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Vicarious somatosensory experiences while observing someone else in pain: an experimental analysis

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TABLE OF CONTENTS

GENERAL INTRODUCTION

‘‘If I slightly knocked my finger, he would immediately grasp his own finger and say ‘‘don’t do that’’ (meaning not to show him) because he felt it”

(Bradshaw and Mattingley, 2001)

PAIN: DEFINITION, PREVALENCE AND IMPACT

The most common health complaint is pain (Crombie, Croft, Linton, LeResche, & Von Korff, 1991). Acute pain is defined by its relatively brief duration, with a sudden onset and an apparent etiology (e.g. everyday hurts, medical procedures, illness; Cummings, Reid, Finley, McGrath, & Ritchie, 1996). Pain is considered chronic when it is continuously present and lasts longer than three months or is recurrent with a minimum duration of 3 months. Chronic pain is often pain that lasts longer than expected (American Pain Society, 2001; (International Association for the Study of Pain Task Force on Taxonomy, 1994; McGrath, 1999). Estimates of the prevalence of chronic pain vary widely and typically range between 10 and 30% of the adult population, although prevalence rates ranging from 2 to 55% have been reported (Breivik, Collet, Ventafridda, Cohen, & Gallacher, 2006; Harstall & Ospina, 2002; Verhaak, Kerssens, Dekker, Sorbi, & Bensing, 1998). This wide variation may be due to the different classifications and definitions of chronic pain in epidemiological studies (e.g. pain duration of three or more than six months), different methods in assessment or may be a true reflection of population differences (Kerssens, Verhaak, Bartelds, Sorbi, & Bensing, 2002). Chronic pain is often reported to be more common among women and in older age groups (Harstall & Ospina, 2002; Breivik et al., 2006) and may also have major implications for personal well-being and functioning. It affects activities of daily living and mental health. Breivik et al. (2006) report that 54% percentage of the patients reporting moderate to severe chronic pain cannot function normally, 46% cannot take care of themselves and other people and 19% report being diagnosed with depression. Mental disorders such as posttraumatic stress disorders, general anxiety disorder, dysthymia and major depressive episode are significantly more prevalent in chronic neck or back pain patients compared with persons without such pain (Bekkering et al., 2011; Demyttenaere et al., 2007). Chronic pain also often implies work absenteeism, resulting in high direct medical and indirect costs (Boonen et al., 2005).

The impact of pain upon the physical, psychological and social functioning fits with the general definition of pain as ‘an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage’ (International Association for the Study of Pain Task Force on Taxonomy, 1994, p. 210). It recognizes that pain not only encompasses specific sensory characteristics, but is often accompanied by emotional responses. Important in this definition is that pain has specific sensory and perceptual characteristics and requires no absolute congruency between pain and tissue damage (Gatchel, Peng, Peters, Fuchs, & Turk, 2007). This entails that a person may have tissue damage without feeling pain and that pain can occur in the absence of tissue damage (Fernandez & Turk, 1992; Fordyce, 1988). Pain is considered as a negative, subjective experience, which cannot be fully comprehended by taking the objective biological factors into account. In sum, the definition and the impact of pain upon these different life domains is in line with a biopsychosocial perspective of pain, postulating psychological and social factors besides the biological factors. They are crucial to fully understand the experience of painful sensations (Gatchel et al., 2007; Gatchel & Turk, 1999). This biopsychosocial perspective is in contrast with the biomedical model, which was especially prevailing before the 21th century. The biomedical perspective posits that the perception of pain is a direct representation of the sensorial input, i.e., the physiological damage. In this model, a direct and unchangeable relationship between the experience of pain and sensorial input is presumed. A biopsychosocial perspective upon pain was put forward since the 20th century as a better framework to understand the human pain experience as the biomedical model could not fully explain the human pain experience of wounded soldiers who survived the battlefield (Beecher, as cited in Morley & Vlaeyen, 2010).

Up to date, the biopsychosocial perspective on pain is in the scientific literature widely acknowledged (Gatchel et al., 2007). Considerable research has focused upon psychological factors related to the experience of pain (e.g., Gatchel & Turk, 1999), such as catastrophizing about pain (Keefe et al., 2000), patients' attentional processes (e.g., Eccleston, 1995), operant and classical conditioning (Fordyce 1976, 1988), etc. Also social factors bringing up a dynamic interplay between a person's pain experience and the social environment in which pain emerges, excited attention of many researchers worldwide. Several studies focused upon communication and empathy in the context of pain, which provide frameworks that help to understand the complex social interactions among persons with pain and others (e.g. Goubert et al, 2005; Hadjistavropoulos et al., 2011; Sullivan, Martel, Tripp, Savard, & Crombez, 2006).

OBSERVING ANOTHER IN PAIN

Observing another in pain may evoke affective distress in the observer. Studies using functional Magnetic Resonance Imaging (fMRI) within the context of pain, suggest that the affective dimension of own pain and observing others' pain are represented in common neural circuits (Jackson, Meltzoff, & Decety, 2005; Singer et al., 2004). The affective component allows us to determine how unpleasant the pain is and to take action (fight or flight response) (Avenanti & Aglioti, 2006). Empathy has been defined in various ways, but generally features the capacity to understand and respond to the unique affective experiences of another person (Decety & Jackson, 2006; Goubert et al., 2005). In a neurocognitive model outlined by Decety and Jackson (2006), the importance of "adequate" empathy is stressed. Adequate empathy is the ability to take the perspective of the other without confusing it with one's own interests. Decety and Jackson (2006) argue that the ability to differentiate between another's and one's own emotional responses, plays a core role in the functional consequences of empathy. Goubert and colleagues (2005) formulated an empathy model in the context of pain, which provides a related heuristic framework to better understand observer estimates of another individual's pain. The model states that the capacity of the observer to imagine him/herself in the thoughts, feelings and motives of the person with pain (i.e., the capacity to empathize) is fundamental to the estimation of the other's pain. These authors identify three distinct empathic responses in the observer that are closely related to each other: (1) cognitive responses that are defined as "a sense of knowing the experience of the other in pain" (e.g., the observers" pain estimates), (2) emotional responses (e.g., the felt distress or sympathy for the patient while observing the patient), and (3) the behavioral responses (e.g., helping or avoidance behavior). In particular, the model distinguishes bottom-up variables (the variables that are related to the individual with pain him/herself such as expressive pain behavior), top-down variables (variables that are related to the observer such as catastrophizing) and contextual variables (e.g. the relationship between the patient with pain and the observer).

Besides the overlapping brain regions tapping into affective-motivational properties of pain when seeing someone else in pain, studies have provided evidence of overlapping activation of brain regions subserving the sensory-discriminative properties of pain (Bufalari, Aprile, Avenanti, Di Russo, & Aglioti, 2007). The sensory-discriminative component allows us to determine where and how intense the pain is in one's body (Avenanti & Aglioti, 2006). Some fMRI studies show that self-reported levels of empathy may correlate with level of brain activity when watching others in pain (Singer et al., 2004). For example, Avenanti, Minio-Paluello, Bufalari, and Aglioti, (2009) showed a decreased cortico-spinal activity that was correlated with the believed pain experienced by the observed person and was specific to the body part observed. This effect was greater in participants who scored highly on an empathy questionnaire.

Observing another in pain (irrespective of an empathic response in the observer) not only modulates neural aspects, but may also lead to behavioral facilitation or interference of somatosensation. Several human studies showed that the exposure to an actor in pain (Craig and Weiss, 1971; Craig et al., 1975) may be associated with higher pain reports. For example, Kirwilliam & Derbyshire (2008) showed participants pictures of unpleasant stimuli (pain, mutilation, etc.) or neutral stimuli (everyday items) using the dot probe task. Afterwards, participants were exposed to a series of heat pulses which they had to score as pain or heat. Those who saw unpleasant images were more likely to report pain instead of heat and were more likely to report feeling a (painful) pulse, even when no pulse was administered. Some processes may account for this kind of modulation. First, observing pain may induce a conditioned autonomic response. During our lives, we learn the combination of visual images of our wounds and the pain caused by them. Through classical conditioning we may experience sympathetic arousal responses to pain images, which may already modulate pain (Rainville, Bao, & Chretien, 2005). Second, the induced negative mood state when observing pain may increase pain perception (Rainville et al., 2005; Villemure, Slotnick, & Bushnell, 2003). Third, social modeling may also partially account for the change in pain ratings as the exposure to the behavior of another individual in pain has been shown to have a significant effect on our own pain behaviors, because it can elicit imitation (Craig and Weiss, 1971; Craig et al., 1975).

Several modulating factors in the facilitation or interference of somatosensation while observing another in pain have been investigated such as for example empathy, similarity and expectation. For example, in a study of Loggia, Mogil, & Bushnell (2008) participants received thermal stimuli while watching a person receiving painful or non-painful thermal stimuli. They were told a story that elicited a high versus a low empathic response in the observer. Results showed that those who had a high empathic response reported a higher intensity and unpleasantness of the stimulus compared with the low empathy condition. Contextual factors such as similarity have also shown to influence the response of the observer. For example, Serino, Pizzoferrato, & Làdavas (2008) showed that observing touch to one’s own face facilitated perception of sub-threshold stimulation on the own face. The facilitation was smaller for observing touch to another person’s face and disappeared when observing touch to an inanimate object. Expectation of a painful event has also been found to elicit reports of pain (Schweiger & Parducci, 1982). Mazzoni, Foan, Hyland, & Kirsch (2010) manipulated expectation experimentally. They asked participants to inhale an inert substance and let them believe it could cause four symptoms: nausea, drowsiness, headache, & itchiness. Half of the participants saw a confederate inhaling the toxic substance. These researchers demonstrated that those who observed the other inhaling the substance and exhibited the symptoms in front of them were more likely to experience these physical symptoms themselves. Apparently, individuals that were open to the experiences of others are more likely to experience symptoms. Besides experimental research, some case studies have reported pain in people expecting pain. For example, Fisher, Hassan, & O'Connor (1995) reported that a builder felt excruciating pain after stepping accidently down onto a 15 cm nails which went completely through his boot. The builder was sedated upon arrival at the hospital but when his boot was removed, it became clear that the nail did not penetrate his foot at all (the nail had passed between his toes). The belief of the penetration of the foot and the expected pain was enough to feel a pain experience.

Next to the literature stating that observing pain/touch may facilitate touch or pain perception, also the inverse relationship has been found. Observation of pain may also inhibit pain experiences. For example Turkat, Guise, & Carter (1983) exposed participants to a confederate with high pain tolerance or low pain tolerance. Participants exhibited higher pain tolerance from baseline while observing high pain tolerance in another compared with observing low pain tolerance. Further, viewing the body may even result in an analgesic effect as it reduces acute pain. Participants rated nociceptive laser stimuli as less painful when viewing the stimulated hand in a mirror-box, versus an object at the same location (Longo, Betti, Aglioti, & Haggard, 2009). These 'visually induced analgesia' stresses the interplay between the brain's pain network and a posterior network for body perception, resulting in modulation of the experience of pain. Mancini, Longo, Kammers and Haggard (2011) replicated this effect using contact heat pain thresholds.

MULTISENSORY INTERACTION

The above-mentioned studies accentuate the strong interaction between the different perceptual systems such as vision and somatosensation. Worth mentioning, the complex interplay between somatosensation and vision is not merely restricted to the observation of somatosensation in another. For example, sensory signals that are presented simultaneously in more than one modality, tend to be detected faster (Hershenson, 1962), more accurately and at lower thresholds than the same signals presented individually (e.g., Frassinetti, Bolognini, & Làdavas, 2002; Stein, London, Wilkinson, & Price, 1996). The effects from multisensory integration are assumed to take place at an early processing level, and are especially enhanced when different sensory stimuli are spatially and temporally congruent (Meredith & Stein, 1983). For example, Johnson, Burton and Ro (2006) showed that participants detected more likely a threshold tactile stimulus when it was presented with a visual stimulus, compared to when the touch was presented alone. Even when the visual stimulus is entirely task-irrelevant (for example a light flash), it may already enhance the detection of a tactile stimulus and boosts the report of false alarms during tactile-absent trials (Lloyd, Mason, Brown, & Poliakoff, 2008). Another example relates to the concept of 'visual enhancement of touch'. Observing a forearm, which is both irrelevant and non-informative in a two-point discrimination task, may already improve the tactile acuity compared with observing a neutral object appearing in the same location through a mirror (Kennett, Taylor-Clarke, & Haggard, 2001).

VICARIOUS SOMATOSENSORY EXPERIENCES

Vicarious pain

For most people, observing somatosensation in another leads to behavioral facilitation or interference of felt touch or pain (see above; e.g. Loggia et al., 2008; Schaefer, Heinze & Rotte, 2005; Serino et al., 2008), but this modulation is normally not associated with the conscious experience of tactile sensations. Intriguingly, observing pain in others may also give rise to a vicarious experience of pain. Vicarious somatosensory experiences are intriguing as they indicate that tactile or nociceptive input may not be necessary to experience touch or pain. The first case reported to exhibit a relationship between observed and experienced pain was described by Bradshaw and Mattingley (2001) in a man with hyperalgesia who felt pain when he observed his wife in pain. The wife of the patient reported that the pain appeared to be qualitatively similar to her husband's own hypersensitivity to touch: ''If I slightly knocked my finger, spontaneously showing him, he would immediately grasp his own finger and say ''don't do that'' (meaning not to show him) because he felt it. No investigations could be done as the man's condition was described by the patient's wife following his death. Another case has been reported by Giummarra et al. (2008) in one upper limb amputee. This patient reported phantom pain when watching footage on television of amputation, others being injured on their arms, or when stimuli associated with potential pain/amputation (e.g., axe, chainsaw, sharp knife) were near her own arm, or near another's limbs. A third documented case of vicarious pain is 'CB', experiencing a long and painful labour with obstruction resulting in an emergency caesarean section delivery. CB reports the experience of ''shooting pains from the groin that radiate down the legs'' since this distressful event, when told of another's traumatic experience (Giummarra & Bradshaw, 2008). These examples show that vicarious experiences have most often been described in patients with a history of intense, traumatic pain (Fitzgibbon et al., 2010b). The highest number of vicarious pain responders (e.g. those reporting vicarious pain) is recorded in amputees who experience phantom pain (see Giummarra & Bradshaw, 2008, Fitzgibbon et al., 2010b). Giummarra et al. (2008) interviewed eight cases of lower-limb phantom-limb patients. They reported that their phantom pain is triggered by thinking about, observing or inferring that another person is in pain. In a study of Fitzgibbon et al. (2010a) in which a group of amputees completed questions on vicarious pain in the context of a broader survey, they found that 16.2% of the amputees experienced pain when observing or imagining pain in another.

Fitzgibbon, Giummarra, Georgiou-Karistianis, Enticott, & Bradshaw (2010b) labeled this experience of vicarious pain as 'synaesthesia for pain'. Synaesthesia occurs when stimulation in one sensory domain causes a sensation in another domain. For example, digits, letters or words evoke the perception of a colour (Simner et al., 2006). It seems to occur involuntarily, and the synaesthetic experience is similar to another perceptual experience (for synaesthesia criteria, see Ward & Mattingley, 2006). Several researchers believe that vicarious pain or touch is a phenomenon related to more well-known forms of synaesthesia as it not common to the general population (e.g. Banissy & Ward, 2007; Fitzgibbon et al., 2012). Not all researchers agree with this statement. Rothen & Meier (2013), for instance, stress that vicarious experiences are not an instance of synaesthesia. Although they seem to share many features (e.g. in both cases the concurrent experiences are triggered automatically and involuntarily), these authors mark the differences between both phenomena. For example, "synaesthesia for pain", also called "mirrored sensory experiences" have a neural basis that is quite different from that of synesthesia. Vicarious somatosensory experiences seem to reflect intramodal activity. In contrast, synesthesia seems to reflect explicitly experienced crossmodal activity (Rothen & Meier, 2013). The fact that the mirrored somatosensory experience is also identical to the experience of the inducing stimulus, constitutes a marked difference compared with established forms of synesthesia, for which the inducer-concurrent relationship is typically somewhat arbitrary and idiosyncratic (see Rothen & Meier, 2013 for more differences between both concepts). In this thesis, we agree with this view of Rothen and Meier (2013) and therefore use the concept 'vicarious' pain, touch or experiences in the different chapters.

Besides these case studies with prior trauma describing vicarious pain acquired following pain-related trauma, also studies describing vicarious somatosensory experiences in the general population exist. There is evidence that also individuals without traumatic pain experiences may feel pain by observing pain in others. Osborn and Derbyshire (2010) found that, when healthy volunteers were presented a series of images and video clips depicting painful events, almost 30% reported at least one pain experience (e.g. vicarious responders). In a follow-up study, 10 of these vicarious pain responders were matched with 10 non-responders (e.g. controls) to take part in an fMRI study, and static images of painful events and emotional images not containing noxious events were shown. When observing the images of the painful events, vicarious pain responders showed higher activation of emotional (i.e. left and right insular) and sensory brain regions (i.e. secondary somatosensory cortex) associated with pain than non-responders.

Underlying mechanisms

Fitzgibbon and colleagues (2010b) proposed a model in which mechanisms in the production of vicarious pain are involved. Specifically, Fitzgibbon et al. (2010b) propose that dysfunctional mirror systems may alter empathic processes by causing the mapping of motor/emotion/perceptual states in a way that exceeds the threshold for conscious experience of those states. This mirror system describes the activation of commonly recruited brain areas when a person performs an action, experiences an emotion or sensation and when a person observes the same action, or emotion and sensation (Fitzgibbon et al., 2010b; Saarela et al., 2007). In that way, they see empathy as a core mechanism in which the observer operates through an automatic internal stimulation of another person's emotional state. Vicarious pain may follow when a person confuses his/her own emotional state with that of another. They speculate that the brain regions activated when processing pain to the self and pain in others may be disinhibited in amputees (Fitzgibbon, et al., 2010a). This disinhibition may result in a failure to prevent a conscious experience of pain when observing another in pain (Fitzgibbon et al., 2010b). As all reports of vicarious pain in amputees have followed a painful and/or traumatic experience (i.e., amputation), this prior pain may be the cause of such disinhibition, perhaps as a byproduct of hypervigilance to pain cues.

These authors suggest that vicarious pain may also be modulated by sensitization to pain and attention to pain cues. Peripheral sensitization to pain is characterized by an increase in pain sensitivity and excitability of the nociceptors at the site of injury or inflammation. This form of sensitization is an adaptive response to nociceptive stimulation signaling tissue or nerve injury and produces short-term hypersensitivity to low threshold stimulation to protect the site of injury which gives the tissue the ability to repair (Ji, Kohno, Moore, & Woolf, 2003; Zusman, 2002). Central sensitization however, is a hypersensitivity to painful stimuli (hyperalgesia), expansion of the receptive fields, and reduced pain threshold with low threshold, non-painful sensory fibers activating high threshold nociceptive neurons (allodynia) (Ji, et al., 2003). It increases pain responses and extends pain sensitivity. It can be enhanced and/or maintained through cognition, attention and emotion (Fitzgibbon et al., 2010b; see Zusman, 2002). Central sensitization may follow after trauma and occurs in chronic pain patients (Ji et al., 2003; Giummarra & Bradshaw, 2008).

Processing pain draws on attentional resources. Pain ratings are significantly lower when performing a high load compared with low load attentional task (Veldhuijzen, Kenemans, de Bruin, Olivier, & Volkerts, 2006). In a study of Gu & Han (2007) participants were asked to attend to pain in photos or asked to count the number of hands in the picture (drawing attention away from pain). Depending on the instruction, another pattern of activation was seen during fmri methodology. This suggest that empathy for pain may be influenced by the attention to pain cues. Negative emotions such as depressive and anxious feelings, pain catastrophizing and somatic awareness also extend the attentional demand of painful stimuli (Arnts, Dreessen, & Merckelbach, 1991; Veldhuijzen et al., 2006). In this perspective, vicarious pain may be caused by sensitization to pain and hypervigilance to pain cues resulting in disinhibition of the mirror system involved in empathic processing of pain in another (Fitzgibbon et al., 2010b) (see Figure 1).

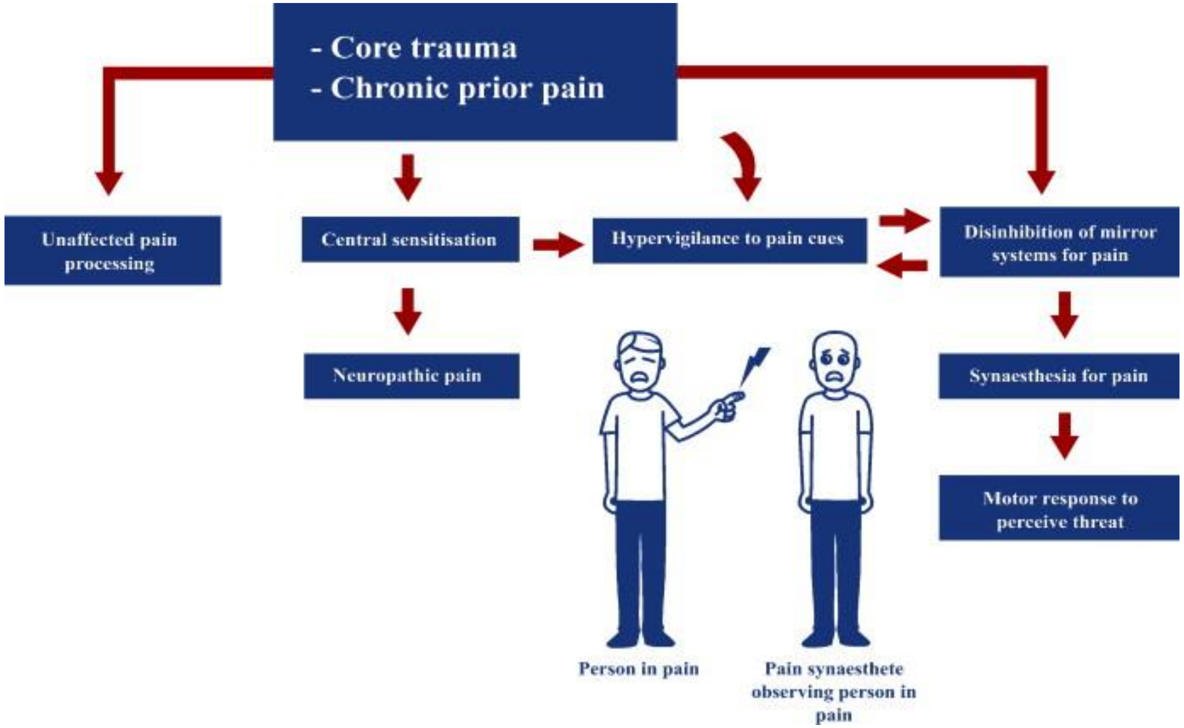

Figure 1. Proposed mechanisms involved in the production of vicarious pain (from Fitzgibbon et al., 2010b)

Because of the reports of vicarious somatosensory experiences in the general population without prior trauma, Fitzgibbon et al. (2012) adapted their model to take the occurrence of vicarious somatosensory experiences without prior trauma into account (see figure 2). They categorize vicarious somatosensory experiences in a developmental or an acquired category of ‘mirror sensory synaesthesia’. The developmental forms may occur because of the result of an atypical development, or as occurring naturally, through a genetic predisposition as in several forms of synaesthesia. In both categories, an atypical connectivity or altered function produce hyperactivity of the somatosensory mirror systems that may result in ‘mirrorsensory synaesthesia’ (Fitzgibbon et al., 2012).

