However, there are some unresolved issues from the studies described above. Specifically, in these studies only somatosensory stimuli were used. As a result, it is not yet clear if prioritization of the threatened location *only* applies to stimuli in the somatosensory modality, or whether it also affects the processing of stimuli in other sensory modalities. Recent neurophysiological studies indicate that the detection of bodily threat concerns a *multimodal* network. An extensive cortical network of the brain, including somatosensory, insular, cingulate, frontal as well as parietal areas, functions as a multisensory salience detection system through which significant events for the body's integrity are detected (Legrain, Iannetti, Plaghki, & Mouraux, 2011; Van Damme & Legrain, 2012). More specifically, it has been shown that there exist cross-modal interactions between pain stimuli and visual stimuli occurring close to the pain location (e.g., De Paepe, Crombez, Spence, & Legrain, 2014; Favril, Mouraux, Sambo, & Legrain, 2014; Van Damme, Crombez, & Lorenz, 2007). Accordingly, these findings raise the question whether the expectation of pain at a particular location of the body also leads to the prioritized processing of *non-somatic* information at the threatened location. Interesting in this regard are the findings of a study of Van Damme, Gallace, Spence, Crombez, and Moseley (2009). Participants made judgments regarding two tactile stimuli, one administered to each hand, or two auditory stimuli, one administered close to each hand, had been presented first. It was found that the presentation of a physical threat picture (e.g., a knife) in front of one or the other hand shortly before the pair of stimuli resulted in quicker awareness of stimuli on the side of the picture, and that this effect was larger for tactile than for auditory trials. These findings suggest a modality-specific effect, i.e. physical threat shifts attention to somatosensory rather than auditory information at its location. However, in the study of Van Damme et al. (2009) only visual representations of physical threat were used, so it has to be investigated if a similar effect can be found when there is actual threat of pain. Furthermore, only auditory stimuli were used for the non-somatosensory modality, and it would be interesting to involve other sensory modalities such as vision.

The aim of the present study was to test two conflicting hypotheses, i.e., whether the attentional prioritization to a location where pain is expected is modality-specific or multisensory. We investigated in healthy volunteers, using a TOJ task, whether the anticipation of (experimentally induced) pain at one hand, makes one more quickly aware of stimuli at the threatened hand relative to the other hand. In half of the blocks, participants were asked to indicate which of two tactile stimuli, one administered to each hand at a range of different stimulus onset asynchronies (SOAs), was perceived first (tactile condition). In the other half of the blocks, pairs of visual stimuli had to be judged (visual condition). Each trial was preceded by a tone (high or low frequency) that signaled the possible occurrence of pain on one hand (threat trials). The other frequency of the tone signaled that no pain would follow (control trials). According to the notion of prior entry (Titchener, 1908), attending to a stimulus will speed up perceptual processing relative to when the same stimulus is unattended (see Spence & Parise, 2010). Therefore, we expected that stimuli would be perceived more rapidly on the threatened hand than on the neutral hand (see also Vanden Bulcke, Crombez, Spence, & Van Damme, 2014). In addition, if the attentional prioritization would be modality-specific (see Van Damme et al., 2009), we expected this prioritization effect to be larger in the tactile condition than in the visual condition. In contrast, if the prioritization effect would be multisensory (Legrain et al., 2011), no differences between the tactile and the visual conditions should be expected.

2. Method

2.1. Participants

Based on a previous study with a similar paradigm (Vanden Bulcke et al., 2013), an a priori power-analysis was conducted which aimed to obtain a medium effect size and a power of 0.80. This resulted in a required sample size of thirty-four 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 two of the participants reported being right-handed. The participants rated their general health on average as 'very good.'