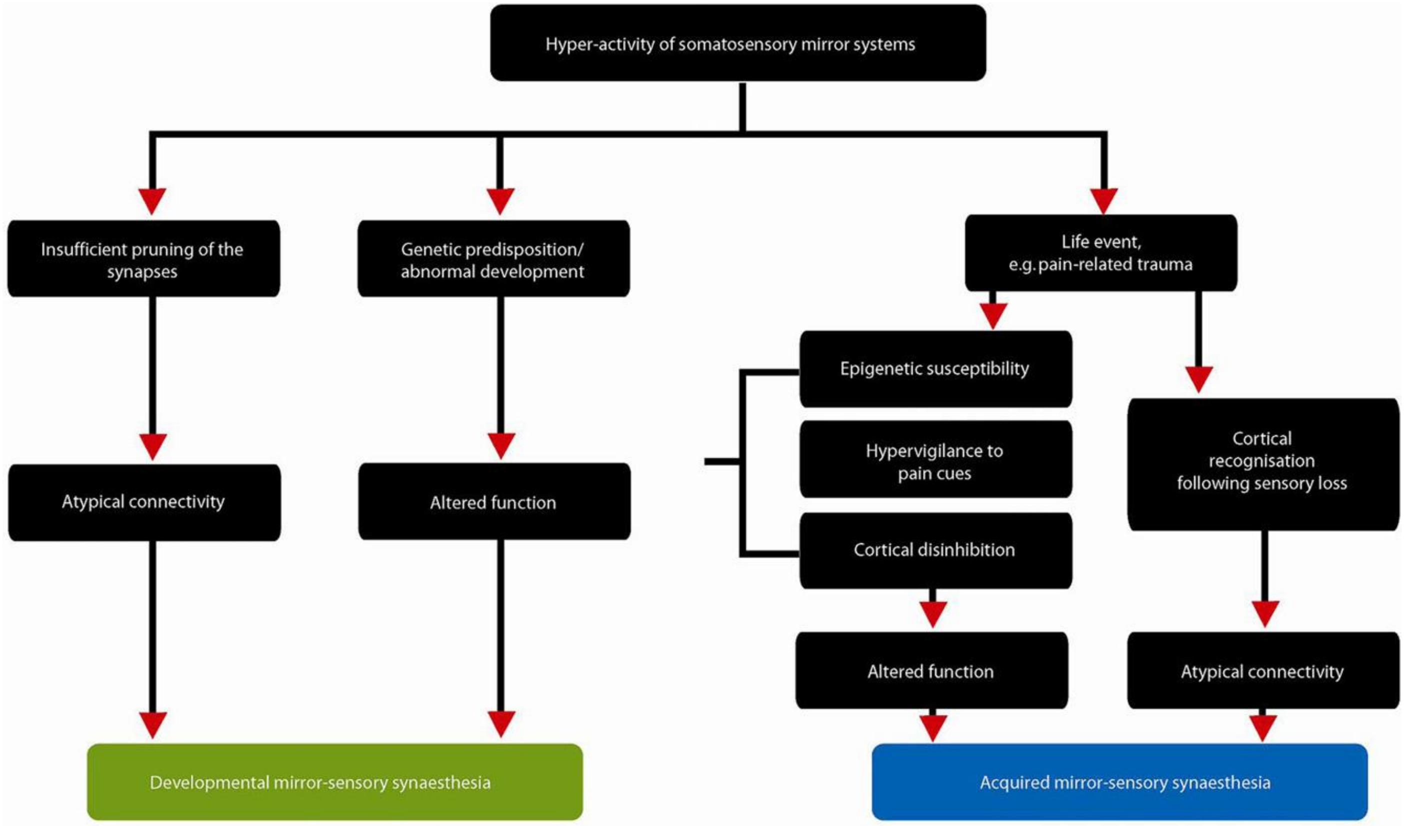

Figure 2. Hyperactivity in de somatosensory mirror systems may result in developmental and acquired forms of 'mirror-sensory synaesthesia' (Fitzgibbon et al., 2012)

Vicarious touch

Besides vicarious pain, also vicarious touch in the general population has been reported. Vicarious touch occurs when the observation of tactile stimulation to another induces the experience of being touched in oneself. In a study of Banissy, Kadosh, Maus, Walsh, & Ward (2009), undergraduates were asked to indicate on a five point scale the extent to which they agreed with the question ‘‘do you experience touch sensations on your own body when you see them on another person’s body?’’. All participants who gave positive responses to the above question (10.8% of all subjects) were contacted and interviewed about their experiences. They were shown a series of online videos showing another person, object, or cartoon face being touched. Typical responses of potential vicarious responders (approximately 2.5% of all subjects) included reports that observing touch elicits a tingling somatic sensation in the corresponding location on their own body, and that a more intense and qualitatively different sensation is felt for painful stimuli (i.e. videos of a pin pricking a hand rather than observed touch to the hand).

Blakemore, Bristow, Bird, Frith, and Ward (2005) proposed several explanations for the occurrence of vicarious experiences such as the experience of vicarious touch. The first possibility is that vicarious touch reflects direct connectivity between visual and somatosensory regions as a cross-modal leakage explanation. This means that vicarious touch is not dependent upon the same mechanisms that are believed to be involved in visual-tactile integration in the rest of the population. A second possibility is that bimodal cells in the parietal cortex, which respond to both visual and tactile stimuli are activated above the threshold for tactile perception during the observation of touch. A third explanation is the overactivation of somatosensory regions normally activated during the observation of touch (the tactile mirror system). This system is activated above a threshold for conscious tactile perception. This latter idea is in line with the conceptual models of Fitzigibbon and colleagues (2010b, 2012) postulating a disinhibition of the mirror system involved in empathic processing of pain in another.

EVIDENCE FOR THESE UNDERLYING MECHANISMS

The role of disinhibition of otherwise normal connections is supported by research investigating vicarious pain and touch in vicarious responders that show greater vicarious activation in somatosensory brain regions compared to controls (Blakemore et al., 2005; Osborn & Derbyshire, 2010). First evidence supporting this hypothesis, stems from fmri research done by Blakemore et al. (2005) in a group reporting vicarious touch and a control group. They showed that observing touch activated the tactile mirror system in both groups, although activation was greater in those reporting vicarious touch.

Further, the modulating role of empathy was investigated by Banissy and Ward (2007). They found that those experiencing vicarious touch scored higher than controls on the emotional reactivity subscale of the empathy quotient (EQ). This is congruent with research done by Osborn & Derbyshire (2010) who found that those reporting vicarious pain scored higher than controls on a measure of empathy. Familiarity to the observed person may influence the empathy felt for the other in pain. Azevedo et al. (2013) provided neural and autonomic evidence of in-group bias in empathic reactivity and demonstrate that both perceived familiarity/similarity and racial attitudes modulate motivational and affective responses to outgroup members' pain. We seem to preferentially resonate with the pain of individuals belonging to the same social group. It shows that empathy for pain may not be an entirely automatic process as a result of passive observation (De Vignemont & Singer, 2006). As such, methodological factors such as inconsistent instructions and stimuli between studies, or other differences such as description of the stimuli, pain intensity of the stimuli, experience or perspective taking and attention may influence the way empathy is felt for the observed person (Fitzgibbon et al., 2010b).

To investigate the neuronal and behavioral mechanisms of perspective taking upon somatosensation, a pain observation paradigm has been used as a widely recognized methodology (Decety, Jackson, & Brunet, 2006; Fitzgibbon et al., 2010b; Lamm, Decety, & Singer, 2011). For example, in a study of Canizales, Voisin, Michon, Roy and Jacskon (2013), twenty healthy adults were instructed to rate a series of pictures depicting hands in either painful or non-painful scenarios, presented either in first perspective or third perspective (180° angle), while changes in brain activity was measured with EEG methodology. The ratings demonstrated that the same scenarios were rated on average as more painful when observed from the first perspective than from the third perspective. They showed a visuospatial congruency between the viewer and the observed scenarios which is associated with both a higher subjective evaluation of pain and an increased modulation in the somatosensory representation of observed pain. This is congruent with research performed by Saxe, Jamal, and Powell (2006). These authors showed that viewing body parts in first-person perspective produced greater activation of the somatosensory cortex than viewing the same parts in third person perspective.

Haggard (2006) suggest a purely sensory interpersonal sharing of body representations, making it less crucial whether the own body of parts of the body are observed, of those of another person. In this study (Haggard, 2006), participants had to judge the orientation of gratings presented to the index finger tip, either when viewing their own hand, when viewing a neutral object presented in approximately the same location, or when viewing the undisguised hand of a third person standing behind them. Crucially, the hands of this third person were presented in a first perspective. Orientation discrimination was significantly more accurate when viewing one’s own body and viewing another’s body compared to when viewing a neutral object. Performance when viewing one’s own body did not differ significantly from performance when viewing the body of another person. Most importantly, these results show that the visual enhancement effect is social or interpersonal, and is not merely restricted to one’s own body. It involves body-specific modulation of touch, rather than person-specific modulation. The cross-modal link between touch and vision can transfer from one body or person to another.

Up to date, the question remains why some individuals acquire vicarious somatosensory experiences such as pain following pain-related trauma and other do not in similar circumstances. There is little research yet available on the occurrence of vicarious pain and underlying proposed mechanisms. Most evidence stems from clinical studies, using self-report questionnaires, describing the phenomenon and research in amputees. Several bottom-up variables and top-down variables seem to be important but are rarely investigated. No objective tests of vicarious pain or touch is available as it is difficult to distinguish those reporting actual vicarious touch or pain and those who empathize with another just on the affective level. Little is known whether vicarious pain experiences can be elicited in a more systematic way, for example by means of an experimental paradigm in a lab. In the studies described in this PhD project, unlike some previous studies that investigated vicarious experiences, an experimental paradigm was used to measure these experiences. We tried to elicit this rare phenomenon in a more systematic way. Our experimental paradigm is largely based upon the work of Banissy and Ward (2007). These authors investigated vicarious touch by means of an experiment in which participants were required to detect a site touched on their own face (left, right, both or none) while observing touch to another person's face. For vicarious responders, but not for controls, the observed touch elicited a tactile sensation, whose location was either in the same spatial location as the actual touch (congruent condition) or in a different spatial location (incongruent condition). For example, in an incongruent trial they might receive an actual touch on the left cheek (and are thus required to give the response 'left'), but a vicarious touch on the right cheek. In particular, these authors were interested in errors in which the participant treated the vicarious touch as if it were an actual touch (that is, giving the response 'both' in the example above): 'a mirror-touch error'. Vicarious responders produced a higher percentage of mirror-touch errors than did controls. This pattern of errors implies that these responders can't make the difference between vicarious touch and real touch (see Figure 3).

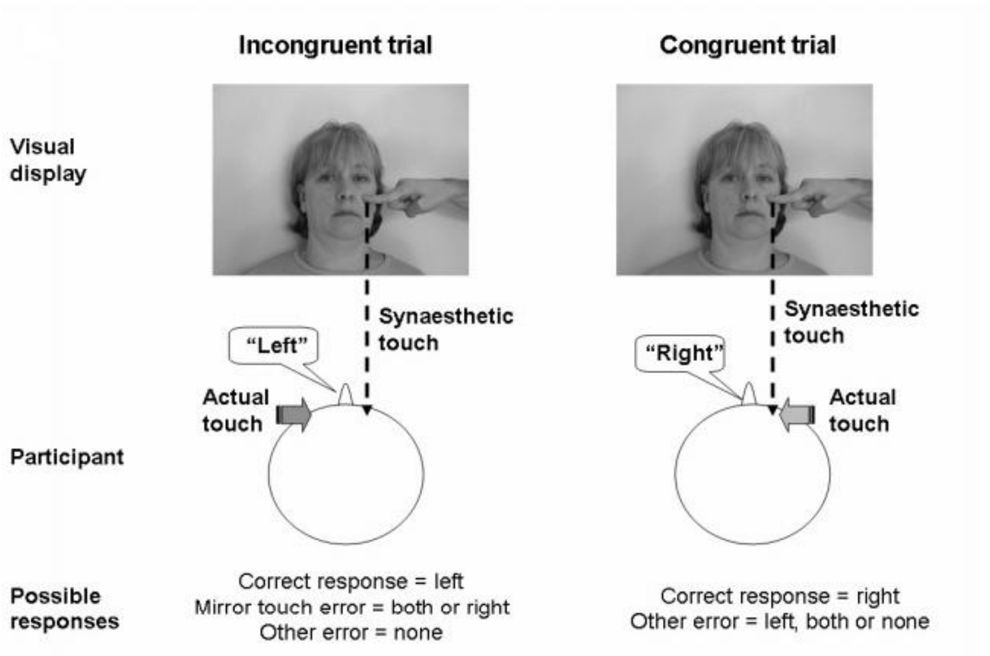

Figure 3. Experimental set-up in a study measuring vicarious touch (Banissy & Ward, 2007)

AIMS AND OUTLINE

This PhD project has three aims. The **first aim** is to develop an appropriate experimental paradigm allowing the measurement of vicarious experiences and somatosensory modulation. The **second aim** is to systematically investigate the effects of viewing another in pain and touch upon elicitation versus modulation of somatic sensations. A **third aim** is to explore the conditions in which vicarious experiences and modulation of somatosensory input occur, such as the role of perspective taking, dispositional empathy, hypervigilance for pain, chronic pain and central sensitization. The three research questions will be investigated in both the general population (i.e., individuals recruited from the community and undergraduates) and chronic pain patients (fibromyalgia patients). Systematic research on the conditions in which vicarious experiences occur and on the underlying mechanisms is of major significance for both theory about pain as a biopsychosocial phenomenon and clinical practice. Theoretically, insight into the conditions and processes of vicarious pain may fundamentally change the view about how pain is processed in the brain, demonstrating the important role of psychosocial variables, not only in the modulation (e.g., Van Damme, Legrain, Vogt, & Crombez, 2010) but also as cause of pain experiences. Clinically, this might for instance shed light on potential underlying processes in "unexplained" pain conditions for which no biomedical cause can be identified. In this project, the influence of the above-mentioned variables on the observers' vicarious experiences and somatosensation was investigated.

The **first research aim** is addressed throughout several chapters in several groups of participants: **chapter 1 and 3** (vicarious pain responders and controls), **chapter 2** (chronic pain patients and controls) and **chapter 4 and 5** (undergraduates). To address this aim, we developed a variant of the crossmodal congruency task inspired by the work of Banissy and Ward (2007) on vicarious touch. Participants were presented a series of videos showing hands being pricked, whilst receiving occasionally pricking experiences themselves (chapter 1) or vibrotactile somatosensory stimuli (chapter 2,3,4,5) in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual stimuli. Participants were instructed to report as rapidly as possible the spatial location of the administered somatosensory stimuli. Throughout the different chapters, the paradigm was adapted (adaptions in the type of trials, content of videos, ..) and other groups of participants were selected dependent upon the hypotheses.

The **second research aim** is again addressed throughout the different chapters. **In chapter 1,** two studies are described that investigated whether vicarious pain responders and controls reported vicarious pain experiences while observing pain-related videos. In **chapter 2,** vicarious experiences were assessed by means of self-report in a group of chronic pain patients and controls. In addition to chapter 1, chapter 2 not only investigated the experience of vicarious sensation while observing pain-related information but also assessed modulation of somatosensory stimuli and presented non-pain related information. In **chapter 3**, two studies are described that investigated the experience of vicarious non-painful sensations in vicarious pain responders and controls and the modulation of somatosensory stimuli while observing pain-related and non-pain related information. In **chapter 4 and 5**, the effect of observing pain, touch and control videos upon vicarious experiences and modulation of somatosensory experiences in undergraduates is investigated.

Finally, throughout the several chapters, the **third research aim** in which the effect of different conditions and underlying mechanisms was investigated. **In chapters 1, 2, 3, 4 and 5** the role of hypervigilance to pain and dispositional empathy upon the experience of vicarious experiences and modulation of somatosensation was investigated. In **chapter 2,** the role of central sensitization in the experience of vicarious experiences was examined in a group of chronic pain patients by means of temporal summation of heat pulses. The study reported in **chapter 3** investigated the stability of vicarious somatosensory experiences in those experiencing vicarious pain in daily life and controls. In **chapter 4,** the impact of perspective taking upon somatosensation was investigated, by means of an adapted paradigm in which undergraduates were exposed to several types of videos (touch, pain, control) in first- and third-person perspective (videos turned upside down). **In chapter 5,** the impact of perspective taking upon the experience of vicarious sensations and somatosensory modulation while observing pain, touch and control scenes was examined by manipulating the activity in the right tempoparietal junction (rTPJ). The TPJ is linked to self-other representations, including perspective taking (e.g., Aichhorn, Perner, Kronbichler, Staffen, & Ladurner, 2006), agency discrimination (e.g., Farrer & Frith, 2002) and empathy (e.g., Völlm et al., 2006).

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CHAPTER 1

Vicarious pain while observing another in pain: an experimental approach[1]

ABSTRACT

Objective: This study aimed at developing an experimental paradigm to assess vicarious pain experiences. We further explored the putative moderating role of observer's characteristics such as hypervigilance for pain and dispositional empathy.

Methods: Two experiments are reported using a similar procedure. Undergraduate students were selected based upon whether they reported vicarious pain in daily life, and categorized into a pain responder group or a comparison group. Participants were presented a series of videos showing hands being pricked whilst receiving occasionally pricking (electrocutaneous) stimuli themselves. In congruent trials, pricking and visual stimuli were applied to the same spatial location. In incongruent trials, pricking and visual stimuli were in the opposite spatial location. Participants were required to report on which location they felt a pricking sensation. Of primary interest was the effect of viewing another in pain upon vicarious pain errors, i.e., the number of trials in which an illusionary sensation was reported. Furthermore, we explored the effect of individual differences in hypervigilance to pain, dispositional empathy and the rubber hand illusion (RHI) upon vicarious pain errors.

Results: Results of both experiments indicated that the number of vicarious pain errors was overall low. In line with expectations, the number of vicarious pain errors was higher in the pain responder group than in the comparison group. Self-reported hypervigilance for pain lowered the probability of reporting vicarious

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[1] Based on: Vandenbroucke, S., Crombez, G., Van Ryckeghem, D.M.L, Brass, M, Van Damme, S., & Goubert, L. (2013). Vicarious pain while observing another in pain: an experimental approach. *Frontiers in Human Neuroscience, 7*, 265. doi:10.3389/fnhum.2013.00265

pain errors in the pain responder group, but dispositional empathy and the RHI did not.

Conclusion: Our paradigm allows measuring vicarious pain experiences in students. However, the prevalence of vicarious experiences of pain is low, and only a small percentage of participants display the phenomenon. It remains however unknown which variables affect its occurrence.

GENERAL INTRODUCTION

Viewing someone in pain has been suggested to elicit distress in observers (Goubert et al., 2005; 2009). In addition, several brain regions tapping into the affective-motivational properties of pain have been found to become activated when seeing someone else in pain (Jackson et al., 2005). Furthermore, studies have provided evidence that observing others' pain activates brain regions subserving the sensory-discriminative properties of pain (Bufalari et al., 2007). Intriguingly, observing pain in others may also give rise to a vicarious experience of pain. This experience has most often been described in patients with a history of intense, traumatic pain. For example, Giummarra and Bradshaw (2008) documented a case of vicarious pain in a woman who had an emergency caesarean section delivery because of a long and painful labor with obstruction. This woman reported the experience of "shooting pains from the groin that radiate down the legs" when told of another's traumatic experience. In another study with 74 phantom limb patients (Fitzgibbon et al., 2010a), sixteen percent of the participants reported that observing or imagining pain in another person triggers their phantom pain. There is little research yet available on the occurrence of vicarious pain and underlying mechanisms (but see Fitzgibbon et al., 2012a; 2012b). Most evidence stems from clinical studies, using self-report questionnaires, describing the phenomenon and research in amputees. Little is known whether vicarious pain experiences can be elicited in a more systematic way, for example by means of an experimental paradigm in a lab.

There is preliminary evidence that also individuals without traumatic pain experiences may feel pain by observing pain in others. Osborn and Derbyshire

(2010) found that, when healthy volunteers were presented a series of images and video clips depicting painful events, almost 30% reported at least one pain experience. In a follow-up study, 10 of these vicarious pain responders were matched with 10 non-responders to take part in an fMRI study, and static images of painful events and emotional images not containing noxious events were shown. When observing the images of the painful events, vicarious pain responders showed higher activation of emotional (i.e. left and right insular) and sensory brain regions (i.e. secondary somatosensory cortex) associated with pain than non-responders.

The mechanisms and conditions that affect these vicarious experiences are largely unknown. Fitzgibbon and colleagues (2010b) proposed a framework to further our understanding of vicarious pain, which they dubbed "synaesthesia for pain". They proposed several mechanisms to explain vicarious pain, amongst which empathy or processes underlying empathy, hypervigilance to pain, chronic prior pain and trauma. According to this model, vicarious pain is a maladaptive form of empathic processing. Empathy has been defined in various ways, but generally features the capacity to understand and respond to the unique affective experiences of another person (Decety & Jackson, 2006). The role of empathy in vicarious pain experiences is yet unclear. In the study of Osborn and Derbyshire (2010), a group of pain responders and non-pain responders were subsequently matched for trait empathy (Interpersonal Reactivity Index – IRI); consequently no differences occurred between both groups regarding this trait. Undergraduate students who reported an actual noxious somatic experience in response to images or clips depicting noxious events scored higher on a measure of state empathy than non-vicarious pain responders. Although the pain responders displayed more state empathy evoked by the images and movie clips, this was not correlated with reported pain intensity. However, in two recent studies, no differences were found between amputees with vicarious pain, amputees without vicarious pain responses, and non-amputee controls on measures of empathic ability (Fitzgibbon et al., 2012b, Giummarra et al., 2010).

Prior trauma may be the modulating variable inducing hypervigilance to pain cues, according to the model of Fitzgibbon et al. (2010b). Hypervigilance for pain is an over-alertness to pain-related information, and is installed when pain or anticipated pain becomes a current concern (Crombez, et al., 2005). As such, vicarious pain may be an exaggerating response to the anticipation of observed pain (Fitzgibbon, 2012c, Giummarra et al., 2010). Therefore, we may expect that participants high in hypervigilance for pain report more vicarious pain experiences independent of any pre-existence of chronic (prior) pain. As yet, the proposed underlying mechanisms remain largely untested (Fitzgibbon et al., 2010b).

The primary aim of the present study is to develop an experimental paradigm allowing the measurement of vicarious pain experiences in people who explicitly report vicarious pain in daily life. A secondary aim was to explore the role of two potential moderators, i.e., dispositional empathy and hypervigilance for pain. To address these questions we developed a paradigm inspired by the work of Banissy & Ward (2007) on vicarious touch. In a first experiment, pre-selected undergraduate students reporting vicarious pain in daily life (i.e., “pain responders”) and a comparison group not reporting vicarious pain, were presented a series of videos showing hands being pricked, whilst receiving occasionally pricking experiences themselves in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual stimuli. Participants were instructed to report as rapidly as possible the spatial location of the administered somatosensory stimuli. First, we expected a higher frequency of vicarious pain during the experiment in the group reporting vicarious pain in daily life compared to the comparison group. In analogy with the study of Banissy & Ward (2007) in vicarious touch responders, we also expected that vicarious pain responders would be slower in incongruent relative to congruent trials. Second, we explored the effects and moderating role of dispositional empathy and hypervigilance to pain upon experiences of vicarious pain. In experiment 2, we aimed at replicating the findings of experiment 1, though with some procedural changes. Additionally, we explored the effect of the rubber hand illusion (RHI) upon vicarious pain, and differences between pain responders and controls in RHI experience. As pain responders experience bodily illusions in response to another in pain, we expect their experience of the rubber hand illusion to be more pronounced compared to controls.

EXPERIMENT 1

METHOD

Participants

Participants were recruited from a pool of approximately 682 undergraduate students from Ghent University who were invited to complete questionnaires screening for, amongst others, the experience of vicarious pain in daily life (November 2010 to January 2011). Specifically, participants were asked to indicate the extent to which they agreed with the question "Do you have the feeling experiencing pain when you observe another person in pain?" on a five point scale (0 = strongly disagree; 1 = disagree; 2 = neutral; 3 = agree; 4 = agree; 5 = strongly agree). This item was specifically developed for this study and was based upon the work of Banissy and colleagues (2009). Two-hundred fourteen students completed the screening questionnaires (31.38%). In line with Banissy and colleagues (2009), participants scoring 4 or higher (22.90%, *n*=49) were invited to take part in the experiment. We also invited randomly 20 of those who scored 1 or lower. In total, thirty students (23 women, 7 men) agreed to participate. Mean age was 21.87 years (*SD* = 5.99, range: 18-49 years). All participants were Caucasian. Participants received either course credits for participation in this experiment (*n* = 13) or were paid (*n* = 17) 8 euro. Ethical approval was obtained from the Ethics committee of the Faculty of Psychology and Educational Sciences of Ghent University, Belgium.

Apparatus and stimuli

Visual stimuli

Visual stimuli consisted of 10 short videos with a duration of 3 seconds. Each video depicted a scene in which a left and right hand was presented, with one of the two hands being pricked by a sharp object (2000ms after video onset).

Five types of sharp objects were used across all videos, i.e., a safety pin, a needle, and 3 different syringes. Location of penetration (left versus right hand) and type of sharp object were counterbalanced across videos. Videos were presented by INQUISIT Millisecond software (Inquisit, 2002) on a Dell computer with a 19-inch CRT-monitor.

Somatosensory stimuli

Somatosensory stimuli were electrocutaneous stimuli (ES, bipolar, sinusoide, 200Hz), delivered between thumb and index finger by two lubricated Medcat surface electrodes (1cm diameter) of a constant current stimulator (DS5, Digitimer Ltd, Hertfordshire, UK). The duration of the ES was always 200ms. The intensity of the electrocutaneous stimulus was individually determined. In a work up procedure, individuals were presented with stimuli of increasing intensity until a pricking sensation was reported. At the start the intensity was 0.25mA, and increased by 0.25mA for each next stimulus. Such procedure was performed for both the left and the right hand (used intensities: left: M = 0.78 mA, range: 0.25mA - 1.5mA; right: M = 0.75mA, range: 0.25mA – 1.5mA).

Self report measures

To assess vicarious pain experiences in daily life, participants were asked to indicate the extent to which they agreed with the question “Do you have the feeling experiencing pain when you observe another person in pain?” on a five point scale (0=strongly disagree; 5=strongly agree). This question was used for the initial screening and readministered during the lab experiment to classify participants in the pain responder group and the comparison group. At our university, the initial screening is anonymous and data from the screening can only be used to select participants but not for other research purposes.

Hypervigilance for pain was assessed by the Dutch version of the Pain Vigilance and Awareness Questionnaire (PVAQ; McCracken, 1997; Roelofs et al., 2003). This questionnaire consists of 16 items to be scored on a six-point scale (0=never; 5=always). The PVAQ consists of two subscales: attention to pain (e.g. ‘I pay close attention to pain’) and attention to changes in pain (e.g. ‘I am quick to notice changes in pain intensity') (Roelofs et al., 2003). The questionnaire can be used in both clinical (McCracken, 1997; Roelofs et al., 2003) and non-clinical (McWilliams & Asmundson, 2001; Roelofs et al., 2002) samples. Higher scores are indicative of more vigilance to pain. The Dutch version of the PVAQ is reliable and valid (Roelofs et al., 2002; 2003). Cronbach's alpha for the present study was 0.89.

Dispositional empathy was assessed with the Dutch version of the Interpersonal Reactivity Index (IRI; Davis, 1983; De Corte et al., 2007). The questionnaire contains 28 items and consists of 4 subscales: 'Perspective Taking' (i.e., cognitively taking the perspective of another, e.g. "I sometimes try to understand my friends better by imagining how things look from their perspective."), 'Fantasy' (i.e., emotional identification with characters in books, films etc., e.g. "When I watch a good movie, I can very easily put myself in the place of a leading character."), 'Empathic Concern' (i.e., feeling emotional concern for others, e.g. "I am often quite touched by things that I see happen.") and 'Personal Distress' (i.e., negative feelings in response to the distress of others, e.g. "When I see someone who badly needs help in an emergency, I go to pieces."). Each item is rated on a scale ranging from 1 ('does not describe me very well') to 5 ('describes me very well'). This questionnaire has shown to be reliable and valid (Davis, 1983; De Corte et al., 2007). Cronbach's alpha's in the current study were 0.78 (fantasy scale), 0.61 (empathic concern), 0.79 (personal distress) and 0.39 (Perspective Taking). The latter subscale was omitted from the analyses because of the low reliability score.

Intensity and the (un)pleasantness of the electrocutaneous stimuli were rated on eleven-point numerical rating scales (0='not intense'; 10='intense' respectively -5='unpleasant'; +5='pleasant').

Procedure

Preparation phase. Participants were informed that they would feel stimuli, varying in intensity and length, on their left, right or both hands during the experiment. After signing the informed consent, a pair of electrodes was attached to each hand. The skin at the electrode sites was first abraded with a peeling cream (Nihon Kohden) in order to reduce skin resistance. Subsequently, the stimulus intensity level was established for each hand. Questions measuring the (un)pleasantness and intensity of the somatosensory stimulus were administered. Participants were seated in front of a table, at about 60cm away from the computer screen and were informed that different videos would be presented which they needed to watch attentively. Hands of the participants were covered by means of a box and placed on the table in front of the screen. Participants were told that when a somatosensory stimulus was administered on both hands, the intensity could vary across hands and that also trials without any stimulus would be included. In reality, only one fixed predetermined intensity was applied for each hand.

Experiment phase. Each trial began with a fixation cross (1000 ms duration) presented in the middle of the screen. Next, one of 10 different videos was presented. In two third of the trials, an electrocutaneous stimulus was delivered 2050ms after video onset either on the left hand, the right hand, or on both hands of the participant. In line with Banissy & Ward (2007), the electrocutaneous stimulus was administered with a delay, which was 50ms after the penetration of the sharp object in the observed hand. This resulted in the following trial types: (1) congruent trials, (2) incongruent trials, (3) trials in which no somatosensory stimuli were administered and (4) trials in which both hands of the participant received somatosensory stimuli. In congruent trials, somatosensory stimuli and visual stimuli were presented at the same spatial location (e.g., right). In incongruent trials, somatosensory stimuli and visual stimuli were presented in the opposite spatial location (e.g., left and right). The experiment started with 8 practice trials. The actual experiment phase consisted of three blocks of 64 trials, resulting in a total of 192 trials. There were 60 congruent trials, 60 incongruent trials, 60 trials without ES and 12 trials with ES at both hands equally divided over the three blocks. This latter trial type was added to make the response ‘both’ applicable and feasible. Visual stimuli were presented when ES was present or absent. Trial types were equally distributed across blocks. Order of trial types was randomized within each block. An overview of all trial types is presented in Table 1. During each trial, participants were requested to report whether a physical sensation was felt and indicate its location as quickly and accurately as possible by reporting aloud “left”, “right” or “both”. Reaction times were recorded by means of a voice key (see Figure 1). The experimenter coded the response by pressing the corresponding response button (left, right or both). The participant was instructed not to respond when no sensation was felt. In such situation a trial was considered completed when 2000ms had elapsed after the video was ended. The completion of the experiment took approximately 50 minutes. Vicarious pain errors were calculated from incongruent trials and from trials in which no ES was administered. A vicarious pain error was considered present when participants reported feeling a pricking sensation in the same spatial location as the visual stimulus without the administration of an actual ES at that location.

Post-experiment phase. After the experiment, participants were requested to fill out self-report scales measuring vicarious pain experiences in daily life, hypervigilance for pain (PVAQ) and empathic disposition (IRI).

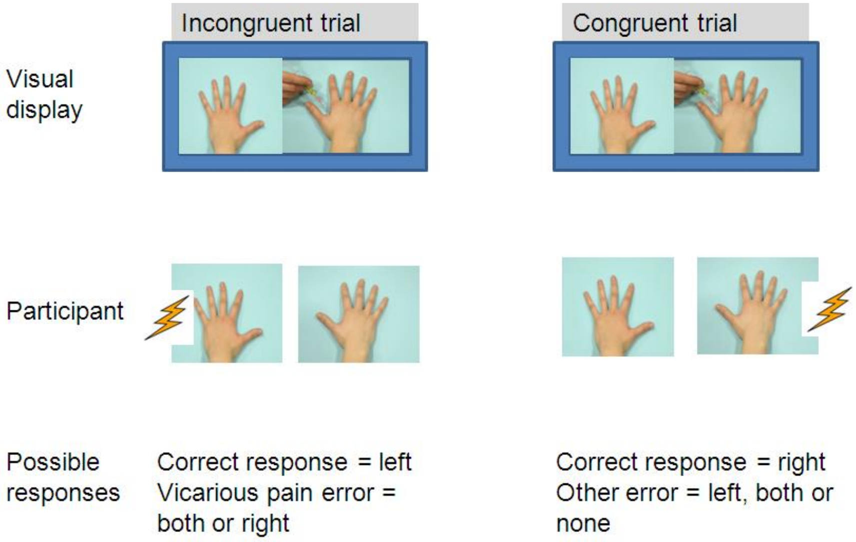

Figure 1. Example of a possible trial

Table 1

An overview of all trial types (experiment 1 - experiment 2). Voice key errors are not included.

Experiment 1	Congruent trials				Incongruent trials				No tactile stimulation			
Reported site	Correct site	Opposite site to visual and tactile	Both hands	No hands	Correct site	Opposite site (=visual site) *vicarious error*	Both hands *Vicarious error*	No hands	Site congruent to visual *Vicarious error*	Opposite site to visual	Both hands	No hands
%	93.27%	0.33%	2.07%	3.27%	90.40%	0.93%	3.00%	4.53%	1.40%	0.33%	0.20%	97.60%

Experiment 2	Congruent trials				Incongruent trials				No tactile stimulation			
Reported site	Correct site	Opposite site to visual and tactile	Both hands	No hands	Correct site	Opposite site (=visual site) *vicarious error*	Both hands *Vicarious error*	No hands	Site congruent to visual *Vicarious error*	Opposite site to visual	Both hands	No hands
%	94.00%	0.17%	.42%	4.25%	92.00%	0.25%	1.42%	5.17%	0.67%	0.42%	0.00%	98.17%

Statistical analysis

Using the same criteria as during the screening, 14 participants were categorized in the pain responder group and 11 in the comparison group. Participants who did not fulfill these criteria at the moment of testing were excluded from analysis (*n* = 5).

To test the hypothesis that pain responders make more vicarious pain errors, count regression models were applied as the use of linear models is considered less appropriate when the frequency of responses has a skewed distribution that violates the normality assumption (e.g., Vives et al. 2006). Poisson regression is the basic model to analyze count data, but the variance of counts is often larger than the mean (overdispersion). The Negative Binomial (NB) regression, a Poisson regression with an overdispersion, may therefore better fit the data (e.g. Gardner et al. 1995). As count data may additionally exhibit a lot of zero counts, zero-inflated extensions of both models, called Zero-Inflated Poisson (ZIP) and Zero-Inflated NB (ZINB) models have been developed (see Loeys et al., 2012; Karazsia & van Dulmen, 2010). Deviance tests and Vuong test were used to select the best fitting count distribution for the dependent variable.

After the best fitting count model was chosen, several models were run. The first model contained the predictor 'group'; the dependent variable was the number of vicarious pain errors. In subsequent analyses, participants' characteristics were added as second predictor in the model to explore whether PVAQ respectively IRI (subscales) had a moderating role.

Dummy coding was used for the categorical variables and standardized z-scores for the continuous predictors. Regression coefficients are exponentiated (e^B) and called Rate Ratios (RRs). In percentages—100 x (e^B -1)—RRs reflect the percentage decrease (RR < 1) or increase (RR > 1) in the expected frequency of vicarious pain errors for every 1-unit increase in the independent variable. R (version 2.15.1) was used to fit the count models.

To test whether participants in the pain responder group have higher hypervigilance and dispositional empathy scores compared with the comparison group, independent-samples *t*-tests were performed. To test whether pain responders show a larger congruency effect than non-pain responders (see Banissy

& Ward, 2007), a 2 (congruency: congruent versus incongruent) x 2 (group: comparison versus pain responders) repeated measures ANOVA was performed, with congruency entered as within-subject variable and group as between-subject variable. Error trials and trials with responses faster than 200 ms or slower than 3 *SD* above the individual mean reaction time of each trial type were removed from RT analyses. These analyses were conducted with an $\alpha < 0.05$, using SPSS statistical software, version 21.0 for Windows.

RESULTS

Descriptive statistics

Mean scores, standard deviations and correlations of experiment 1 are presented in Table 2 and 3. Because the variable (un)pleasantness did not have a normal distribution, Spearman correlations were computed for this particular variable (Kolmogorov-Smirnoff, $p < .05$). Mean age was 21.50 years in the pain responder group (*SD* = 4.16, range: 18 - 34 years) and 23.27 years (*SD* = 8.76, range: 18 - 49 years) in the comparison group. Of all participants, 27.3% indicated to have experienced an episode of chronic pain during their life (pain duration longer than 3 months). There was no significant difference between both groups ($t(20) = -1.16$, $p = .26$). In 2.7% of the incongruent trials and trials without any ES, vicarious pain errors were made (80 vicarious pain errors from a total of 3000 trials), mainly in the pain responder group (83.75% of all vicarious pain errors; $n = 67$). Two participants in the pain responder group were responsible for 66.25% of all vicarious pain errors (53 of a total of 80 vicarious pain errors). The number of vicarious pain errors did not differ across the 3 blocks (Kruskal-Wallis, $p = .12$). No difference was found between both groups in PVAQ scores ($t(23) = -.93$, $p = .07$) or empathy scores (subscales all $p \geq .10$).

Table 2

Mean scores and standard deviations of all measures (study 1)

	M (SD) pain responder group	M(SD) comparison group	M(SD) total group
1. RT incongruent trials	784.48 (118.44)	674.45 (74.34)	736.07 (114.06)
2. RT congruent trials	719.79 (136.86)	628.82 (70.88)	679,76 (119.84)
3. Intensity (0-10)	4.46 (1.66)	4.77 (1.65)	4.6 (1.63)
4. (Un)pleasantness	-1.43 (1.41)	-1.95 (.76)	-1.66 (1.18)
5. PVAQ	39.62 (13.64)	30.0 (10.52)	35.39 (13.06)
6. EC	19.21 (3.38)	17.91 (3.75)	18.64 (3.53)
7. FS	21.29 (4.46)	19.00 (4.77)	20.28 (4.65
8. PD	12.50 (6.16)	15.82 (3.34)	13.96 (5.30)

Note. Pain Vigilance and Awareness Questionnaire (PVAQ), Empathic Concern (EC), Fantasy Scale (FS), Personal Distress (PD), Reaction times (RT).

Table 3

Pearson/Spearman correlations of all measures (study 1)

	2.	3.	4.	5.	6.	7.	8.
1. RT incongruent trials	.91**	-.17	-.05	.03	-.23	.17	-.51**
2. RT congruent trials	-	-.24	-.02	.01	-.32	.09	-.57**
3. Intensity (0-10)		-	-.62**	.41*	.12	.26	.53**
4. (Un)pleasantness			-	-.41*	.22	-.43*	-.24
5. PVAQ				-	.13	.18	-.07
6. EC					-	.41*	.17
7. FS						-	.04
8. PD							-

Note. Pain Vigilance and Awareness Questionnaire (PVAQ), Empathic Concern (EC), Fantasy Scale (FS), Personal Distress (PD), Reaction times (RT).
* $p<0.05$; ** $p<0.01$

Vicarious pain errors

The NB model was found to be the best fitting count model ($\chi^2[1, N = 25] = 149.26$, p < .001; V = -1.33, *p* = .09) to test the influence of group (pain responder versus comparison group) upon the number of vicarious pain errors. In a first step, group was added as a predictor. Results showed that the number of vicarious pain errors significantly raised with 305% (RR = 4.05, *p* = .04; [95% CI: -.02, 2.78]) when participants reported vicarious pain experiences in daily life (pain responder group) compared to the comparison group.

In order to explore the moderating role of individual differences in hypervigilance for pain (PVAQ) and dispositional empathy (IRI), additional models were run with PVAQ or IRI subscales entered as a second predictor and in interaction with group. A significant interaction was found between group and PVAQ (*p* < 0.01; [95% CI: -3.40, -.57]). For pain responders, the probability of making vicarious pain errors decreased by 74% (RR = .26) for every 1-unit increase in hypervigilance for pain. For the comparison group, the probability of making vicarious pain errors increased by 79% (RR = 1.79) for every 1-unit increase in hypervigilance for pain. No main effect of hypervigilance for pain was found (*p* = .28).

Furthermore, no interaction was found between group and subscales 'fantasy' (*p* = .22),'personal distress' (*p* = .99) and 'empathic concern' (*p* = .61). Also no main effects of these subscales were found (all *p* > .44).

Reaction times

A 2 (congruency: congruent versus incongruent) x 2 (group: comparison versus pain responder group) repeated measures ANOVA showed a main effect of group. In particular, the pain responder group was slower in both congruent and incongruent trials compared to the comparison group (*F*(1,23) = 5.70, *p* = .03). Furthermore, also a main effect of congruency was observed (*F*(1,23) = 29.84, *p* < .01) indicating that all participants were faster on congruent than on incongruent trials. Contrary to expectations, no interaction was found between congruency and group (*F*(1,23) = .89, *p* = .36).

DISCUSSION

Current results indicate that our paradigm allows us to measure vicarious pain experiences in healthy students and revealed only a small percentage of vicarious pain errors. As the sample size of the first experiment was relatively small, a second experiment was performed to test whether the results could be replicated. Furthermore, a more stringent recruitment procedure was used than in experiment 1 where vicarious pain experiences in daily life were measured by means of only one item. As pain responders experience bodily illusions in response to viewing another's pain, an additional aim of the second experiment was to explore whether pain responders report a stronger rubber hand illusion experience than controls (Botvinick & Cohen, 1998). Finally, we also investigated whether the rubber hand illusion experience was related to participants' vicarious pain errors.

EXPERIMENT 2

METHOD

Participants

Participants were recruited from a pool of approximately 647 undergraduate students from Ghent University who were invited to complete several questionnaires (October to November 2011). One of these questionnaires intended to assess the experience of vicarious pain experiences in daily life by means of four items adapted from Banissy et al. (2009). Participants were asked to indicate on an eleven point scale (0 - 10; totally disagree – totally agree) the extent to which they agreed with the questions: “Do you feel pain in your own body when you see someone accidently bump against the corner of a table?”, “Do you have the feeling experiencing pain when you observe another person in pain?”, “Do you feel bodily pain when you observe another person in pain?” and “Do you feel a physical sensation (e.g. tingling, stabbing, …) when you observe another person in pain?”. Completed questionnaires were available from 348 students (53.79%).

As no standard cut-off for the presence of vicarious pain was available, we invited all participants who scored ≥ 6 on all questions (6.61%, *n* = 23). This cut-off preserves a balance between extreme values (inviting the highest scoring vicarious pain responders) and a minimum of pain responders to participate. We also invited randomly 20 of those who scored ≤ 1 on all questions.

In total, 24 undergraduates (23 women) agreed to participate. Their mean age was 19.17 years (*SD* = 1.81, range: 17 - 23 years). All participants, except one, were Caucasian. Participants received either course credits for participation in this experiment (*n* = 21) or were paid (*n* = 3) 8 euro. Ethical approval was obtained from the Ethics committee of the Faculty of Psychology and Educational Sciences of Ghent University (Belgium).

Design, apparatus and stimuli

The design, apparatus and stimuli, were similar as in experiment 1. The mean intensity of the somatosensory stimuli was 0.74mA (range: 0.50mA - 1mA) for the left hand and 0.69mA (range: 0.50mA – 1mA) for the right hand.

Self-report measures

To assess vicarious experiences in daily life, participants were asked to indicate on an 11-point scale (0 - 10; totally disagree – totally agree) the extent to which they agreed with each of the four items, which were also used in the initial screening. This questionnaire was readministered during the procedure in the lab as the first screening was anonymous. Cronbach's alpha in the current study was 0.97.

Hypervigilance to pain (PVAQ; Cronbach's α = 0.91) and empathic disposition (IRI; fantasy scale Cronbach's α = 0.84, empathic concern Cronbach's α = 0.69, personal distress Cronbach's α = 0.77, perspective taking, Cronbach's α = 0.39) were assessed in the same way as in experiment 1. As in experiment 1, the perspective taking subscale was omitted from the analyses because of the low reliability score.

Rubber hand illusion (RHI) experience was measured by means of nine items (e.g., 'It felt as if the rubber hand was my hand'; Botvinick & Cohen, 1998). Participants indicated the extent to which they agreed or disagreed on a 15cm scale. Seven positions were marked ranging from strongly disagree (---) to strongly agree (+++). A total score for the RHI experience was based upon the sum score of all items (Cronbach's $\alpha = 0.79$).

Procedure

The first part of the procedure used in this experiment was identical to the applied procedure in experiment 1. Subsequent to the experiment, participants took part in a rubber hand illusion (RHI) test. The test was set up and conducted in line with previous RHI studies (Botvinick, Cohen, 1998). Participants were seated with their both arms placed upon a table. Their right hand was positioned next to a screen, outside the view of the participant. A right-handed life-sized rubber hand was placed on the table directly in front of the subject with its index finger 20 cm to the right of the participant's index finger. A black cape extending from their neck to the table obscured the view of their upper arms throughout the experiment. Participants were asked to focus on the rubber hand. Two small paintbrushes were used to stroke the participant's and rubber hand's index fingers during three minutes, synchronizing the timing of the brushing as closely as possible. After the RHI test, participants were requested to fill in a short questionnaire about their experience during the RHI test (see Botvinick, Cohen, 1998).

Statistical analysis

Participants were categorized in a pain responder group and a comparison group based upon the sum of their responses on the items measuring vicarious pain in daily life, administered during the experiment. As no cut-off was available, we considered to maintain all participants whose sum score was < 15 ($n = 7$; comparison group) and those whose sum score was > 25 ($n = 13$; pain responder group) as this cut-off preserves a balance between extreme values (the most extreme scoring vicarious pain responders) and a minimum of pain responders to analyze. Four participants scoring between 15 and 25 were excluded from the analyses.

To test the hypothesis that pain responders make more vicarious pain errors, we applied similar statistical analyses as those performed in experiment 1. Additional analyses were performed related to RHI. To investigate whether pain responders had a higher score on the questions measuring the RHI than the comparison group, we used a one sample *t*-test. We also explored whether the RHI experience was related to the number of vicarious pain errors in the behavioral paradigm.

RESULTS

Descriptive statistics

Mean scores, standard deviations and correlations for the second experiment are presented in Table 4 and 5. The variables intensity and empathic concern did not have a normal distribution, therefore spearman correlations are indicated for these particular variables (Kolmogorov-Smirnoff, $p < .05$). The mean age of the participants in the pain responder group was 19.85 years (*SD* = 2.03, range: 18 - 23) and 18.29 years for the comparison group (*SD* = 1.25, range: 17 - 21 years). Of all participants, 52.6% indicated to have experienced an episode of chronic pain during their life (pain duration longer than 3 months). This was not significantly different between both groups ($t(17) = -.62$, $p = .54$).

In 0.88% of the trials, vicarious pain errors were made (21 vicarious pain errors from a total of 2400 trials), especially in the pain responder group (90.48% of all vicarious pain errors, $n = 19$). Three pain responders were responsible for 76.19% of all vicarious pain errors (16 of a total of 21 vicarious pain errors). The number of vicarious pain errors did not differ across the 3 blocks (Kruskal-Wallis, $p = .75$). Furthermore, no significant difference was found between the pain responder group and the comparison group concerning the rubber hand illusion experience ($t(18) = -1.28$, $p = .22$). Also no differences were found between both groups regarding dispositional empathy scores (all $p \geq .60$) and hypervigilance for pain ($t(18) = -.04$, $p = .97$).

Table 4

Mean scores and standard deviations (study 2)

	M (SD) pain responder group	M(SD) comparison group	M(SD) total group
1. RT incongruent trials	711.07 (155.00)	685.51 (86.72)	702.12 (133.06)
2. RT congruent trials	681.10 (150.37)	651.05 (58.46)	670.59 (124.80)
3. Intensity	4.38 (2.31)	3.86 (2.46)	4.20 (2.31)
4. (Un)pleasantness	-1.81 (1.16)	-1.5 (1.08)	-1.70 (1.12)
5. PVAQ	42.23 (14.14)	42.00 (9.13)	42.15 12.36
6. EC	21.62 (2.02)	18 (4.58)	20.35 3.51
7. FS	20.85 (4.63)	19.57 (5.86)	20.40 (4.98)
8. PD	14.54 (4.99)	14.43 (5.22)	14.50 (4.94)
9. RHI	753.77 (206.04)	631.86 (199.73)	711.10 (207.29)

Note. Pain Vigilance and Awareness Questionnaire (PVAQ), Empathic concern (EC), Fantasy Scale (FS), Personal Distress (PD), Rubber Hand Illusion (RHI), Reaction times (RT).

Table 5

Pearson/Spearman correlations of all measures (study 2)

	2.	3.	4..	5.	6.	7.	8.	9.
1. RT incongruent trials	.96**	-.16	.06	-.27	-.12	.18	-.11	.24
2. RT congruent trials	-	-.07	.10	-.33	-.14	.18	-.10	.23
3. Intensity		-	-.61**	.10	-.18	.17	.24	.16
4. (Un)pleasantness			-	.01	.02	-.07	-.21	.11
5. PVAQ				-	.28	.23	.47*	.48*
6. EC					-	.28	.14	.12
7. FS						-	.06	.39
8. PD							-	.46*
9. RHI								-

Note. Pain Vigilance and Awareness Questionnaire (PVAQ), Empathic concern (EC), Fantasy Scale (FS), Personal Distress (PD), Rubber Hand Illusion (RHI), Reaction times (RT). * p<0.05; **p<0.01

Vicarious pain errors

To investigate the impact of group (comparison versus pain responder group) upon the number of vicarious pain errors, the NB-model was chosen as count model ($\chi^2[1, n = 20] = 27.84$, $p < .001$; V = 1.71, $p = .24$). The results of the NB regression testing showed that group did not influence the frequency of vicarious pain errors ($p = .17$).

In subsequent analyses, several models were run containing observer's characteristics such as PVAQ, subscales of the IRI and rubber hand illusion as a second predictor in the interaction to explore a moderating role. PVAQ did not significantly interact with group ($p = .86$), nor did the fantasy scale ($p = .44$), personal distress ($p = .55$), or rubber hand illusion ($p = .39$). Also no main effect was found of the PVAQ ($p = .57$), nor of the different subscales of the IRI (all $p >$ .24) or RHI ($p = .34$).

Reaction times

A 2 (congruency: congruent versus incongruent) x 2 (group: comparison versus pain responder group) repeated measures ANOVA revealed no main effect of group; indicating that pain responders were not slower compared to the comparison group ($F(1,18) = 0.21$, $p = .66$). Results did however reveal a main effect of congruency ($F(1,18) = 13.73$, $p = .002$), indicating that participants in general were faster on congruent than on incongruent trials. No interaction was found between congruency and group ($F(1,18) = .07$, $p = .80$).

DISCUSSION

In contrast to experiment 1, individuals reporting vicarious pain experiences in daily life did not report more vicarious pain errors in our behavioral paradigm than individuals from the comparison group. Although a negative association was observed between the number of vicarious pain errors and hypervigilance for pain in the pain responder group, this effect proved to be non-significant. This may be due to a low sample size ($n = 20$). In that respect, it may however be that the results of both studies do not differ (Schmidt, 2010). To explore this issue further, we performed an analysis of the data combined from both experiments, and added an extra between-subject variable study (experiment 1 versus 2).

Overall analyses - RESULTS

Descriptive results

Mean scores, standard deviations and correlations of the pooled data are presented in Table 6 and 7. As the congruent and incongruent RT as well as the self-report variables intensity, (un)pleasantness, personal distress and fantasy scale were not normally distributed (Kolmogorov-Smirnoff, $p < .05$) we reported Spearman correlations for these variables. To test whether both groups differed in hypervigilance and empathic concern, independent-sample t-tests were performed. Participants in the pain responder group were more empathic concerned compared to participants in the comparison group ($t(43) = -2.33$, $p = .03$). No difference was found between both groups in hypervigilance for pain ($t(43) = -1.59$, $p = .12$). For all analyses regarding reaction times, log10 transformation was used to normalize data.

Table 6

Mean scores and standard deviations (overall analyses)

	M (SD) pain responder group	M(SD) comparison group	M(SD) total group
1. RT incongruent trials	749.14 (139.64)	678.76 (77.04)	720.98 (122.60)
2. RT congruent trials	701.16 (142.09)	637.47 (65.47)	675.69 (120.75)
3. Intensity	4.43 (1.96)	4.42 (1.99)	4.42 (1.95)
4. (Un)pleasantness	-1.61 (1.29)	-1.78 (.89)	-1.68 (1.14)
5. PVAQ	40.88 (13.68)	34.67 (11.43)	38.39 13.06
6. EC	20.37 (3.01)	17.94 (3.96)	19.40 3.59
7. FS	21.07 (4.46)	19.22 (5.06)	20.33 4.74
8. PD	13.48 (5.62)	15.28 (4.08)	14.20 (5.09)

Note. Pain Vigilance and Awareness Questionnaire (PVAQ), Empathic concern (EC), Fantasy Scale (FS), Personal Distress (PD), Reaction times (RT).

Table 7

Pearson/Spearman correlations of all measures (overall analyses)

	2.	3.	4.	5.	6.	7.	8.
1. RT incongruent trials	.89**	-.14	.00	-.14	-.21	.19	-.37*
2. RT congruent trials	-	-.13	-.01	-.15	-.20	.18	-.44**
3. Intensity		-	-.68**	.21	.02	.15	.40**
4. (Un)pleasantness			-	-.22	.07	-.28	-.22
5. PVAQ				-	.22	.20	.16
6. EC					-	.38*	.21
7. FS						-	-.02
8. PD							-

Note. Pain Vigilance and Awareness Questionnaire (PVAQ), Empathic concern (EC), Fantasy Scale (FS), Personal Distress (PD), Reaction times (RT). * $p<0.05$; ** $p<0.01$

Vicarious pain errors

To investigate the impact of group (pain responder versus comparison group) upon the number of vicarious pain errors, the NB-model was again selected as best fitting count model ($\chi^2[1, n = 45] = 198.34$, $p < .001$; $V = -.55$, $p = .29$). First, we checked whether study (experiment 1 versus 2) had an impact upon number of vicarious pain errors. The relation between the number of vicarious pain errors and PVAQ ($p = .66$) and group ($p = .86$) was not dependent upon study (1 versus 2). Also the interaction between the number of vicarious pain errors and study x group ($p = .33$) was not significant. Only a marginal main effect of study was observed, suggesting a slightly higher prevalence of vicarious pain errors in the first study ($p = .06$). No interactions of study with any of the independent variables were found. To test whether pain responders make more vicarious pain errors compared to non-pain responders, group was added as a single predictor. The number of vicarious pain errors significantly raised with 282% (RR = 3.82, $p = .03$; [95% CI: .09, 2.54]) when participants reported vicarious pain in daily life (pain responder group) compared with the comparison group.

Additional analyses were run containing observer's characteristics such as PVAQ or subscales of the IRI as a second predictor in interaction with group to explore a possible moderating role. A significant interaction was observed between group and PVAQ ($p = .02$; [95% CI: -2.52, -.05]). The size of the RR (.96) demonstrated that the probability of making vicarious pain errors for the non-pain responders decreased by 4% for every 1-unit increase in hypervigilance for pain. For the pain responders, the probability of making vicarious pain errors decreased by 73% (RR = .27) for every 1-unit increase in hypervigilance for pain. The subscales of the IRI did not significantly interact with group ('fantasy scale', $p = .26$; 'empathic concern', $p = .68$; 'personal distress', $p = .90$).

Reaction times

A 2 (congruency: congruent versus incongruent) x 2 (group: pain responders versus comparison) x 2 (study: first versus second study) repeated measures ANOVA showed no main effect for group ($F(1,41) = 2.49$, $p = .12$) and for study ($F(1,41) = .30$, $p = .59$). Overall, participants were faster on congruent than on incongruent trials (*F*(1,41) = 39.60, $p < .001$). In contrast with expectations, no interaction was found between congruency and group (*F*(1,41) = .16, $p = .69$).

GENERAL DISCUSSION

Two experiments are reported, in which an experimental paradigm was used to assess the presence of vicarious pain experiences in healthy participants. Additionally, we explored the effects of some potential moderators proposed by Fitzgibbon et al. (2010b), i.e., dispositional empathy, hypervigilance to pain and also the tendency to experience the rubber hand illusion. In both studies, undergraduates were categorized in a pain responder group and a comparison group based upon reported vicarious pain experiences in daily life. They were presented a series of videos showing hands being pricked whilst receiving occasionally painful pricking sensations (electrocutaneous stimuli) themselves. In congruent trials, pricking stimuli and visual stimuli were applied to the same spatial location (e.g., right). In incongruent trials, pricking stimuli and visual stimuli were in the opposite spatial location (e.g., left and right). Participants were required to report as fast as possible where they felt a pricking sensation.

The main results can be readily summarized. In experiment 1, we found that the used paradigm was sensitive to measure vicarious pain experiences in healthy students. Findings indicated that participants who reported vicarious pain experiences in daily life made more vicarious pain errors during the experiment than participants of the comparison group. Furthermore, the probability of making vicarious pain errors decreased steeply for the pain responder group when they showed an increased level of hypervigilance for pain, whereas the probability of making vicarious pain errors increased for the comparison group when they showed an increased level of hypervigilance for pain. In experiment 2, however, findings of experiment 1 were not confirmed. No influence was found of the group to which participants belonged on the number of vicarious pain errors made during the experiment. Also no relationship was found between the level of hypervigilance for pain and the number of vicarious pain errors made. There was also no relationship between the number of vicarious pain errors and the rubber hand illusion experience. In order to explore the possible difference between both experiments, we opted to merge the data of both experiments. Results of these analysis showed that there was no difference in both experiments related to the findings. The overall results (i.e., of the merged data) were in line with findings of experiment 1 and indicated that (1) participants who reported vicarious pain experiences in daily life made more vicarious pain errors during the experiment than participants of the comparison group and (2) the probability of making vicarious pain errors decreased steeply for the pain responder group when they showed an increased level of hypervigilance for pain, while vicarious pain errors showed only a little decrease in the comparison group. For reasons of clarity, the discussion will mainly focus upon the combined findings.

First, our study reveals that undergraduates report vicarious pain experiences in daily life, albeit that the prevalence of pain responders was low. In experiment 1, the prevalence was 22.9%. In experiment 2, it was 6.61%. The difference in prevalence of self-reported vicarious pain experiences in daily life between both experiments is probably due to the use of a more stringent cut-off to categorize pain and non-pain responders compared to Experiment 1. Overall, the prevalence of vicarious pain found in the current study is low in comparison with the prevalence reported by Osborn and Derbyshire (2010), which was almost 30%. One reason for this difference may relate to the fact that the prevalence number in the present study was based upon self-report of vicarious pain experiences in daily life whereas the prevalence number reported by Osborn and Derbyshire (2010) was based upon report of participants who were shown images of people perceiving pain. It is worthwhile for future studies to combine both approaches and to recruit people based upon questions measuring vicarious pain in combination with showing participants video clips of painful situations to check whether they are feeling pain experiences. The variability in prevalence illustrates the need to have clear criteria to identify pain responders in future research.

Second, overall the experimental paradigm was successful in eliciting vicarious experiences of pain, in particular in those reporting vicarious pain experiences in daily life. The number of vicarious pain errors doubled in participants reporting vicarious pain in daily life (i.e., pain responder group) compared to the comparison group. However, it should be noted that the total number of vicarious pain errors was low, and only a few participants from the pain responders group accounted for the phenomenon. Future research may focus upon these few pain responders and investigate on which variables they differ from other participants. First, the low number of vicarious pain errors could be due to the fact that felt and seen stimuli may result in a different sensation. Indeed, it might be that the sensation experienced by the electrocutaneous stimulus differs too much from the sensation experienced when being confronted with images of a pricking sensation. Indeed, the more actual somatosensory sensations are alike to the vicarious experiences, the more vicarious errors may occur in our experimental paradigm. This may however only be achieved with vague somatosensory stimuli of low intensity. Interestingly, in the study of Osborn and Derbyshire (2010), the most frequent descriptor that was selected from the McGill Pain Questionnaire to describe vicarious pain was “tingling”. Therefore, it would be interesting for future research to use tingling stimuli of a low intensity instead of electrocutaneous stimuli to investigate vicarious experiences. In line with this, pain responders in the study of Osborn & Derbyshire (2010) rated the average vicarious pain across all images rather low on a visual analogue scale (*M* = 1.9, *SD* = 2.4) ranging from 0 (no pain) to 10 (most pain imaginable). The experience of vicarious pain was dependent upon the content of the picture. In our study, the intensity of the ES were not rated as highly painful, since intensity ratings were on average around 4.4 on a 10-point scale (0 = not intense and 10 = intense), and unpleasantness ratings were on average -1.6 (-5 “unpleasant”; +5 “pleasant”). Our aim was to provide somatosensory stimuli that were not too painful and which induced experiences that were alike to the shown pricks. If somatosensory stimuli would be experienced too intense, it would be very easy to distinguish vicarious experiences from administered ES. With more intense ES, our prediction would be that no vicarious errors would occur. We included video clips showing hands being pricked. These videos depict less intense pain compared to the images and movies used in the study of Osborn and Derbyshire (2010). Vicarious pain may be elicited more easily when very intense pain is observed. The fact that pain responders in this study already experience vicarious pain during the mere observation of a subtle injury such as a needle prick is therefore very informative and interesting.

We explored the (moderating) role of several individual difference variables such as dispositional empathy, hypervigilance for pain and the degree to which the rubber hand illusion was experienced upon vicarious pain. Current findings do not provide support for the moderating role of dispositional empathy. Although the pain responder group was more empathic concerned, this had no influence upon the occurrence of vicarious pain errors. It might however be that, although dispositional empathy may not play a role as underlying mechanism in normal subjects reporting vicarious pain experiences, it might have an impact in individuals with prior chronic pain or trauma such as amputees, where vicarious experiences of pain are often experienced as more intense (Giummarra & Bradshaw, 2008; Fitzgibbon, 2010a). Also the degree in which the rubber hand illusion was experienced was not different for both groups. It had also no explanatory role in the experience of vicarious pain errors. In line with the model provided by Fitzgibbon and colleagues (2010b), we also explored whether the occurrence of vicarious pain errors was influenced by the degree of hypervigilance for pain. According to the theory of Fitzgibbon (2010b), we expected pain hypervigilance to facilitate the production of vicarious pain errors as we expected pain responders to be overattentive to pain cues. As such, vicarious pain may be an exaggerating response to the anticipation of observed pain. Contrary to our expectations, more hypervigilance for pain was related to less vicarious pain errors in the group of pain responders, suggesting that hypervigilant participants were less misled by the visual stimuli. The same, albeit small, negative relation was found for the non-responder group. A possible explanation for this unexpected finding may relate to the fact that pain responders who are more focused upon the detection of somatic sensations experience less vicarious pain experiences. It is however unclear why hypervigilance for pain has a moderating role in making vicarious pain errors and how exactly this observer's characteristic prevents pain responders to make vicarious pain errors.

Taken all the literature together, there is preliminary evidence for vicarious pain experiences in response to observing pain in others (Fitzgibbon et al., 2010b). Until now there is little empirical investigation into this phenomenon. To date, the preliminary evidence regarding vicarious pain is primarily based upon anecdotal reports, and research in clinical populations with prior pain or trauma. Only little research is available on the conditions in which vicarious pain occurs and on the underlying mechanisms. Especially the role of empathy or processes underlying empathy have predominantly been investigated (e.g. Fitzgibbon et al., 2012a; 2012b).

This study is one of the first to measure whether observers can feel pain themselves by observing pain in another individual measured by means of an experimental design. Insight into the conditions wherein pain is elicited by mere observation is of major significance for both the theory about pain as a biopsychosocial phenomenon and clinical practice. Theoretically, insight into the conditions and processes of vicarious pain is expected to fundamentally change the view about how pain is processed in the brain, demonstrating the important role of psychosocial variables (e.g., empathy, hypervigilance for pain), not only in the modulation (Van Damme, et al., 2010) but also as cause of pain experiences in clinical and non-clinical populations. Further research is needed to investigate the underlying mechanisms of vicarious pain in a general population and in chronic pain patients. Also research is needed about the quality and intensity of the reported vicarious pain experiences and the difference between the reported vicarious experiences and the visual triggers (i.e., pain in another). Besides the neuro-imaging and behavioral research, it would be interesting to explore whether vicarious pain experiences are also reflected in different patterns regarding psychophysiological measures (e.g., heart rate, skin conductance). Other possibilities are to show more intense painful images to enhance chances for vicarious pain errors to occur. Other studies have suggested that empathic responses are substantially influenced by whether or not one attends to the feelings of the target through the explicit imagination of the target's feelings (Fan, & Han, 2008; Jackson et al., 2006; Preston et al., 2007). Future research may therefore consider using not only real life images and movies but also specific instructions to manipulate participants' empathic responses to investigate whether this impacts the occurrence of vicarious experiences.

A number of limitations deserve further consideration, each of which point to directions for future research. First, only few people reported vicarious pain experiences in daily life, resulting in a small sample size in these experiments. We tried to overcome this by additional analyses of the pooled data of the two experiments. Although sample sizes were small, the amount of pain responders who took part in the experiments were comparable to other studies who included participants reporting vicarious bodily sensations (Banissy et Ward, 2007; Osborn & Derbyshire, 2010). Second, for the second experiment, different cut-offs were used for initial screening and during the lab experiment to classify participants in the pain responder group and the comparison group to preserve a minimum of pain responders to analyze. This implies that participants scored the different questions not exactly the same over time. As the initial screening is anonymous at our university, data from the initial screening is not linked to specific individuals, which makes it impossible to compare both ratings in each individual. Future research is needed to investigate the reliability and stability of this phenomenon across time.

Conclusion

This new behavioral paradigm allowed measuring vicarious pain experiences in undergraduates. Vicarious pain experiences were found to be a rather rare phenomenon, elicited in only a subsample of participants reporting vicarious pain experiences in daily life. This behavioral paradigm is promising to investigate other underlying mechanisms (i.e. prior pain) of vicarious experiences of pain.

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CHAPTER 2

Fibromyalgia patients and controls are equally accurate in detecting tactile stimuli while observing another in pain: an experimental study[2]

ABSTRACT

Objective: This study investigated the effects of observing pain in others upon vicarious somatosensory experiences and the detection of somatosensory stimuli in both fibromyalgia patients (FM) and controls. The putative modulatory role of dispositional empathy, hypervigilance to pain, and central sensitization was examined.

Methods: FM patients (N=39) and controls (N=38) saw videos depicting pain-related (hands being pricked) and non-pain related scenes, whilst occasionally experiencing vibrotactile stimuli themselves on the left, right, or both hands. Participants reported the location at which they felt a somatosensory stimulus. Tactile and visual scenes were presented in the same spatial location (congruent, e.g., left-left) or from opposite locations (incongruent, e.g., left-right). We calculated the proportion of correct responses, vicarious somatosensory experiences (i.e., trials on which an illusory somatosensory experience was reported while observing pain-related scenes), and neglect errors (i.e., only reporting the site congruent to the visual pain-related information when both hands had been stimulated).

Results: Observing another in pain resulted in an equal numbers of vicarious somatosensory experiences in both groups and facilitated the detection of tactile stimuli, especially during spatially congruent trials. Counter to our expectations, this facilitation was not moderated by group. FM patients made fewer neglect errors. Hypervigilance for pain, dispositional empathy, and central sensitization did not exert a modulatory role.

Based on: Vandenbroucke, S., Crombez, G., Harrar, V., Devulder, J., Spence, C., & Goubert, L. (2014a). Fibromyalgia patients and controls are equally accurate in detecting tactile stimuli while observing another in pain: an experimental study in fibromyalgia patients and controls. *Attention, Perception & Psychology, 76,* 2548-2559. doi:10.3758/s13414-014-0729-9

Conclusion: Observing pain facilitates the detection of tactile stimuli in FM Patients and controls. Overall, a low incidence of vicarious experiences was Observed. Further research is needed to understand the role of attentional body focus in the elicitation of vicarious experiences.

INTRODUCTION

Our senses do not operate independently of one another (Spence & Driver, 2004). For example, research has demonstrated that presenting visual information (e.g., a flash of light) may give rise to illusory experiences of touch (Lloyd, Mason, Brown, & Poliakoff, 2008; McKenzie, Poliakoff, Brown, & Lloyd, 2010). In particular, those individuals presenting with large number of medically unexplained symptoms have been found to experience illusory tactile experiences (see Katzer, Oberfeld, Hiller, & Witthöft, 2011). Moreover, neuroimaging and neurophysiological studies have demonstrated that observing pain in others may activate brain areas similar to those activated when observers experience pain themselves (Jackson, Brunet, Meltzoff, & Decety, 2006; Osborn & Derbyshire, 2010). For example, those who experience vicarious pain (that is, an actual somatosensory experience in response to the observation of pain) show a hyperactivity of motor mirror neurons (enhanced motor-evoked potentials) to the observation of a needle penetrating the hand, relative to the needle having not yet penetrated the hand, as compared with controls (Fitzgibbon et al., 2012a). These observations are intriguing as they indicate that tactile or nociceptive input may not be necessary to experience touch or pain. Little research is yet available on the occurrence of vicarious somatosensory experiences and the mechanisms and conditions affecting this phenomenon (but see Fitzgibbon et al., 2010; Fitzgibbon et al., 2012b; Vandenbroucke et al., 2013). Fitzgibbon and colleagues (2010; 2012b) have put forward a neurobiological model to further our understanding of vicarious pain. They proposed several mechanisms to explain vicarious pain, such as hyperactivity of the somatosensory mirror systems, empathy or processes underlying empathy, central sensitization, hypervigilance to pain, and a history of chronic pain or trauma. Vision may not only induce vicarious somatosensory experiences, but may also influence the detection of tactile stimuli. For example, it has been demonstrated that simultaneously presenting a brief flash and a threshold-level tactile stimulus increases participants' ability to correctly perceive the tactile stimulus (i.e., increased number of 'hits'; Lloyd et al., 2008). From this perspective, the modulation of somatosensory experiences may represent a less extreme variant of "illusory" experiences when observing another in pain. It has been argued that illusory experiences are akin to the kinds of misperceptions reported by patients with medically unexplained symptoms, and that similar processes are likely to be operating in each case (Lloyd et al., 2008). In the present study, a variant of the crossmodal congruency task was used to investigate differences in vicarious somatosensory experiences between fibromyalgia patients (FM) and controls. FM patients were chosen as the clinical group because these patients suffer from medically unexplained symptoms, characterized by chronic widespread pain and central sensitization (see Staud et al., 2008, 2009), which have all been suggested as vulnerability factors in the production of vicarious and illusory sensations (see Fitzgibbon et al., 2010; 2012b; Katzer et al., 2011). Both groups were presented two categories of videos in which pain-related situations (hands being pricked) or non-pain related situations (e.g., a sponge being pricked) were shown. During this observation, the participants occasionally received vibrotactile stimuli themselves in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual stimuli. The participants were instructed to report the spatial location of the administered somatosensory stimuli as rapidly as possible. We examined whether the observation of pain-related scenes of a hand being pricked facilitated the detection of low-intensity vibrotactile stimuli compared to non-painful scenes. In contrary to our previous study (Vandenbroucke et al., 2013), instead of painful stimuli, we implemented non-painful vibrotactile stimuli near the perceptual threshold. This was done because Osborn and Derbyshire (2010) reported that most patients selected 'tingling' to describe their somatosensory vicarious experiences induced by observing pain. First, we hypothesized that the FM group would report more bodily illusions in response to the observation of pain (vicarious somatosensory experiences) than controls, as they have some of the suggested vulnerability factors to experience vicarious experiences, such as chronic pain, hypervigilance for pain, and central sensitization (Fitzgibbon et al., 2010, 2012b). We also explored whether there were any differences in neglect errors between FM patients and controls during the observation of pain-related videos (i.e. only reporting the site congruent to the visual information when both hands were stimulated). Second, we expected that the observation of pain-related visual scenes would facilitate the detection of vibrotactile stimuli as compared with non-pain related scenes.

Furthermore, we also expected to see a crossmodal congruency effect (CCE, that is, improved tactile acuity in those conditions in which the visual and tactile stimuli were congruent). We hypothesized that this CCE effect would be dependent on the type of visual information (pain-related and non-pain related). As pain-related visual stimuli may facilitate the detection of somatosensory stimuli, a higher CCE was expected when pain-related visual stimuli were shown, as compared to non-pain related visual stimuli. For exploratory reasons, the effects and modulating role of dispositional empathy, hypervigilance to pain, and central sensitization upon vicarious somatosensory experiences and general detectability were also examined.

METHOD

Participants

Participants consisted of 39 patients with fibromyalgia (FM; 37 females; mean age = 39.7 years, SD = 11.2, range 19 - 64 years) and a control group of 38 participants matched for age and sex (36 females; mean age = 38.3 years; *SD* = 12.3; range 21 - 60 years). Fibromyalgia patients were recruited through the Multidisciplinary Pain Clinic of Ghent University Hospital. Inclusion criteria included a diagnosis of fibromyalgia (Wolfe et al., 2010), age between 18 and 65 years, and Dutch-speaking. Potential participants were informed about the possibility to participate by means of a poster in the waiting room, information given by their physician, and information letters. When they agreed to participate, they received a phone call from the researcher providing details about the study. The fibromyalgia group reported pain complaints for, on average, 10.01 years (*SD* = 9.35 years). The mean score on the Widespread Pain Index (WPI) in the FM group was 12.15 (*SD*: 2.72, range: 7 - 18); the mean score on the Severity Symptom scale (SS) scale was 9.64, (*SD*: 1.50, range: 6 - 12). Pain was reported on an average of 174 days *(SD* = 21) over the last 6 months; 46% reported a current poor state of health. All except one were Caucasian. Seventy-four percent were in a relationship, 64% had children and 69% of them were not working because of the pain and received a monthly allowance. Pain medication was used by 36.4% of the participants on the day of testing, especially in the FM group (69.2% of all FM patients). Twenty-six percent had a higher education (beyond the age of 18 years). On average, the FM group reported being unable to perform daily activities (work, household) on 101 days (*SD* = 65) over the last 6 months. The control participants were recruited by means of advertisements in the local newspapers. Inclusion criteria for the control participants were the absence of chronic pain complaints or neurological or psychiatric conditions, Dutch-speaking, and aged between 18 and 65 years. Ninety-seven percent of the participants in the control group (*n* = 38; 36 females; mean age = 38.3 years, range 21 - 60 years) reported a good, very good, or excellent current state of health. Sixty-three percent of the control participants had a relationship and 45% had children. The majority (82%) had had higher education; 18% were unemployed. At the end of the experiment, the participants received 40 euro as reimbursement for their expenses. The experiment lasted for approximately 1.5 hours and was part of a larger protocol that had been approved by the Ethical Committee of the Ghent University Hospital.

Apparatus and stimuli

Visual stimuli

The visual stimuli consisted of two categories of videos (pain-related versus non-pain related), each with a duration of 3000ms. The pain-related category included two scenes depicting a left and right hand, with one of the two hands being pricked with a syringe or safety pin (2000ms after the onset of the video). The non-pain related category also consisted of 2 scenes. In one scene, a left and right hand was presented in which one of these hands was approached by a hand that was not holding an object (though executing the same action as in the pain-related videos). In the second scene, one of the two hands was replaced by a sponge that was pricked with a syringe. In this way, a human feature was always present in the videos (e.g. a left or right hand). The penetration took place after

2000ms as in the first category. The different scenes and the location of the sponge and movement were counterbalanced across videos. The location of the penetration (left versus right hand) and type of category were counterbalanced across videos. Videos were presented by INQUISIT Millisecond software ((http://www.millisecond.com)) on a Dell computer with a 19-inch CRT-monitor.

Somatosensory stimuli

Vibrotactile stimuli (50 Hz, 50 ms) were delivered by means of two resonant-type tactors (C-2 tactor, Engineering Acoustics, Inc.) encased in a housing that was 3.05 cm in diameter and 0.79 cm high, with a skin contactor that was 0.76 cm in diameter. The somatosensory stimuli were delivered on the skin between the thumb and index finger on the back of the hand. All stimulus characteristics (amplitude, duration, and frequency) were controlled through a self-developed software program that was used to control the tactors. For each participant, the threshold intensity level was individually determined prior to the experiment (see Procedure-Preparation phase). Both hands were placed on the table in front of the screen and covered with a cardbord box so that they were not visible. Four different series of 20 stimuli/trials (two series for each hand) were randomly administered (80 stimuli/trials in total). First, a visual stimulus (an “X” in the middle of the screen, 1000ms duration) was presented combined with a somatosensory stimulus on the left or right hand. The participants were instructed to report whether they felt a somatosensory stimulus (“yes” or “no”). Responses were entered by the experimenter who pressed the corresponding response button on a keyboard. Each series started with a stimulus of 0.068W. The intensity was decreased by 0.0002W whenever the participants reported feeling the stimulus, and increased by 0.0002W when no sensation was reported. After 80 trials, this resulted in a threshold intensity for each hand, which was based upon the mean intensity of the last stimuli of the two series for that particular hand. From these threshold intensities (threshold left hand: *M* = 0.06W, *SD* = 0.006W, range: 0.004W - 0.21W; threshold right hand: *M* = 0.05W, *SD* = 0.008W, range: 0.006W - 0.17W), 1/8 was subtracted (termed subthreshold) and added to the threshold (termed above threshold), which resulted in four different intensities (sub and above threshold, one for each hand; see Press et al., 2004). Threshold intensities did not differ between groups (left hand: *t*(75) = -.25, *p* = .80; right hand: *t*(75) = -.25, *p* = .80).

Central sensitization: temporal summation

Central sensitization was assessed using a temporal summation (TS) procedure (Staud et al., 2008). TS refers to an increased pain experience evoked by the repeated presentation of stimuli of the same intensity. Staud et al. (2009) has provided support for the presence of an alteration of central pain sensitivity in FM patients. The probe temperature was adjusted to each individual's heat pain sensitivity, which was determined during a preliminary phase (Staud et al., 2008) and was administered by means of a 'Contact Heat Evoked Potential Stimulator" (CHEPS) (Medoc Advanced Medical Systems, Ramat Yishai, Israel). During this preliminary phase of the study, a train of 6 stimuli at 0.33Hz were administered starting with peak pulse temperatures of 47°C. After each pulse train, the participants reported the intensity of pain experienced between the first and last pulse by means of a 100-point Numeric Rating Scale (NRS; 0 = no sensation; 100 = intolerable pain). This intensity was subsequently raised until the participants achieved NRS ratings of 45 ± 10 after 6 pulses. The participants were informed that the intensity could increase, decrease, or stay the same within each train of pulses. The test phase procedure consisted of a train of 6 heat pulses to the palm of the right hand in which the probe temperature was adjusted to each individual's heat pain sensitivity determined during the preliminary phase. Each train started with a 40s baseline followed by 6 pulses. The temperature of the thermal probe increased from baseline to peak temperature by 8°C/s, before returning to baseline at a rate of 8°C/s. The duration of each heat pulse was always 3s (1.5s rise time; 1.5s return time; 0.33 Hz). The TS test phase procedure was repeated six times.

Self report measures

The scale to rate the intensity of the different pulses during the acquisition of temporal summation ranged from 0 to 100 in increments of 5 (Vierck, Cannon, Fry, Maixner, & Whitsel, 1997) with verbal descriptors at intervals of 10: 10, warm; 20, a barely painful sensation; 30, very weak pain; 40, weak pain; 50, moderate pain; 60, slightly strong pain; 70, strong pain; 80, very strong pain; 90;

nearly intolerable pain; and 100, intolerable pain.

Vigilance to pain was assessed by the Dutch version of the Pain Vigilance and Awareness Questionnaire (PVAQ; McCracken, 1997, Roelofs, Peters, Muris, & Vlaeyen, 2002). This questionnaire consists of 16 items assessing awareness, consciousness and vigilance to pain on a six-point scale (0 = never; 5 = always). Higher scores on the PVAQ are indicative of greater pain-related vigilance and awareness. The questionnaire can be used in both clinical (McCracken, 1997; Roelofs, Peters, McCracken, & Vlaeyen, 2003) and non-clinical (McWilliams & Asmundson, 2001; Roelofs et al., 2002) samples. The Dutch version of the PVAQ is reliable and valid (Roelofs et al., 2002, 2003). Cronbach's alpha for the present study was 0.87.

Empathic disposition was assessed by means of the Dutch version of the Interpersonal Reactivity Index (IRI; Davis, 1983; De Corte et al., 2007). The questionnaire contains 28 items and consists of 4 subscales: Perspective Taking (i.e., cognitively taking the perspective of another, e.g., "I sometimes try to understand my friends better by imagining how things look from their perspective."), Fantasy (i.e., emotional identification with characters in books, movies etc., e.g., "When I watch a good movie, I can very easily put myself in the place of a leading character."), Empathic Concern (i.e., feeling emotional concern for others, e.g., "I am often quite touched by things that I see happen.") and Personal Distress (i.e., negative feelings in response to the distress of others, e.g., "When I see someone who badly needs help in an emergency, I go to pieces."). Each item is answered on a scale ranging from 1 ('does not describe me very well') to 5 ('describes me very well'). This questionnaire is reliable and valid (Davis et al., 1893; De Corte et al., 2007). Cronbach's alpha's in the current study were 0.84 (fantasy scale), 0.68 (empathic concern), 0.72 (personal distress), and 0.32 (perspective taking). The latter subscale was omitted from the analyses because of the low reliability of the scores.

Anxiety and depression was measured with the Dutch version of the Hospital Anxiety and Depression Scale (HADS; Spinhoven et al., 1997, Zigmond & Snaith, 1983) consisting of 14 items, of which 7 screen for symptoms of anxiety and 7 for symptoms of depression. Items are rated on a 4-point scale representing the degree of distress experienced during the previous week. Higher scores indicate higher feelings of anxiety and depression. In the present study Cronbach's alpha was 0.93.

Vicarious pain sensations in daily life were measured by means of four items adapted from Banissy et al. (2009). Participants were asked to indicate on an eleven point scale (0-10; totally disagree – totally agree) the extent to which they agreed with the questions: "Do you feel pain in your own body when you see someone accidently bump into the corner of the table?", "Do you have the feeling that you are experiencing pain when you observe another person in pain?", "Do you feel bodily pain when you observe another person in pain?", "Do you feel a physical sensation (e.g., tingling, stabbing) when you observe another person in pain" (see Vandenbroucke et al., 2013). In the present study Cronbach's alpha was 0.87.

Procedure

Upon arrival, the procedure started with signing the informed consent form. Subsequently, the Fibromyalgia diagnostic criteria (Wolfe et al., 2010) were checked for each participant. All FM patients fulfilled the Fibromyalgia diagnostic criteria (Wolfe et al., 2010). Thereafter, the participants were seated in front of a table, about 60 cm away from the computer screen.

Behavioral paradigm

Preparation phase. First, the detection threshold was determined for each hand separately. The participants were informed that during the experiment they would feel subtle stimuli, varying in intensity and length, on their left, right, or both hands. Participants were informed that different videos would be presented which they needed to watch attentively. The hands of the participants were placed on the table and covered by a cardboard box placed on the table in front of the screen. The participants were told that the intensity of the somatosensory stimuli could vary across their hands and that there would also be trials without any stimulus. In reality, only two fixed predetermined intensities with a fixed duration were applied (threshold intensity ± 1/8) for each hand.

Experiment phase. Each trial began with a fixation cross (1000 ms duration) presented in the middle of the computer screen. Next, one of the scenes was presented. In 75% of the trials, a tactile stimulus was delivered 2450ms after video onset to either the left hand, the right hand, or to both hands of the participant. In line with Banissy and Ward (2007), the somatosensory stimulus was administered with a delay (in this study 450ms after the visual image of the needle penetrating). This resulted in the following trial types: congruent trials, incongruent trials, and trials in which no somatosensory stimuli were administered or in which both of the participant's hands received somatosensory stimuli. In congruent trials, the somatosensory and visual stimuli were presented from the same spatial location (e.g., on the right). In the incongruent trials, the somatosensory and visual stimuli were presented from opposite locations (e.g., one on the left and the other on the right). The experiment started with 8 practice trials.

The actual experimental phase consisted of three blocks of 64 trials, resulting in a total of 192 trials. There were 48 congruent trials, 48 incongruent trials, 48 trials without sensory stimuli and 48 trials with somatosensory stimuli presented to both hands. The order of the trial types was randomized within each block and the intensity of the somatosensory stimuli (under and above threshold) were equally distributed within and across each block. An overview of all trial types is presented in Table 1. During each trial, the participants reported whether a physical experience was felt by reporting as rapidly as possible 'YES' and to discriminate the spatial location of the somatosensory stimuli by reporting "left", "right" or "both" (see Figure 1). After the video had ended and 2000 ms elapsed, the word 'next' was presented on the screen. Then, the experimenter coded the response by pressing the corresponding response button (left, right, both or no response). In this manner, the time to respond was equal for every participant. The experiment took approximately 20 min.

Post-experiment phase. After the experiment, participants filled out self-report scales measuring hypervigilance for pain (PVAQ) and empathic disposition (IRI). After a short break, the participants continued with the temporal summation measurement.

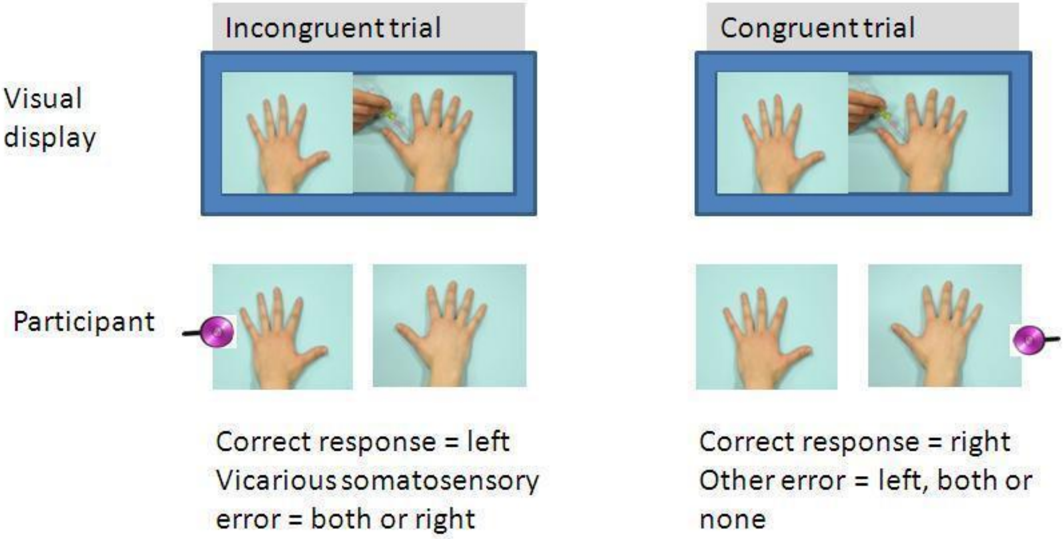

Figure 1. Example of a possible trial

Table 1

Detection accuracy for both groups and all video types

	INCONGRUENT				CONGRUENT				NO TACTILE STIMULATION				BOTH HANDS STIMULATED			
Reported site	Correct site	Opposite site (=visual site)	Both hands	No hands	Correct site	Opposite site to visual and tactile	Both hands	No hands	Site congruent to visual	Opposite site to visual	Both hands	Correct No hands	Visual site	Opposite site to visual	Correct Both hands	No hands
Visual pain/ Control group	41.45%	1.43% *Vicarious error*	1.32% *Vicarious error*	55.81%	53.62%	.33%	.55%	45.50%	2.52% *Vicarious error*	.66%	.22%	96.60%	22.59% *Neglect error*	8.77%	34.65%	33.99%
Visual pain/ FM group	40.02%	1.21% *Vicarious error*	2.08% *Vicarious error*	56.69%	49.12%	.44%	2.30%	48.14%	1.32% *Vicarious error*	.99%	.44%	97.26%	15.79% *Neglect error*	8.99%	40.02%	35.20%
Visual control/ Control group	36.62%	.33%	.66%	62.39%	38.60%	.11%	.44%	60.86%	.88%	.55%	0%	98.58%	12.28% *Neglect error*	12.50%	28.84%	46.38%
Visual control/ FM group	33.33%	.22%	.11%	66.34%	35.42%	.33%	1.21%	63.05%	.66%	.66%	.11%	98.58%	11.18% *Neglect error*	11.51%	28.95%	48.36%

Statistical analysis

The number of false alarms was calculated from the incongruent trials and from the trials without any somatosensory stimuli when erroneously a somatosensory stimulus was reported in the same spatial location as the visual stimulus. These false alarms were labeled ‘vicarious somatosensory experiences’ when the visual stimulus contained pain-related information. First, we tested whether the number of false alarms was dependent upon the type of video. As all participants observed both categories of videos and the number of false alarms during both categories of movies were not normally distributed, non-parametric analyses for related samples (Wilcoxon) were used. As we were particularly interested in those false alarms during pain-related videos, the number of vicarious somatosensory experiences was further selected as the dependent variable. To test whether group predicted the number of vicarious somatosensory experiences, count regression models were applied. The use of linear models was not appropriate due to the fact that the frequency of responses had a skewed distribution that violated the normality assumption (Vives, Losilla, & Rodrigo, 2006). Poisson regression is the basic model to analyze count data, but the variance of counts is often larger than the mean (overdispersion). The Negative Binomial (NB) regression, a Poisson regression with an overdispersion, may therefore fit the data better (e.g., Gardner, Mulvey, & Shaw, 1995). As count data may additionally exhibit a lot of zero counts, zero-inflated extensions of both models, called Zero-Inflated Poisson (ZIP) and Zero-Inflated NB (ZINB) models have been developed (see Karazsia & Van Dulmen, 2010; Loeys et al., 2012). Deviance tests and the Vuong test were used to select the best fitting count distribution for the dependent variable. After the best fitting count model was chosen, a model with ‘group’ as predictor was added. In a further exploration of the data, central sensitization, hypervigilance for pain, and dispositional empathy were added as a second predictor in separate models to test whether they had a modulating role. Dummy coding was used for the categorical variables and standardized z-scores for the continuous predictors. Regression coefficients were exponentiated (eB) and called Rate Ratios (RRs). In percentages—100 x (eB - 1)—RRs reflect the percentage decrease (RR<1) or increase (RR>1) in the expected frequency of vicarious somatosensory experiences for each 1-unit increase in the independent variable.

Second, to investigate whether the observation of pain-related and non-pain related scenes modulated the detection of tactile stimuli, the proportion of correct responses (left versus right) for congruent and incongruent trials for each category of visual information was calculated (pain-related versus non-pain related). A 2 (video category: pain-related versus non-pain related) x 2 (congruency: congruent versus incongruent) repeated measures ANOVA was performed, with congruency and type of video entered as a within-participant variables and 'group' as a between-subject variable. In a further exploration of the data, central sensitization, hypervigilance for pain, and dispositional empathy were added as a covariate in separate models to test whether they had a modulating role.

The number of neglect errors was also calculated based upon those trials in which both hands were stimulated, defined as reporting *only* the site congruent to the visual information and missing the fact that there had been two tactile stimuli, one on each hand. Non-parametric analyses for related samples (Wilcoxon) were used to test whether the number of neglect errors was dependent upon the type of video. Count regression models were applied in which the dependent variable was the number of neglect errors during pain-related visual information. After the best fitting count model was chosen, a model with 'group' as predictor was added. In a further exploration of the data, central sensitization, hypervigilance for pain, and dispositional empathy were added as a second predictor in separate models to test whether they had a modulating role. R (version 2.15.1) was used to fit the count models. Repeated measures were conducted with an alpha < 0.05, using SPSS statistical software, version 21.0 for Windows.

RESULTS

Descriptives

Mean scores, standard deviations, and correlations are presented in Tables 2 and 3. Because the variables vicarious somatosensory experiences, vicarious pain during daily life, neglect errors, empathic concern, and temporal summation (difference in reported intensity between first and last stimulus) did not have a normal distribution (Kolmogorov-Smirnoff, $p < .05$), Spearman correlations were computed for these particular variables. A significant difference was found between FM patients and controls in fantasy scale scores (*t*(75) = 3.49, *p* = .001), PVAQ (*t*(75) = -4.27, *p* < .001), and HADS (*t*(75) = -8.99, *p* < .001), indicating that FM patients were more hypervigilant for pain, obtained lower scores on the fantasy scale and were more anxious and felt more depressed compared with control participants. Threshold intensities for the left hand (*t*(75) = -.25, *p* = .80) and right hand (*t*(75) = -.25, *p* = .80) were similar for both groups. The control group reported significantly more vicarious pain experiences during daily life than the FM group (Mann-Whitney, p = .03). Regarding temporal summation, no differences in perceived intensity of the thermal stimuli were found across both groups (*t*(75) = -1,29, *p* = .20). The average reported intensity of the first stimulus (*M* = 33.86; *SD* = 18.74) and last stimulus (*M* = 39.89; *SD* = 17.84) over 6 trains was calculated. The average of the reported intensity of the first stimulus was not normally distributed (Kolmogorov-Smirnov, *p* < .05). Therefore, a log10 transformation was performed for the reported intensity of first and last stimuli in the analysis. A repeated measures ANOVA was performed including a within-participant variable stimulus (first versus last) and between-participant variable group (FM versus control). The reported intensity of the last stimulus was significant larger compared with the first (*F*(1,75) = 28,94, *p* < .001). No group x stimulus interaction was observed (*F*(1,75) = 2.4, *p* = .13). In 2.5% of a total of 3648 trials, vicarious somatosensory experiences were reported (90 vicarious somatosensory experiences from a total of 3648 trials). Of all vicarious somatosensory experiences, 46.7% occurred in the FM group (*n* = 42) and 53.3% in the control group (*n* = 48). In 19.2% of the trials in which both hands were stimulated during the observation of pain-related stimuli, neglect errors were made (350 from a total of 1824). Of all neglect errors, 41.1% occurred in the FM group (*n* = 144) and 58.9% in the control group (*n* = 206). Data of 1 FM participant were excluded from the analyses with regard to the crossmodal congruency task, as data on this task were missing.

Table 2

Pearson/Spearman correlations of all measures

	2.	3.	4.	5.	6.	7.	8.	9.
1. Vicarious somatosensory errors	.32**	-.03	-.08	.08	.10	-.00	-.02	.09
2. Neglect errors (pain-related videos)	-	-.03	-.05	.16	-.01	-.16	-.29*	-.01
3. Hypervigilance (PVAQ)		-	-.02	-.30**	-.04	.06	.40**	-.01
4. Empathic concern			-	.22	.16	-.06	.07	-.01
5. Fantasy scale				-	.14	-.43**	-.33**	.17
6. Personal distress					-	.00	.21	.12
7. Temporal summation, (intensity last-first stimuli)						-	.04	-.11
8. Hospital and Anxiety Scale (HADS)							-	.09
9. Vicarious pain experiences during daily life								-

Note. Pain Vigilance and Awareness Questionnaire (PVAQ). * p<0.05; **p<0.01

Table 3

Mean scores and standard deviations of all measures

	M (SD)	M(SD)	M(SD)
	FM group	comparison group	total group
1. Vicarious somatosensory errors	1.11 (1.67)	1.26 (2.30)	1.18 (1.99)
2. Neglect errors (pain-related videos)	3.79 (2.73)	5.42 (2.85)	4.61 (2.89)
3. Hypervigilance (PVAQ)	41.98 (10.07)	30.12 (14.04)	36.12 (13.50)
4. Empathic concern	20.43 (4.27)	19.95 (4.54)	20.19 (4.38)
5. Fantasy scale	12.46 (5.96)	17.35 (6.32)	14.87 (6.58)
6. Personal distress	11.89 (5.86)	11.32 4.34	11.61 (5.14)
7. Temporal summation, (intensity last-first stimuli)	7.57 (11.18)	6.46 (6.40)	6.04 (9.22)
8. Hospital Anxiety and Depression Scale (HADS)	18.70 (7.13)	6.01 (5.03)	12.44 (8.86)
9. Vicarious pain experiences during daily life	3.21 (4.86)	6.14 (8.33)	4.63 (6.89)

Note. Pain Vigilance and Awareness Questionnaire (PVAQ).

Vicarious somatosensory experiences

Participants reported significantly more false alarms when scenes from the pain-related category were shown, as compared to the non-pain related category (Wilcoxon, $p < .001$). This indicates that the type of visual information (pain-related versus non-pain related) is important as participants erroneously reported more somatosensory stimuli in the same spatial location as the visual stimulus when it contained pain-related information. To test the influence of group on the number of vicarious somatosensory experiences, the NB model was found to be the best fitting count model ($\chi^2[1, N = 77] = 54.38$, $p < .001$; V = -.79, $p = .21$). In a first step, group was added as a predictor. In contrary to our hypothesis, the results revealed that the number of vicarious somatosensory experiences was not dependent upon group ($p = .72$). In order to explore the role of individual differences in PVAQ and the IRI, several additional models were run with PVAQ or IRI as a second predictor and in interaction with group to explore its modulating role. No interactions were found between group and EC ($p = .86$), FS ($p = .41$), PD ($p = .93$), and temporal summation ($p = .72$). A marginally significant interaction was found between group and PVAQ ($p = .052$). For FM patients, the probability of making vicarious somatosensory errors decreased by 57% (RR = .43) for every 1-unit increase in hypervigilance for pain. For the control group, the probability of making vicarious somatosensory errors increased by 7% (RR = 1.07) for every 1-unit increase in hypervigilance for pain. No main effect of hypervigilance for pain was found ($p = .76$).

Detection accuracy

In line with our hypotheses, a 2 (video: pain-related versus non-pain related) x 2 (congruency: congruent versus incongruent) repeated measures ANOVA with the between-participant variable ‘group’ (FM versus control) showed a main effect for video ($F(1,74) = 73.82$, $p < .001$, Cohen’s d = .46, [95% CI: .35, .57]). In general, pain-related videos resulted in better detection of tactile stimulation compared with non-pain related videos both in congruent trials ($t(75) = 8.44$, $p < .001$, Cohen’s d = .65, [95% CI: .48, .82]) as in incongruent trials ($t(75) = 4.10$, $p < .001$, Cohen’s d = .26, [95% CI: .14, .37]). Also, a main effect of congruency was found (F(1,74) = 29.30, p < .001, Cohen’s d = .27, [95% CI: .16, .38]). An interaction occurred between congruency and video: the CCE depended on the type of video presented (*F*(1,74) = 17.08, *p* < .001, Cohen's d = .59, [95% CI: .26, .91]) (Figure 2). A paired sample t-test showed that the CCE was only significant for the pain-related videos (*t*(75) = -6.39, *p* < .001, Cohen's d = .45, [95% CI: .30, .61]), indicating that the increased detection accuracy in congruent trials compared with incongruent trials occurred only when pain-related videos were shown. The CCE was not significant for the non-pain related videos (*t*(75) = -1.4, *p* = .17). No main effect occurred for group (F(1,74) = .42, *p* = .52): Fibromyalgia patients were not more or less sensitive to the sensory stimuli. No interaction was found between group and video (F(1,74) = .01, *p* = .91), between group and congruency (*F*(1,74) = .40, *p* = .53), or between group, video and congruency (*F*(1,74) = .58, *p* = .45). Centered PVAQ and IRI subscales were entered separately as covariates. No main effects were found for PVAQ, *F*(1,73) = .18, *p* = .68, fantasy scale, *F*(1,73) = 2.67, *p* = .11, personal distress, *F*(1,73) = .44, *p* = .51, empathic concern, *F*(1,73) = .90, *p* = .35. Next, the centered difference between the first and the last intensity score (temporal summation) was added as a covariate in the above-described analyses. No main effect of temporal summation upon the proportion of correct responses was found (*F*(1,73) = .54, *p* = .46).

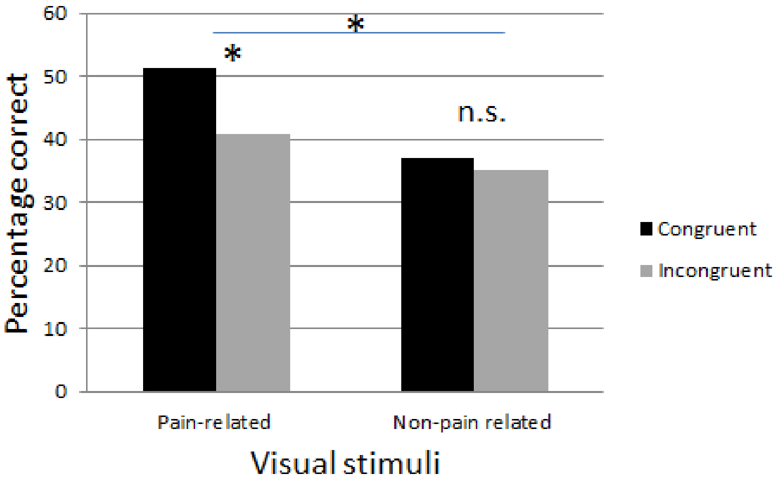

Figure 2. *The relationship between congruency and video*

Neglect errors

Trials in which both hands were stimulated, with participants only reporting sensory experiences on the side congruent with the visual stimulus, provide additional information concerning somatosensory modulation. When both hands were stimulated, the participants tended to neglect the side that was incongruent with the visual stimulus more when scenes of the pain-related category were shown, as compared to the non-pain related category (Wilcoxon, $p < .001$); i.e., they reported significantly more often the side that was congruent with the visual stimulus when a pain-related situation was depicted compared with a non-pain related visual situation. Next, the impact of group (FM versus control) was examined. The NB model was found to be the best fitting count model (χ^2[1, N = 77] = 19.35, $p < .001$; V = .24, $p = .40$). In a first step, group was added as a predictor. Results showed that the number of neglect errors during the observation of pain-related stimuli was dependent upon group ($p = .02$, RR = .70). Noteworthy here is the fact that FM patients made 30% *less* neglect errors than the control group. In order to explore the role of individual differences in PVAQ, IRI, and central sensitization, several additional models were run with a second predictor and testing the interaction with group to explore its modulating role. No significant interactions were found with PVAQ ($p = .64$), EC ($p = .17$), FS ($p = .43$), PD ($p = .43$), or temporal summation ($p = .24$).

DISCUSSION

The present study was designed to investigate (1) whether the observation of pain-related scenes elicits more vicarious somatosensory experiences in those patients suffering from FM compared with healthy controls; and (2) whether the observation of pain-related and non-pain related scenes modulates the detection of tactile stimuli. Additionally, we explored the effects of potential moderating factors proposed by Fitzgibbon et al. (2010, 2012b), i.e., dispositional empathy, hypervigilance to pain, the presence of chronic pain, and central sensitization. Participants were presented with a series of videos showing hands being pricked and non-pain related information such as a sponge being pricked whilst receiving occasionally near-threshold vibrotactile stimuli themselves. In congruent trials, the somatosensory and visual stimuli were applied to the same spatial location (e.g., on the right). In the incongruent trials, the somatosensory and visual stimuli were presented from the opposite spatial location (e.g., left and right). Trials in which both of the participant’s hands were stimulated and trials without tactile stimulation were present. Participants were required to report if and where they felt a somatosensory stimulus.

In this study, only a small number of vicarious somatosensory experiences were observed (2.5%). In the literature, percentages range from 1.6% for vicarious touch (Banissy et al., 2009), 16.2% for vicarious pain in amputees (Fitzgibbon et al., 2010a), 6.6% (Vandenbroucke et al., 2013, study 1), 22.9% (Vandenbroucke et al., 2013, study 2), and 30.0% for vicarious pain in a general population (Osborn & Derbyshire, 2010). This variability is largely dependent upon the group investigated, and the criteria that are used (questionnaires versus experimental paradigm). The percentage of reported vicarious pain in this study is smaller than that reported in amputees (Fitzgibbon et al., 2010a), suggesting that prior trauma may be an important modulator. Contrary to our hypotheses, no differences were found in vicarious somatosensory experiences between the FM patients and the controls. In general, and across groups, the observation of pain in another enhanced stimulus detection as compared to non-pain related scenes in both the congruent and incongruent trials. In line with our expectations, detection was better in congruent trials than in incongruent trials only when pain-related information was shown. In general, neglect errors were more frequently made (19.2%) compared with vicarious somatosensory experiences. FM patients made significantly fewer neglect errors (30%) as compared with controls. Dispositional empathy, hypervigilance for pain, and central sensitization had no modulating role upon the detection of vibrotactile stimuli, the experience of vicarious experiences, or on neglect errors. Neglect errors were frequently observed in this study, which suggests that the observation of pain-related information may modulate somatosensory experiences rather than induce illusory experiences. The lower number of neglect errors in the FM group is intriguing and needs further exploration and elaboration. One possible explanation here is that an excessive attentional focus on the body may have come into play. It is assumed that chronic pain patients are preoccupied with bodily cues signaling potential physical harm (Crombez et al., 2013). In this way, the FM patients may have been less misled by the presence of visual pain-related stimuli as their attention was focused on both hands, in contrast with controls who appear to have been paying more attention to the site congruent to the visual pain-related information. This assumed preoccupation with bodily cues may also explain the same number of vicarious somatosensory errors in both groups. On the other hand, self-report of hypervigilance did not seem to modulate the number of neglect errors. Another possibility may be that FM patients lack response inhibition as they detect vibrotactile stimuli on both hands, whereas healthy controls tend to report only the vibrotactile stimulus congruent to the visual stimulus and inhibit the detection of the incongruent vibrotactile stimulus. This is consistent with the results of a study by Glass et al. (2011) reporting that FM patients showed lower activation in the inhibition and attention networks and increased activation in other areas. Further research could explore whether this inhibition theory played a role in the different number of neglect errors reported in the two groups tested here.

Our findings corroborate previous research demonstrating that spatial coincidence plays a role in multisensory integration (Spence, 2013). In the present study, the higher proportion of correct responses in congruent as compared with incongruent trials, when pain-related information was shown, suggests that the visual system may dominate somatosensation when visual and tactile processing provide conflicting information (e.g., incongruent trials), or that vision may enhance sensitivity when providing similar information (e.g., congruent trials). The finding that the congruency effect was only present when pain-related scenes were shown attests to the relevance of the content of the visual information for tactile sensitivity. That vision should dominate somatosensation may also explain the occurrence of neglect errors, as attention may be more directed to the site congruent to the visual pain-related information. The content of the visual information was relevant as the site congruent to the pain-related videos was more frequently reported compared with non–pain related information, although both hands were stimulated. Our results are generally not supportive of Fitzgibbon et al.'s (2010, 2012b) model, in which hypervigilance for pain, central sensitization, and the presence of chronic pain were suggested as precursors of vicarious somatosensory experiences. In addition, controls reported even more vicarious pain experiences during daily life compared with FM patients. A trend (p=.052) suggested that, the more hypervigilant for pain FM patients were, the less vicarious somatosensory experiences they reported during the experimental paradigm in contrast to the control group in which more hypervigilance for pain was associated with more vicarious somatosensory errors. This is in line with a study in which hypervigilance for pain was associated with less vicarious somatosensory experiences in the pain responder group than in a non-pain responder group (Vandenbroucke et al., 2013). Hypervigilance for pain may lead to a focus on the body involving a higher sensitivity for somatosensory stimuli resulting in a better discrimination between false vicarious experiences and actual bodily experiences. Further research is needed in order to understand the role of hypervigilance in the elicitation of vicarious experiences in healthy controls and chronic pain patients. The results are also not in line with those of Brown et al. (2010), who suggested that there might be an interrelation between illusory tactile perceptions and the degree of pseudoneurological symptoms, nor with Katzer et al. (2011) who suggested medically unexplained symptoms might be related to touch illusions, because both groups in the present study reported a comparable number of vicarious somatosensory experiences. Some previous studies have demonstrated that patients with FM have a hypersensitivity for mechanical, cold and heat pain perception (Kosek et al., 1996; Smith et al., 2008) and mixed results exist for non-painful sensations such as cold, warm and touch (Desmeules et al., 2003; Klauenberg et al., 2008). The results of the present study show that threshold intensities for vibrotactile stimuli, although individually determined, were not significantly different for both groups. In general, the results show that although FM patients experience a lot of pain and medically unexplained symptoms, they are as good as controls at detecting subtle vibrotactile stimuli on their hands despite seeing relevant pain-related scenes.

Some limitations of the present study deserve further consideration. First, vibrotactile stimuli were administered instead of painful stimuli as in our previous study (Vandenbroucke et al., 2013). A study by Osborn and Derbyshire (2010), found that most patients selected ‘tingling’ as a descriptor to describe the somatosensory vicarious experiences while observing pain. Therefore, we used near-threshold intensity stimuli instead of painful stimuli in order to enhance the occurrence of vicarious somatosensory experiences, which were consequently not labeled as vicarious pain. Further research could therefore include painful stimuli to test whether the number of vicarious somatosensory experiences would remain the same. Second, we included video clips showing hands being pricked. These videos depict less intense pain compared to the images and movies used in the study by Osborn and Derbyshire (2010). Vicarious experiences may be elicited more easily when very intense pain is observed. That said, participants in the present study reported more false alarms during the observation of a subtle injury (the needle prick) as compared with control videos, indicating that vicarious experiences can also be observed with low intensity pain-related stimuli. Third, participants may have been more aroused when viewing the pain videos as compared to when viewing the control videos. As pain captures attention and may induce threat, it may have been more arousing than the control videos (an inherent feature of pain-related stimuli). Our aims were to investigate pain videos and control videos, regardless of their arousal capacity. Fourth, in the non-painful videos, human features were still present (e.g. hand(s)). It would be interesting to test whether the discrepancy in detection accuracy while observing both videos would increase if all human features were to be removed during non-painful videos, as tactile perception may be facilitated by simply viewing the body (Kennett, Taylor-Clarke, & Haggard, 2001). Another limitation of the present study may be that both groups have different educational levels (82% of the controls had a higher education compared with 26% in the FM group). It is well known that socio-economic position is negatively associated with pain and general health (Lacey, Belcher, & Croft, 2012). Further research could match groups regarding socio-economic demographics.

In general, this study shows that FM patients and controls are equally accurate in detecting subtle somatosensory stimuli while observing another in pain. The results further indicate that chronic pain may not act as a vulnerability factor for the presence of vicarious experiences as suggested by Fitzgibbon et al. (2010, 2012b). The lower number of neglect errors in FM patients suggest that they stay focused upon bodily processes even when observing another's pain, and more so than control participants. More research is needed to explain this discrepancy between controls and FM patients (e.g. accounting for attentional or disinhibition mechanisms).

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CHAPTER 3

Observing another in pain facilitates vicarious experiences and modulates somatosensory experiences[3]

ABSTRACT

Objective: This study investigated whether individuals reporting vicarious pain in daily life (e.g. the self-reported vicarious pain group) display vicarious experiences during an experimental paradigm, and also show an improved detection of somatosensory stimuli while observing another in pain. Furthermore, this study investigated the stability of these phenomena. Finally, this study explored the putative modulating role of dispositional empathy and hypervigilance for pain.

Methods: Vicarious pain responders (i.e., reporting vicarious pain in daily life; N=16) and controls (N=19) were selected from a large sample, and viewed videos depicting pain-related (hands being pricked) and non-pain related scenes, whilst occasionally experiencing vibrotactile stimuli themselves on the left, right or both hands. Participants reported the location at which they felt a somatosensory stimulus. We calculated the number of vicarious errors (i.e., the number of trials in which an illusionary sensation was reported while observing pain-related scenes) and detection accuracy. Thirty-three participants (94.29%) took part in the same experiment five months later to investigate the temporal stability of the outcomes.

Results: The vicarious pain group reported more vicarious errors compared with controls and this effect proved to be stable over time. Detection was facilitated while observing pain-related scenes compared with non-pain related scenes.

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[3] Based on: Vandenbroucke, S., Loeys, T., Crombez, G., & Goubert, L. (2014) Observing another in pain facilitates vicarious experiences and modulates somatosensory experiences. *Frontiers in Human Neuroscience, 8,* 631. doi:10.3389/fnhum.2014.00631

Observers' characteristics, i.e., dispositional empathy and hypervigilance for pain, did not modulate the effects.

Conclusion: Observing pain facilitates the detection of tactile stimuli, both in vicarious pain responders and controls. Interestingly, vicarious pain responders reported more vicarious errors during the experimental paradigm compared to controls and this effect remained stable over time.

INTRODUCTION

Evidence reveals that similar brain areas are activated when observing pain in another and when experiencing pain ourselves (Bufalari et al., 2007; Corradi-Dell'Acqua et al., 2011; Gu & Han, 2007; Jackson et al., 2006; Keysers et al., 2010; Lamm et al., 2010; 2011). These observations are intriguing as they show that actual nociceptive input is not necessary to activate those brain regions which are also activated when being in pain. While most individuals feel empathic and distressed in response to the observation of another in pain (Goubert et al., 2005), a minority actually reports vicarious somatosensory experiences. Percentages range from 1.6% for vicarious touch (Banissy et al., 2009), 16.20% for vicarious pain in amputees (Fitzgibbon et al., 2010a), to 6.61% (Vandenbroucke et al., 2013, study 1), 22.90% (Vandenbroucke et al., 2013, study 2) and 30% for vicarious pain in a general population (Osborn & Derbyshire, 2010). The variability is probably dependent upon the criteria used for categorizing individuals as vicarious pain responders.

Little research is available regarding the robustness of vicarious experiences and whether these change within individuals over time. Recruitment of participants reporting vicarious experiences and pain is largely based upon self-reports, mainly using questionnaires or interviews (Banissy & Ward, 2007; Fitzgibbon et al., 2010a; Vandenbroucke et al., 2013). For example, individuals are asked to rate whether they experience vicarious sensations in specific situations or in daily life. Based upon these ratings, participants are selected in a second phase, to take part for example in neuroimaging (e.g. Osborn &

Derbyshire, 2010) or in an experimental study (e.g. Vandenbroucke et al., 2013). An implicit assumption of this recruitment procedure is that vicarious experiences are stable across time and across situations. However, to our knowledge, no study has examined whether the report of vicarious experiences is stable over time.

Also, little is known about the conditions affecting this phenomenon (but see Fitzgibbon et al., 2010b, 2012, Vandenbroucke et al., 2014). Many moderators have been proposed, but research is needed to corroborate these ideas and to replicate preliminary findings. For example, Vandenbroucke et al. (2013) showed that vicarious pain responders reported more vicarious pain experiences compared with controls. Hypervigilance to pain, or the over-alertness to pain-related information (as measured by a self-report instrument) moderated this effect, with vicarious pain responders reporting less vicarious errors when more hypervigilant for pain. However, in general, only few vicarious pain experiences occurred in this study (experiment 1: 2.7%; experiment 2: .88%) suggesting that it is a rare phenomenon, occurring in only some participants. Interestingly, in the study of Osborn and Derbyshire (2010), the most frequent descriptor that was selected from the McGill Pain Questionnaire to describe vicarious pain was "tingling." Therefore, it is unclear whether vicarious pain responders in the general population (e.g. undergraduates) do experience vicarious pain or rather vicarious vague sensations while observing another in pain. Furthermore, observing somatosensation in another may not only induce vicarious somatosensory experiences, but may also influence the detection of tactile stimuli (Cardini et al., 2013; Gillmeister, 2014). For example, observing a face being touched enhances tactile perception on the face (Serino et al., 2008). In this context, the modulation of somatosensory experiences may represent a less extreme variant of the elicitation of "illusory" experiences when observing another in pain. Common pathways exist in experiencing touch and pain, such as multimodal neurons which both respond to nociceptive and tactile inputs (Bars, 2002). An overlap between processing nociceptive and non-nociceptive events has also been observed by Mouraux et al. (2011). These authors stress that the brain responses typically triggered by nociceptive stimuli are largely the result of both multimodal neural-and somatosensory-specific activities, rather than the result of nociceptive-specific neural activities. Of particular interest to this study, Vandenbroucke et al. (2014) showed that the observation of pain in others resulted in vicarious tactile experiences, which further attests to the interplay in processing touch and pain.

The aims of this study were threefold. First, we investigated whether the experience of vicarious somatosensory experiences and the detection of subtle somatosensory stimuli while observing another in pain differs in a group of vicarious pain responders versus controls. Second, we examined whether these outcomes remain stable over time. Finally, the modulating role of dispositional empathy and hypervigilance for pain was explored. Using a variant of the crossmodal congruency task (see Vandenbroucke et al., 2013), vicarious pain responders (i.e., those who report vicarious pain during daily life; N = 16) and controls (i.e., those not reporting vicarious pain during daily life; N = 19) were presented videos of two categories, i.e. videos of pain-related situations (hands being pricked) and videos of non-pain related situations (e.g. sponge being pricked, hand approached by another hand). Participants occasionally received non-painful subtle vibrotactile stimuli themselves on the left, right or both hands. In 25% of the trials no vibrotactile stimulus was presented. Participants were instructed to report as rapidly as possible the spatial location of the administered somatosensory stimuli. Five months later, the same participants were invited again to execute the experiment a second time. First, we hypothesized that vicarious pain responders would report more bodily illusions in response to the observation of pain (vicarious experiences) than controls. As such we wanted to replicate the findings of Vandenbroucke et al. (2013). However, an important difference with this study is the inclusion of tingling instead of painful somatosensory stimuli. The use of vibrotactile instead of electrocutaneous “pricking” stimuli (see Vandenbroucke et al., 2013) may lead to an increase in vicarious experiences, as vicarious sensations has been most often described by vicarious pain responders as “tingling” rather than painful (Osborn & Derbyshire, 2010). Second, we examined the stability of vicarious experiences: if the experience of vicarious sensations is a robust and reliable phenomenon, comparable results should be obtained regarding the number of vicarious experiences at both time moments. Third, we expected that the observation of pain-related visual scenes would modulate the detection of vibrotactile stimuli compared with non-pain related scenes. In particular, we expected a crossmodal congruency effect (CCE) in which more tactile acuity is observed when the visual and tactile stimuli are spatially congruent. We hypothesized this CCE effect to be dependent upon the type of visual information (pain-related versus non-pain related). As pain-related visual stimuli may facilitate detection of somatosensory stimuli, a higher CCE was expected when pain-related visual stimuli were shown as compared to non-pain related visual stimuli. We expected this CCE during pain-related videos to be most pronounced in the vicarious pain responder group. Relatedly, we explored whether the observation of pain-related scenes would result in neglect errors (i.e. only reporting the site congruent to the visual information when both hands are stimulated). Fourth, we explored whether dispositional empathy and hypervigilance to pain moderates the effects upon vicarious experiences and the detection of tactile stimuli.

MATERIALS AND METHOD

Participants

Participants were recruited from a pool of approximately 536 undergraduate students from Ghent University who were invited to complete questionnaires screening for, amongst others, the experience of vicarious pain in daily life (October 2012 to February 2013) (see Figure 1). One of these questionnaires assesses the experience of vicarious pain experiences in daily life by means of four items adapted from Banissy et al. (2009). Participants were asked to indicate on an eleven point scale (0 - 10; totally disagree – totally agree) the extent to which they agreed with the questions: “Do you feel pain in your own body when you see someone accidently bump against the corner of a table?”, “Do you have the feeling experiencing pain when you observe another person in pain?”, “Do you feel bodily pain when you observe another person in pain?” and “Do you feel a physical sensation (e.g. tingling, stabbing, …) when you observe another person in pain?”. Completed questionnaires were available from 412 students. As no standard cut-off for the presence of vicarious pain is available, we invited the highest scoring vicarious pain responders (10%, *n* = 41) over all questions (average score on all items for each individual was ≥ 6.5). This cut-off preserves a balance between extreme values (inviting the highest scoring vicarious pain responders) and a minimum of vicarious pain responders to participate (see Vandenbroucke et al., 2013). We also invited randomly 49 of those who scored 0 on all questions.

In total, 38 undergraduates (34 women) agreed to participate. Their mean age was 19.97 years (*SD* = 3.47, range: 18 - 36 years). All participants were Caucasian. Participants received either course credits for participation in this experiment (*n* = 21) or were paid (*n* = 17) 10 euro. Participants were categorized in a vicarious pain group and a comparison group based upon the sum of their responses on the items measuring vicarious pain in daily life, administered during the experiment. We considered maintaining all participants whose sum score was ≤ 15 (*n* = 19; comparison group) and those whose sum score was ≥ 25 (*n* = 16; vicarious pain responder group) as this cut-off preserves a balance between extreme values (the most extreme scoring vicarious pain responders) and a minimum of vicarious pain responders to analyze. Three participants scoring between 15 and 25 were excluded from the analyses (see Vandenbroucke et al., 2013). Mean age was 20 years in the vicarious pain responder group (*SD* = 4.35, range: 18 - 36 years) and 20.21 years (*SD* = 2.90, range: 18 - 29 years) in the comparison group. Of all included participants, one indicated to have experienced an episode of chronic pain during the past 6 months (pain duration was 90 days). This participant was not excluded for participation. Ethical approval was obtained from the Ethics committee of the Faculty of Psychology and Educational Sciences of Ghent University (Belgium).

Approximately 5 months later (Time 2), participants were invited by phone for their participation in a second part, which was described as a subsequent phase of the first experiment in which they participated. The categorization of participants based upon their vicarious pain report in daily life at Time 1 was maintained[4]. The two non-participating individuals were two vicarious pain responders. Thirty-three of the 35 participants (94%; 29 women) agreed to participate a second time. These participants did not make many vicarious errors at time 1 (n = 0 and n = 3 respectively). Mean age of the participating group was 20.68 years (*SD* = 3.85, range: 18 - 37 years). All participants were paid 20 euro for their second participation.

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[4] If categorization of Time 2 would be used, 2 controls and 2 vicarious pain responders would be categorized to the other group

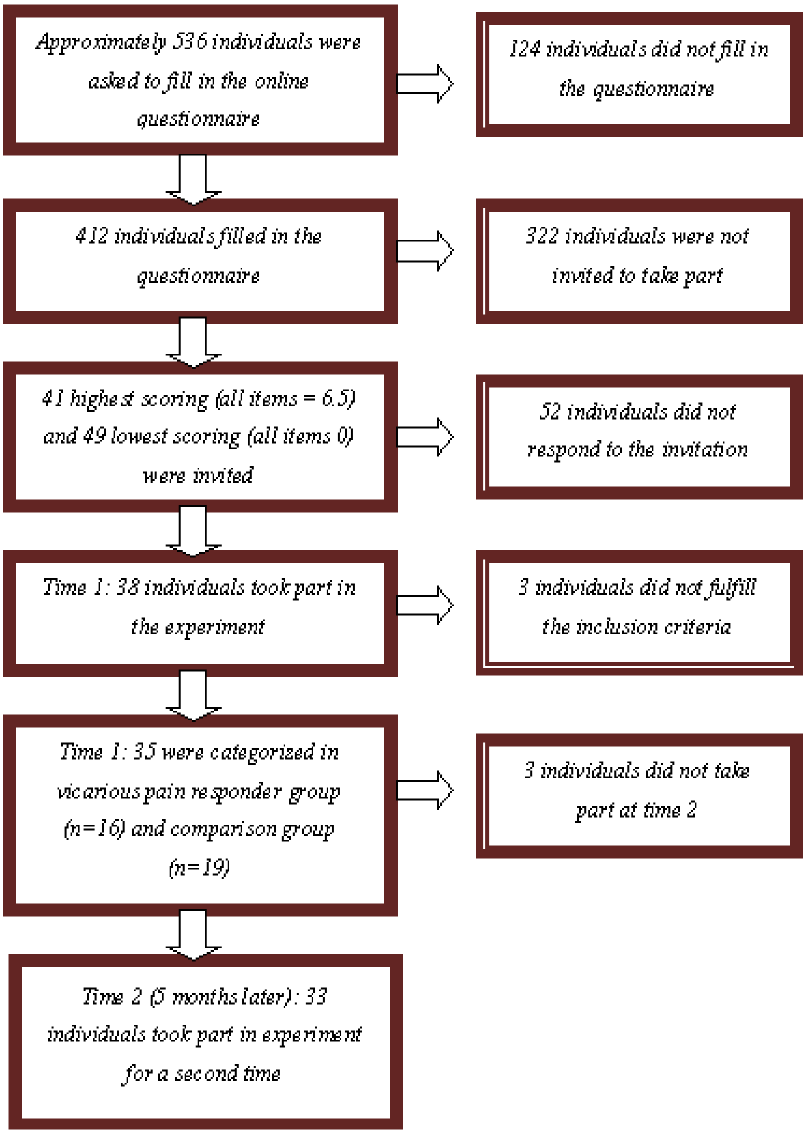

Figure 1. Flow chart of recruitment of vicarious pain responders and controls

Apparatus and stimuli

Somatosensory stimuli

Vibrotactile stimuli (50 Hz, 50 ms) were delivered by means of two resonant-type tactors (C-2 tactor, Engineering Acoustics, Inc.) consisting of a housing that was 3.05 cm in diameter and 0.79 cm high, with a skin contactor that was 0.76 cm in diameter. The somatosensory stimuli were delivered on the skin between thumb and index finger. Through a self-developed software program that was used to control the tactors, all stimulus characteristics (amplitude, duration, and frequency) were entered. The threshold intensity level was individually determined prior to the experiment for each participant (see Procedure-Preparation phase). Both hands were placed on the table in front of the screen and covered of sight by means of a carton box. Four different series of 20 stimuli/trials (two series for each hand) were randomly administered (80 stimuli/trials in total). First, a visual stimulus (an “X” in the middle of the screen, 1000ms duration) was presented combined with a somatosensory stimulus on the left or right hand. Participants were instructed to report whether they felt a somatosensory stimulus (“yes” or “no”), which was coded by the experimenter by pressing the corresponding response button. Each series started with a stimulus of 0.068W. The intensity was decreased by 0.0002W whenever the participants reported feeling a stimulus, and increased by 0.0002W when no sensation was reported. This resulted, after 80 trials, in a threshold intensity for each hand, which was based upon the mean intensity of the last stimuli of the two series for that particular hand. From this threshold intensity, 1/8 was subtracted (subthreshold) and added to the threshold (above threshold) which resulted in four different intensities (sub and above threshold, one for each hand; see Press, Taylor-Clarke, Kennett, & Haggard, 2004). Thresholds for left and right hand were not significantly different at T1 (*t*(34) = .69, *p* = .50), (threshold left hand: *M* = .038W, *SD* = .004W, range = .008W - .133W; threshold right hand: *M* = .033W, *SD* = .004W, range = .008W - .124W) and at T2 (*t*(32)= .87, *p* = .39), (threshold left hand: *M* = .033W, *SD* = .004W, range = .006W - .133W; threshold right hand: *M* = .029W, *SD* = .004W, range = .003W - .089W).

Visual stimuli

The visual stimuli consisted of videos from two categories (pain-related versus non-pain related), each with a duration of 3 seconds. The pain-related category included two scenes depicting a left and right hand. One of the two hands was pricked by a syringe (scene 1) or safety pin (scene 2) 2000ms after video onset. The non-pain related category also consisted of 2 scenes. In the first scene, a left and right hand was presented in which one of these hands was approached by a hand that was not holding an object. In the first scene, a left and right hand was presented in which one of these hands was approached by a hand that was not holding an object. That way, we wanted to control for the motor movement (the same action is performed as in the first category of videos). In the second scene, one hand (left or right) was still present as in all other scenes mentioned above, but at the other site no second hand but a sponge was being pricked by a syringe (see Figure 2). That way, we wanted to control for the possible aversion for the presence of the syringe. The penetration took place also after 2000ms. The different scenes and the location of the sponge and movement were counterbalanced across videos. The location of the penetration (left versus right hand) and type of category were counterbalanced across videos. Videos were presented by INQUISIT Millisecond software (http://www.millisecond.com) on a Dell computer with a 19-inch CRT-monitor.

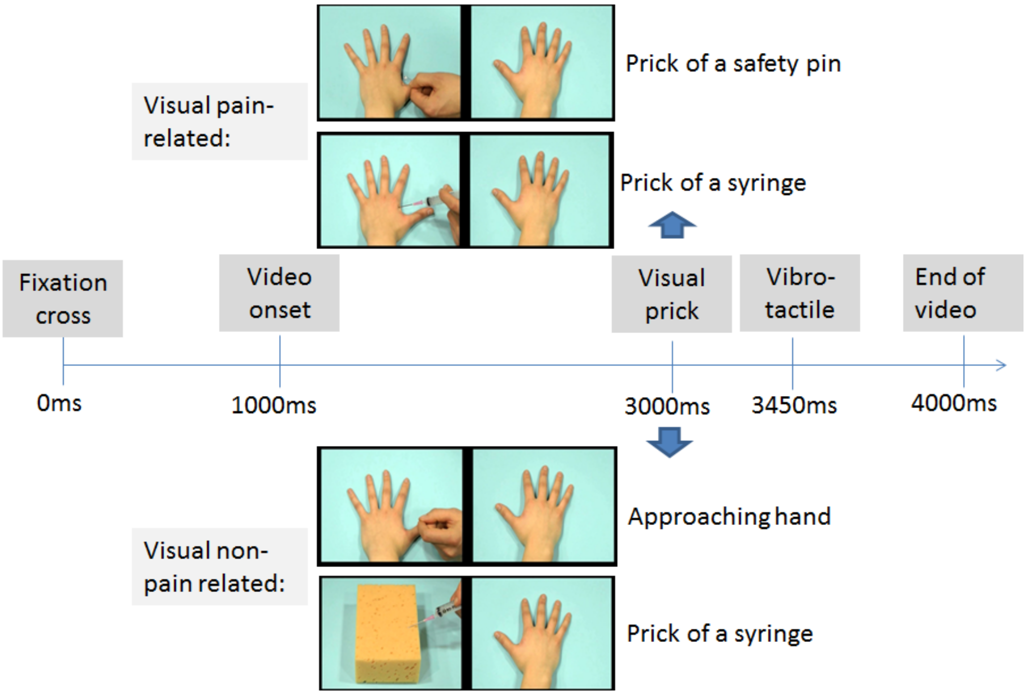

Figure 2. Timeline of a possible trial

Self report measures

The Dutch version of the Pain Vigilance and Awareness Questionnaire (PVAQ; McCracken, 1997, Roelofs et al., 2002) was used to measure vigilance to pain. This questionnaire consists of 16 items assessing awareness, consciousness and vigilance to pain on a six-point scale (0 = never; 5 = always). Higher scores on the PVAQ are indicative of greater pain-related vigilance and awareness. The questionnaire can be used in both clinical (McCracken, 1997, Roelofs et al., 2003) and non-clinical (Roelofs et al., 2002, McWilliams & Asmundson, 2001) samples. The Dutch version of the PVAQ is reliable and valid (Roelofs et al., 2002, Roelofs et al., 2003). Cronbach's alpha for the present study was 0.88 at Time one and 0.95 at Time two.

The Dutch version of the Interpersonal Reactivity Index assessed empathic disposition (IRI; Davis, 1983, De Corte et al., 2007). This questionnaire includes 28 items and consists of 4 subscales: Perspective Taking (i.e., cognitively taking the perspective of another, e.g., "I sometimes try to understand my friends better by imagining how things look from their perspective."), Fantasy (i.e., emotional identification with characters in books, movies etc., e.g., "When I watch a good movie, I can very easily put myself in the place of a leading character."), Empathic Concern (i.e., feeling emotional concern for others, e.g., "I am often quite touched by things that I see happen.") and Personal Distress (i.e., negative feelings in response to the distress of others, e.g., "When I see someone who badly needs help in an emergency, I go to pieces."). Each item is answered on a scale ranging from 1 ('does not describe me very well') to 5 ('describes me very well'). This questionnaire has shown to be reliable and valid (Davis, 1983, De Corte et al., 2007). Cronbach's alpha's in the current study were 0.77 (empathic concern), 0.77 (personal distress), and 0.55 (perspective taking) and 0.40 (fantasy scale) for Time one. Perspective taking and Fantasy scale were omitted from the analyses because of the low reliability score. At time two, Cronbach's alpha's were 0.81 (empathic concern), 0.77 (personal distress), 0.85 (fantasy scale) and 0.66 (perspective taking). Only those scales showing sufficient reliability at both time moments were maintained in analyses, i.e. hypervigilance for pain, empathic concern and personal distress. Vicarious pain experiences during daily life were measured by means of four items adapted from Banissy et al. (2009) as described in the participants section. In the present study Cronbach's alpha was 0.97 at Time 1.

Procedure

After signing the informed consent, the participants were seated in front of a table, at about 60 cm away from the computer screen.

Preparation phase. First, the detection threshold was determined for each hand separately. The participants were informed that during the experiment they would feel subtle stimuli varying in intensity and length, on their left, right, or both hands and that different videos would be presented which they needed to watch attentively. A carton box covered the hands of the participants which were placed upon the table. The participants were told that the intensity of the somatosensory stimuli could vary across hands and that also trials without any stimulus would be included. In reality, only two fixed predetermined intensities with a fixed duration were applied (threshold intensity ± 1/8) for each hand.

Experiment phase. Each trial began with a fixation cross (1000ms duration) presented in the middle of the computer screen. Next, one of the scenes was presented. In 75% of the trials, a tactile stimulus was delivered 2450ms after video onset either on the left hand, the right hand, or on both hands of the participant. The somatosensory stimulus was administered with a delay (450ms after the visual stimulus of penetration of the needle), in line with Banissy and Ward (2007). As such, the following trial types were created: congruent trials, incongruent trials, trials without tactile stimuli, and trials with both hands stimulated. In congruent trials, visual and tactile stimuli were presented at the same spatial location (e.g., on the right). In the incongruent trials, the somatosensory and visual stimuli were presented at opposite locations (e.g., one on the left and the other on the right). The experiment started with 8 practice trials. The actual experimental phase consisted of 192 trials divided over three blocks of 64 trials. There were 48 congruent trials, 48 incongruent trials, 48 trials without sensory stimuli and 48 trials with somatosensory stimuli at both hands. Order of trial types was randomized within each block and the somatosensory stimuli were equally distributed within and over each block with an intensity under and above threshold. An overview of all trial types is presented in Table 1. During each trial, participants were requested to report whether a physical sensation was felt by reporting as rapidly as possible ‘YES’ and to discriminate the spatial location of the somatosensory stimuli by reporting “left”, “right” or “both” (see Figure 3). After the video had ended and 2000 ms elapsed, the word ‘next’ was presented on the screen (see Figure 2). Then, the experimenter coded the response by pressing the corresponding response button (left, right, both or no response). In this way, the time to respond was equal for every participant. The experiment took approximately 20 min.

Post-experiment phase. After the experiment, participants were requested to fill out self-report scales measuring hypervigilance for pain (PVAQ), vicarious pain and empathic disposition (IRI). The same procedure was performed at time 2.

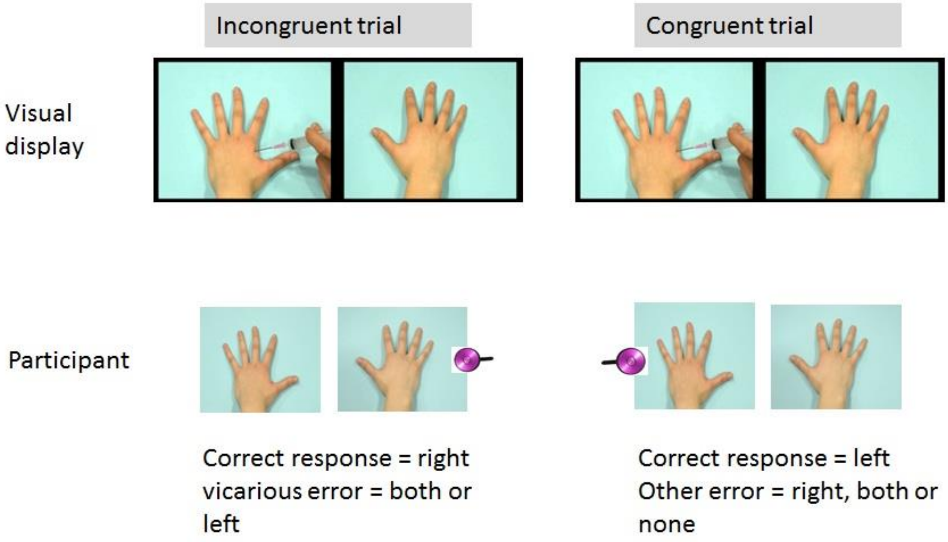

Figure3. Example of a possible trial

Table 1

Detection accuracy for both groups and all video types

Pooled effects	INCONGRUENT TRIALS				CONGRUENT TRIALS				TRIALS WITHOUT TACTILE STIMULI				TRIALS WITH BOTH HANDS OF PARTICIPANT STIMULATED			
Site reported by participant	Correct site	Opposite site (=site of visual)	Both hands	No hands	Correct site	Opposite site to visual and tactile	Both hands	No hands	Site congruent to visual	Opposite site to visual	Both hands	Correct No hands	Visual site	Opposite site to visual	Correct Both hands	No hands
Visual pain Vicarous pain responder group	49.31%	10.97% vicarious errors	10.42% vicarious errors	29.32%	77.92%	.97%	2.36%	18.75%	15.69% vicarious errors	1.81%	.97%	81.53%	26.81% neglect error	11.25%	48.61%	13.33%
Visual control Vicarious pain responder group	46.39%	1.67%	2.92%	49.03%	50.00%	.42%	2.36%	47.22%	2.22%	1.11%	.56%	96.11%	17.92% neglect error	13.33%	36.81%	31.94%
Visual pain Control group	61.51%	2.19% vicarious errors	3.07% vicarious errors	33.22%	67.43%	.66%	2.19%	29.71%	4.17% vicarious errors	1.53%	.55%	93.75%	19.96% neglect error	13.16%	49.45%	17.43%
Visual control Control group	48.68%	.66%	1.21%	49.45%	49.45%	.33%	1.21%	49.01%	.44%	1.86%	.11%	97.59%	15.57% neglect error	14.04%	37.94%	32.46%

Statistical analysis

Vicarious errors

False alarms were calculated from the incongruent trials and from the trials without any somatosensory stimuli when erroneously a somatosensory stimulus was reported in the same spatial location as the visual stimulus. These false alarms were labeled ‘vicarious experiences’ or ‘vicarious errors’ when the visual stimulus contained pain-related information. First, we tested whether the number of false alarms was dependent upon the category of video. As all participants observed both categories of videos and the number of false alarms during both categories of movies were not normally distributed, non-parametric analyses for related samples (Wilcoxon) were used. The number of vicarious experiences was further selected as the dependent variable, as we were particularly interested in those false alarms during pain-related videos (=vicarious errors). To test whether group predicted the number of vicarious errors, count regression models were applied as the use of linear models is considered less appropriate (Vives et al., 2006) when the frequency of responses has a skewed distribution that violates the normality assumption. The basic model to analyze count data is poisson regression, but the variance of counts is often larger than the mean (overdispersion). The Negative Binomial (NB) regression, a Poisson regression with an overdispersion, may therefore better fit the data (e.g., Gardner et al., 1995). As count data may additionally exhibit a lot of zero counts, zero-inflated extensions of both models, called Zero-Inflated Poisson (ZIP) and Zero-Inflated NB (ZINB) models have been developed (see Karazsia et al., 2010, Loeys et al., 2012). Deviance tests and the Vuong test were used to select the best fitting count distribution for the dependent variable. A model with ‘group’ as predictor was added, after the best fitting count model was chosen. In a further exploration of the data, hypervigilance for pain, and dispositional empathy and their interaction with group were added in separate models to test whether they had a moderating role. Dummy coding was used for the categorical variables. Regression coefficients are exponentiated (eB) and called Rate Ratios (RRs). In percentages—100 x (eB - 1)—RRs reflect the percentage decrease (RR < 1) or increase (RR > 1) in the expected frequency of vicarious errors for each 1-unit increase in the continuous predictor. Same statistical analyses were performed at Time 2. To measure the stability of the vicarious errors, generalized linear mixed models assuming the same count distribution as at the single time moments were applied. As both time moments were included for the same participants, a random intercept was used to capture the dependency within participants. R (version 2.15.1) was used to fit the count models.

Detection accuracy

The proportion of correct responses (left versus right) for congruent and incongruent trials for each category of visual information was calculated (pain-related versus non-pain related), to investigate whether the observation of pain-related and non-pain related scenes modulated the detection of tactile stimuli. Detection accuracy was measured by means of a 2 (video category: pain-related versus non-pain related) x 2 (congruency: congruent versus incongruent) repeated measures ANOVA, with congruency and type of video entered as within-participant variables and ‘group’ as between-subject variable. In a further exploration of the data, hypervigilance for pain and dispositional empathy were added as a covariate in separate models to test whether they had a moderating role. Same statistical analyses were performed at Time 2. Subsequently, to analyze the stability of detection accuracy, Repeated Measure ANOVAs were again executed with the inclusion of an extra within-variable Time (Time 1 versus Time 2). Repeated measure ANOVAs were conducted with an alpha < 0.05, using SPSS statistical software, version 21.0 for Windows.

Neglect errors

The number of neglect errors was calculated based upon those trials in which both hands were stimulated, defined as reporting only the site congruent to the visual information and missing the actual tactile stimuli on both hands. To test whether the number of neglect errors was dependent upon the category of video, non-parametric analyses for related samples (Wilcoxon) were used. Count regression models were applied in which the dependent variable was the number of neglect errors during pain-related visual information. After the best fitting count model was chosen, a model with ‘group’ as predictor was added. In a further exploration of the data, hypervigilance for pain and dispositional empathy and their interaction with group were added in separate models to test whether they had a moderating role. Same statistical analyses were performed at Time 2.

To measure the stability of the neglect errors, generalized linear mixed models for count data were applied as described above in the section of the vicarious errors.

RESULTS

Descriptives

Mean scores, standard deviations and correlations at Time 1, 2 and both time moments are presented in Table 2 and 3. For variables that were not normally distributed (Kolmogorov-Smirnoff, $p < .05$), Spearman correlations were computed.

At both time points, a significant difference was found between both groups in empathic concern (time 1: $t(33) = -2.36$, $p = .02$; time 2: $t(31) = -2.28$, $p = .03$) and PVAQ (time 1: $t(33) = -2.79$, $p < .01$; time 2: $t(31)= -2.59$, $p = .01$). The vicarious pain responder group was more empathic concerned and more hypervigilant for pain.

Table 2

Pearson/Spearman correlations of all measures (T1, T2 and pooled effects)

	TIME 1					TIME 2				Pooled effects			
	2.	3.	4.	5.	6.	2.	3.	4.	5.	2.	3.	4.	5.
1. Vicarious errors	.45**	.32	.37*	.38*	.39*	.36*	.22	.20	.08	.41**	.26*	.29*	.22
2. Neglect errors (pain-related videos)	-	.14	.20	.01	.20	-	.23	.18	.17	-	.17	.11	.08
3. Hypervigilance (PVAQ)		-	.32	.16	.52**		-	.11	.18		-	.22	.17
4. Empathic concern			-	-.09	.33			-	.17			-	.06
5. Personal distress				-	.39*				-				-
6. Vicarious pain during daily life					-								

Note. Pain Vigilance and Awareness Questionnaire (PVAQ).
* p<0.05; **p<0.01

Table 3

Mean scores and standard deviations of all measures (T1, T2 and pooled effects)

	TIME 1			TIME 2			Pooled effects		
	M (SD) vicarious pain responders	M(SD) controls	M(SD) total group	M(SD) vicarious pain responders	M(SD) controls	M(SD) total group	M (SD) vicarious pain responders	M(SD) controls	M(SD) total group
1. Vicarious errors	6.56 (10.94)	1.84 (2.34)	4.00 (7.84)	11.57 (15.23)	2.68 (3.32)	6.45 (10.97)	8.90 (13.13)	2.26 (2.86)	5.19 (9.50)
2. Neglect errors (pain-related videos)	6.31 (3.93)	5.05 (2.70)	5.63 (3.33)	6.57 (4.07)	4.53 (2.25)	5.39 (3.26)	6.43 (3.93)	4.79 (2.46)	5.51 (3.27)
3. Hypervigilance (PVAQ)	44.25 (10.59)	33.95 (11.16)	38.66 (11.94)	46.94 (11.58)	34.53 (14.88)	39.79 (14.76)	45.51 (10.95)	34.24 (12.98)	39.21 (13.29)
4. Empathic concern	20.63 (3.32)	17.21 (4.91)	18.77 (4.54)	21.36 (3.73)	17.79 (4.91)	19.30 (4.73)	20.97 (3.48)	17.50 (4.85)	19.03 (4.61)
5. Personal distress	14.75 (4.54)	13.05 (3.72)	13.83 (4.14)	15.36 (4.53)	13.66 (4.00)	14.38 (4.25)	15.03 (4.47)	13.36 (3.82)	14.10 (4.17)
6. Vicarious pain during daily life	28.88 (4.00)	6.37 (5.10)	16.66 (12.25)						

Note. Pain Vigilance and Awareness Questionnaire (PVAQ).

Vicarious errors

Time 1. The effect of group on vicarious errors moderated by hypervigilance and empathic concern.

A main effect of video category upon the presence of false alarms was found (Wilcoxon, $p < .01$), indicating that participants more often reported false alarms when the visual stimulus contained pain-related information. In 8.33% of the trials vicarious errors were made (140 vicarious errors from a total of 1680 trials), mainly in the vicarious pain responder group (75% of all vicarious errors; $n = 105$). Two participants in the vicarious pain responder group were responsible for 62.86% of all vicarious errors (66 of a total of 105 vicarious errors). Results based on negative binomial regression models further showed a main effect of group; i.e. the number of vicarious errors was 256% higher in the vicarious pain responder group compared with the comparison group (RR = 3.56; $p = .005$). No interactions were found between group and Personal distress ($p = .12$). A significant interaction was found between group and PVAQ ($p = .02$). For vicarious pain responders, the number of vicarious errors decreased by 5% (RR = .95) for every 1-unit increase in hypervigilance for pain. For the comparison group, the number of vicarious errors increased by 5% (RR = 1.05) for every 1-unit increase in hypervigilance for pain. Also a significant interaction was found between group and empathic concern (p = .003). For the comparison group, the number of vicarious errors decreased by 2% (RR = .98) for every 1-unit increase in empathic concern. For vicarious pain responders, the number of vicarious errors increased by 36% (RR = 1.36) for every 1-unit increase in empathic concern measured at Time 1.

Time 2. The effect of group on vicarious errors, but no moderation.

Again, a main effect of video category upon the presence of false alarms was found (Wilcoxon, $p < .01$). indicating that participants more often reported false alarms when the visual stimulus contained pain-related information. In 13.45% of the trials vicarious errors were made (213 vicarious errors from a total of 1584 trials), mainly in the vicarious pain responder group (76.06% of all vicarious errors; *n* = 162). Four participants in the vicarious pain responder group were responsible for 82.72% for all vicarious errors (134 of a total of 162 vicarious errors). Negative binomial regression models revealed that the number of vicarious errors was again dependent upon group (*p* = .001). The vicarious pain responder group made 331% more vicarious errors than the comparison group (RR = 4.31). No interactions were found between group and personal distress (p = .54), empathic concern (p = .53) and hypervigilance for pain (p = .44) measured at Time 2.

Stability of vicarious errors. The effect of group on vicarious errors, but no moderation.

In line with Time 1 and Time 2 results, a main effect of video category upon the presence of false alarms was found (Wilcoxon, *p* < .01). In 10.81% of the trials vicarious errors were made (353 vicarious errors from a total of 3264 trials), mainly in the vicarious pain responder group (75.64% of all vicarious errors; *n* = 267). Four participants in the vicarious pain responder group were responsible for 59% for all vicarious errors at both moments (209 of a total of 353 vicarious errors). Two of these four vicarious pain responders showed a lot of vicarious errors at time two (35 and 32 vicarious errors respectively) but did not show this pattern at time one (4 and 5 vicarious errors respectively). The other two vicarious pain responders showed a relative stable number of vicarious errors (T1: *n* = 28 and *n* = 38; T2: *n* = 45 and *n* = 22).

The generalized linear mixed model assuming a negative binomial distribution revealed a main effect of time (*p* = .04), with vicarious errors increasing with 61% at time two (RR = 1.61). Also, the number of vicarious experiences was, across Time 1 and Time 2, dependent upon group (*p* = .02). Vicarious pain responders made 177% more vicarious errors compared with controls (RR = 2.77). No interaction occurred between group and time (*p* = .66). Group did not significantly interact with hypervigilance for pain (*p* = .99), empathic concern (*p* = .07) or personal distress (*p* = .46) measured at both time moments.

Detection accuracy

Time 1. The effect of video and congruency on detection accuracy moderated by group.

In line with our hypotheses, a 2 (video category: pain-related versus non-pain related) x 2 (congruency: congruent versus incongruent) repeated measures ANOVA with 'group' (vicarious pain responder versus comparison group) as between-subject variable showed a main effect of video category (*F*(1,33) = 38.31, *p* < .0001, Cohen's d = 1.02, [95% CI: 0.63, 1.42]). Pain-related videos resulted in a better detection of vibrotactile stimuli compared with non-pain related videos. Also a main effect for congruency was found (*F*(1,33) = 12.83, *p* = .001, Cohen's d = 0.49, [95% CI: 0.20, 0.78]). An interaction occurred between congruency and video category: the CCE was dependent upon the type of video presented (*F*(1,33) = 24.96, *p* < .0001, Cohen's d = -.84, [95% CI: -1.27, -.41]). A paired sample t-test showed the CCE was only significant for the pain-related videos (*t*(34) = -4.36, *p* < .001, Cohen's d = 0.78, [95% CI: 0.37, 1.18]) and not for the non-pain related videos (*t*(34) = 0.12, *p* = .91, Cohen's d = 0.01, [95% CI: -0.21, 0.24.])). A significant interaction was found between group, video and congruency (*F*(1,33) = 6.39, *p* = .02), showing that the interaction between video and congruency was only significant for the vicarious pain responder group (*F*(1,15) = 23.44, *p* < .001, Cohen's d = -1.63, [95% CI: -2.64, -0.62]). In the comparison group, detection accuracy during pain-related and non-pain related was independent of congruency. No main effect occurred for group (*F*(1,33) = 0.21, *p* = .65, Cohen's d = -.39, [95% CI: -.80, 0.02]). No interaction was found between group and video (*F*(1,33) = 0.07, *p* = .79) and between group and congruency (*F*(1,33) = 3.45, *p* = .07). No moderating role was found of hypervigilance or dispositional empathy measured at Time 1 (all *p* > *.05*).

Time 2. The effect of video and congruency on detection accuracy moderated by group.

In line with Time one, a main effect of video category was found (*F*(1,31) = 30.19, *p* < .0001, Cohen's d = 0.80, [95% CI: .48, 1.11]); the observation of pain-related videos resulted in a better detection of vibrotactile stimuli compared with non-pain related videos. Also a main effect for congruency occurred (*F*(1,31) = 15.86, *p* < .001, Cohen's d = 0.54, [95% CI: 0.18, 0.90]). An interaction occurred between congruency and video category: the CCE was dependent on the type of video presented (*F*(1,31) = 14.59, *p* = .001, Cohen's d = .66, [95% CI: 0.19, 1.13]). A paired sample t-test showed the CCE was only significant for the pain-related videos (*t*(32) = -3.41, *p* = .002, Cohen's d = 0.79, [95% CI: 0.25, 1.32]). A significant interaction was found between group, video category and congruency (*F*(1,31) = 10.30, *p* = .003). The interaction between video category and congruency was only significant for the vicarious pain responder group (*F*(1,13) = 16.17, *p* = .001, Cohen's d = -1.28, [95% CI: -2.13, -.44]). No main effect occurred for group (*F*(1,31) = 0.56, *p* = .46). An interaction was found between group and congruency (*F*(1,31) = 9.10, *p* = .005), indicating that the congruency effect was only present in the vicarious pain responder group (*F*(1,13) = 10.59, *p* = .006). No interaction was found between group and video category (*F*(1,31) = 0.11, *p* = .75). No moderating role was found of the individual difference variables measured at Time 2 (all *p* > *.05*).

Stability of detection accuracy. Effect of video and congruency on detection accuracy moderated by group.

Overall results across time showed a main effect for video category (*F*(1,31) = 46.35, *p* < .001, Cohen's d = 1.09, [95% CI: .72, 1.45]) in which pain-related videos resulted in a better detection compared with non-pain related videos. Also a main effect of congruency occurred (*F*(1,31) = 25.81, *p* < .0001, Cohen's d = -0.62., [95% CI: -1.08, -0.17.]). An interaction occurred between congruency and video category: the CCE was dependent on the type of video presented (*F*(1,31) = 30.40, *p* < .0001, Cohen's d = -.75, [95% CI: -1.11, -.38]). A paired sample t-test showed the CCE was only significant for the pain-related videos (*t*(67) = -5.41, *p* < .001, cohen's d = -0.80, [95% CI: -1.14, -0.47]) and not for the non-pain related videos (t(67) = -1.24, *p* = 0.22, cohen's d = -0.11, [95% CI: -0.27, 0.06]). No main effect occurred for group (*F*(1,31) = .97, *p* = .77) and time (*F*(1,31) = 0.09, *p* =

0.77). An interaction was found between group and congruency (*F*(1,31) = 12.06, *p* = .002). The congruency effect was present in the vicarious pain responder group (*F*(1,13) = 17.09, *p* = .001) but not in the comparison group (F(1,18) = 4.01, p = .06). A significant interaction was found between group, video category and congruency (*F*(1,31) = 13.50, *p* = .001) (Figure 4). The interaction between video category and congruency was only significant for the vicarious pain responder group (*F*(1,13) = 23.37, *p* < .001, cohen's d = -0.98, [95% CI: -1.44, -0.53]). No moderating role was found of any of the individual difference variables measured at both time moments (*all* > *.05*).

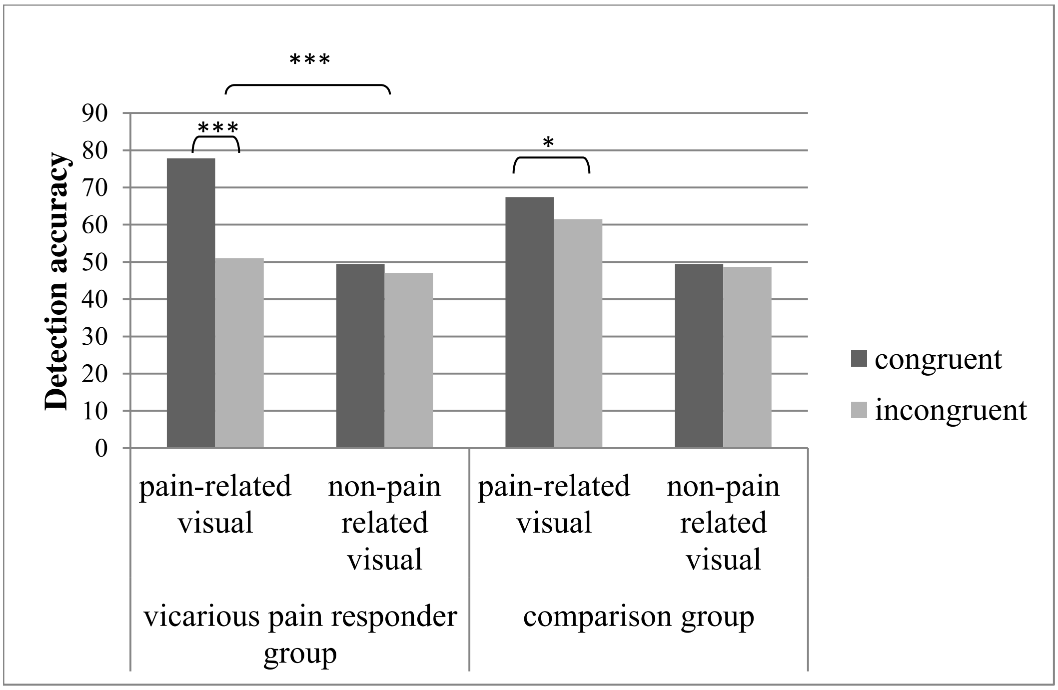

Figure 4. The relationship between video category and congruency for vicarious pain responders and controls (pooled effects).

Neglect errors

Time 1. No effect of group on neglect errors.

A main effect of video category upon the presence of neglect errors was found (Wilcoxon, *p* < .01), indicating that participants more often tended to neglect the side that was incongruent with the visual stimulus when this latter contained pain-related information. In 23.45% of the trials in which both hands were stimulated during the observation of pain-related stimuli, neglect errors were made (197 from a total of 840 trials). Of all neglect errors, 51.27% (*n* = 101) occurred in the vicarious pain responder group. Results based on negative binomial regression models showed that the number of neglect errors during pain-related visual stimuli was not dependent upon group (*p* = .24). No significant interaction was found of group with hypervigilance for pain (*p* = .50) and personal distress (*p* = .29). A significant interaction was found between empathic concern and group (p = .004). For the comparison group, the number of neglect errors during pain-related visual stimuli decreased with 4% (RR = .96) for every 1-unit increase in empathic concern. For the vicarious pain responder group, the number of neglect errors increased with 8% (RR = 1.08) for every 1-unit increase in empathic concern measured at Time 1.

Time 2. No effect of group on neglect errors.

Again, a main effect of video category upon the presence of neglect errors was found (Wilcoxon, *p* < .01) indicating that participants more often tended to neglect the side that was incongruent with the visual stimulus when this latter contained pain-related information. In 22.47% of the trials in which both hands were stimulated during the observation of pain-related stimuli, neglect errors were made (178 from a total of 792 trials). Of all neglect errors 51.69% occurred in the vicarious pain responder group (*n* = 92). Results based on negative binomial regression models showed that the number of neglect errors during pain-related visual stimuli was not dependent upon group (*p* = .07). No significant interaction was found of group with hypervigilance *(p* = .47), empathic concern (*p* = .73) or personal distress (*p* = .07) measured at Time 2.

Stability of neglect errors. No effect of group on neglect errors.

In line with Time 1 and Time 2 results, a main effect of video category upon the presence of neglect errors was found (Wilcoxon, *p* < .01). Neglect errors were made in 22.98% of the trials in which both hands were stimulated during the observation of pain-related stimuli (375 from a total of 1632 trials). Of all neglect errors 51.47% occurred in the vicarious pain responder group (*n* = 193). In contrast with vicarious errors, no large discrepancies occurred in the number of neglect errors during pain-related videos within subjects over time (maximum discrepancy between T1 and T2 was 8 neglect errors). The generalized linear mixed model analysis including Time showed that the number of neglect errors during pain-related videos was independent from group (*p* = .10) or time *(p* = .76). Also no interaction occurred between group and time (*p* = .46). Group did not significantly interact with hypervigilance for pain (*p* = .71), empathic concern (*p* = .11) or personal distress (*p* = .06) measured at both time moments.

GENERAL DISCUSSION

This study investigated whether vicarious pain responders (who report vicarious pain in daily life) and controls (comparison group) differ in the report of vicarious experiences and the detection of somatosensory stimuli while observing another in pain during an experimental paradigm. Furthermore, the stability of vicarious experiences was examined. Additionally, we explored the effects of some potential modulators proposed by Fitzgibbon et al. (2010b, 2012), i.e., dispositional empathy and hypervigilance to pain. Participants were presented a series of videos showing hands being pricked and non-pain related information such as a sponge being pricked whilst receiving occasionally near-threshold vibrotactile stimuli themselves. Participants were required to report whether and where they felt a somatosensory stimulus.

Overall, the occurrence of vicarious experiences was low (8.33% at Time 1, 13.45% at Time 2). Nevertheless, the percentage of vicarious errors was larger than those reported by Vandenbroucke et al. (2013; 0.88% in study 1 and 2.7% in study 2) using a highly similar paradigm. A notable difference was the use of vibrotactile stimuli near threshold in the present study, whereas in the study of Vandenbroucke et al. (2013) electrocutaneous stimuli that elicited painful pricking experiences were used. Probably, the vicarious experiences are subtle, vague sensations that are more easily confused with low intense tactile sensations than with painful sensations. This explanation is in line with the study of Osborn & Derbyshire, 2010), who reported that participants most often described vicarious sensations as “tingling”.

Of interest to this study was whether participants who reported vicarious pain experiences in daily life, also displayed more vicarious experiences in an experimental setup. Our results show that this is indeed the case, and therefore extend the results of a previous study (Vandenbroucke et al., 2013). Our study did not only focus upon vicarious experiences, but also a less extreme position, i.e. the modulation of detection of tactile stimuli during the observation of pain-related and non-pain related situations. This objective was accomplished by investigating detection accuracy of vibrotactile stimuli and neglect errors. The observation of pain-related videos facilitated the detection of vibrotactile stimuli. In the present study, vicarious pain responders were also better in detecting vibrotactile stimuli when pain-related videos and vibrotactile stimuli were presented in the same spatial location than when presented in an opposite location. This is consistent with reaction time research of Banissy & Ward (2007) showing that vicarious responders were faster at identifying a site touched on their face or hands when actual touch was congruent with their vicarious touch compared with incongruent trials. This pattern was not found in the study of Banissy & Ward (2007) when participants observed touch to objects. The results in this experiment are consistent with the idea that observing bodily sensations might influence own somatic experiences (Constantini et al., 2008; Godinho et al., 2006; Han et al., 2009; Jackson et al., 2006). Neuroimaging and EEG studies have shown that the observation of touch leads to an enhanced activation in the somatosensory cortices (Blakemore et al., 2005; Ebisch et al., 2008; Martinez-Jauand et al., 2012; Pihko et al., 2010; Schaefer et al., 2006) which could explain the conscious experience of vicarious sensations as these brain regions are more related to interpreting the localization and intensity of a nociceptive stimulus (Bushnell et al., 1999). In our study, both groups evidenced a similar number of neglect errors. Compared with vicarious errors, neglect errors were more frequently made (Time 1: 23.45%;

Time 2: 22.47%) and were as common in both groups. This again suggests that the observation of pain-related information may rather give rise to a modulation of somatosensory experiences rather than the pure induction of illusionary experiences.

Furthermore, the phenomenon seemed to be robust: the phenomenon was also observed when these participants performed the experiment a second time, five months later. This is an important finding. Often participants who report vicarious experiences in daily life are invited for further investigations at a later time. It is therefore important to know that the phenomenon is stable across time. The general increase of vicarious errors at time two may be due to other factors such as memory processes as participants may recognize the experiment in which they all already participated. Nevertheless, there are some issues that deserve further scrutiny. First, stability was observed at group level, but there was variation at the individual level. We observed that two of the four vicarious pain responders who were responsible for most vicarious experiences at time two (35 and 32 vicarious errors respectively) did not show this pattern at time one (4 and 5 vicarious errors respectively). A similar variability between individuals, but to a lesser extent was observed for individuals from the comparison group. Further research may examine those individuals demonstrating stability in the report of vicarious experiences on a single case level. Probably these individuals may share features in contrast to those showing a variability in the report of vicarious experiences. Second, some models (Fitzgibbon et al., 2010b, 2012) proposed that individual characteristics such as dispositional empathy and hypervigilance are important moderators. Our results regarding these variables are variable and not consistent across time. It may well be that these individual difference variables may be less important than previously suggested. In order to further the research, we propose that authors are transparent about which individual difference variables are assessed, and systematically report these results, albeit that they are not significant (Simmons et al., 2011). That way a publication bias may be prevented, and a strong database for future secondary or meta-analytic analyses may be developed.

Some limitations of the present study deserve further consideration. First, vibrotactile stimuli were administered instead of painful stimuli. This enhanced the occurrence of vicarious experiences which we consequently not labeled as vicarious pain. Second, only few people reported vicarious pain experiences in daily life, resulting in a small sample size. Also, our sample was unbalanced in terms of gender. The number of vicarious pain responders who took part in the experiment was, however, comparable to other studies including participants reporting vicarious bodily sensations (Banissy and Ward, 2007; Osborn and Derbyshire, 2010, Vandenbroucke et al., 2013). Third, it is unclear to what extent the observed effects are specific to observing pain: We did not include videos in which a hand is being touched. Future research may compare the effects of touch videos and pain videos upon several outcomes to disentangle the pain-specific effects upon somatosensation. Previous studies were also not able to disentangle the effects of observing pain versus touch as they compared observing touch versus no touch (i.e. a light), human parts being touched versus the observation of the human body, observing touch and experiencing touch (e.g. Blakemore et al., 2005; Cardini et al., 2011; Gillmeister, 2014; Keysers et al., 2004; Serino et al., 2008). Finally, we included video clips showing hands being pricked. These videos depict less intense pain compared to the images and movies used in the study of Osborn and Derbyshire (2010). Some may argue that vicarious experiences may be elicited more easily when very intense pain is observed. That said, vicarious pain responders in this study reported more vicarious errors during the observation of a subtle injury (the needle prick) as compared with controls, indicating that vicarious experiences can also be observed with low intense pain stimuli.

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CHAPTER 4

Vicarious experiences and detection accuracy while observing pain and touch: the effect of perspective taking[5]

ABSTRACT

Objective: This study investigated the effects of observing pain and touch in others upon vicarious somatosensory experiences and the detection of subtle somatosensory stimuli. Furthermore, the effect of taking a first versus third-person perspective was investigated.

Methods: Undergraduates (N = 57) viewed videos depicting hands being pricked (pain), hands being touched by a cotton swab (touch), and control scenes (same approaching movement as in the other video categories but without the painful/touching object), while experiencing vibrotactile stimuli themselves on the left, right or both hands. Participants reported the location at which they felt a somatosensory stimulus. Vibrotactile stimuli and visual scenes were applied in a spatially congruent or incongruent way. There were also trials without vibrotactile stimuli. The videos were depicted in first-person perspective and third-person perspective (videos upside down). We calculated the proportion of correct responses and false alarms (i.e., number of trials in which a vicarious somatosensory experience was reported congruent to the site of the visual information).

Results: Pain-related scenes facilitated the detection of tactile stimuli and augmented the number of vicarious somatosensory experiences compared with observing touch or control videos. Detection accuracy was higher for videos depicted in first-person perspective compared with third-person perspective. Perspective had no effect upon the number of vicarious somatosensory experiences.

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[5] Based on: Vandenbroucke, S., Crombez, G., Loeys, T., & Goubert, L. (under review). Vicarious experiences and detection accuracy while observing pain and touch: the effect of perspective taking. Attention, perception & Psychophysics.

Conclusion: This study indicates that somatosensory detection is particularly enhanced during the observation of pain-related scenes compared to the observation of touch or control videos. These research findings further demonstrate that perspective taking impacts somatosensory detection, but not the report of vicarious experiences.

INTRODUCTION

Our senses do not operate independently (Spence & Driver, 2004). For example, tactile perception is facilitated when viewing the body. Such findings suggest a strong link between vision and somatosensation (Kennett, Taylor-Clarke, & Haggard, 2001). Also, observing somatosensory stimuli being applied to another person influences the detection of tactile stimuli in the observer (Cardini, Haggard, & Lavadas, 2013; Gillmeister, 2014; Vandenbroucke et al., 2014a, 2014b). In line with this finding, brain processing studies have shown that somatosensory activity is enhanced when observing bodily sensations in others (Blakemore et al. 2005; Ebisch et al. 2008; Keysers, Kaas, & Gazola, 2010; Schaefer et al., 2005, 2012). An extreme variant of the modulation of somatosensory detection by observing touch or pain, is the actual experience of such sensations although no stimulus is presented ('vicarious somatosensory experiences'). Vicarious somatosensory experiences are intriguing as they indicate that tactile or nociceptive input may not be necessary to experience touch or pain (Fitzgibbon et al., 2010b).

Little systematic research is available on the occurrence of vicarious somatosensory experiences and the factors affecting this phenomenon (Fitzgibbon et al., 2010b, 2012; Osborn & Derbyshire, 2010; Vandenbroucke et al., 2013, 2014a). Vandenbroucke et al. (2013, 2014b) showed that individuals reporting vicarious pain in daily life ('pain responders') reported more vicarious somatosensory experiences during an experimental paradigm, but the frequency was very low. Using the same paradigm, Vandenbroucke et al. (2014a) showed that the presence of chronic pain did not affect the frequency of somatosensory experiences. Derbyshire, Osborn & Brown (2013) investigated the influence of prior pain experience and bodily ownership upon the experience of vicarious sensations. They showed that the tendency to report vicarious experiences was enhanced when the type of observed pain (e.g., toothache) had been commonly experienced by the observer him/herself. Interestingly, previous studies also demonstrated that the observation of pain facilitates the detection of tactile stimuli (Vandenbroucke et al., 2014a, 2014b).

It is yet unclear whether the modulatory effects of observing pain upon somatosensation are specific (or different) for pain, or may equally be present when observing touch. Some studies did not investigate the experience in terms of behavioral somatosensory detection in response to the observation of painful stimuli but rather looked at the somatosensory brain activity. Bufalari et al. (2007) showed a reduction of somatosensory activity with respect to baseline when observing non-painful tactile stimuli in comparison with an increase when observing painful stimuli. Cheng et al. (2008) reported that both observing painful and non-painful situations were associated with enhanced activation of somatosensory cortex as compared with baseline. Martínez-Jauand et al. (2012) showed that the observation of both pain and touch video clips led to an enhancement of P50 amplitudes as compared to viewing a hand without stimulation. Of particular relevance is the study of Valentini et al. (2012). These authors showed that viewing pain in another specifically modulates specifically the neural activity in the onlookers' sensorimotor cortex, and that this modulation occurs only in the neural activity elicited by stimuli belonging to the nociceptive, rather than to another sensory modality. There is evidence that observing touch improves tactile discrimination (Kennett et al., 2001) and that observing pain enhances detection accuracy (Vandenbroucke et al., 2014a, 2014b). However, there is yet no research investigating whether there is a difference between observing touch versus pain in another. Some behavioral studies did focus upon the somatosensory modulation, but no study directly compared the effect between observing pain and touch. Some studies compared the effects between human parts being touched versus the observation of the same parts merely being approached (Cardini et al., 2011; Serino et al., 2008), between observing touch and experiencing touch (Blakemore et al., 2005; Keysers et al., 2004), between observing touch to a person versus touch to an object (Blakemore et al., 2005; Cardini et al., 2011; Serino et al., 2008), between experiencing touch versus observing an object being touched (Keysers et al., 2004) and between observing pain versus an object being pricked or approached (Vandenbroucke et al., 2014a, 2014b). The first aim of the present study was therefore to investigate whether the effects upon vicarious experiences or the detection of somatosensory stimuli differ between the observation of touch versus pain in another.

A variable that may play a role in the production of vicarious experiences is perspective taking (Fitzgibbon et al., 2010b), i.e., whether one considers the observed pain or touch from first-person versus third-person (another's) perspective. It has been proposed that vicarious somatosensory experiences may be enhanced when a self-perspective is adopted (Fitzgibbon et al., 2010b). No study has investigated this idea. However, studies indicate that the installation of a first-person perspective, either by means of an experimental paradigm or by means of instructions or visual appearance facilitates/affects the detection of somatosensory stimuli (Loggia, Mogil, & Bushnell, 2008; Serino, Giovagnoli, & Lavadas, 2009; Serino et al., 2008). In the paper of Serino et al. (2009), similarity between the self and the observed other was manipulated by increasing and decreasing physical similarity. These authors depicted someone of the own or a different ethnic group or mentioned political opinions of the observed person (e.g. similar or opposite to the participants' opinions). This paper showed that observing another facilitated tactile perception in particular when self-other similarity was high. In the study of Loggia et al. (2008), similarity was manipulated by showing participants video interviews with an actor in which empathy for the actor was manipulated. At the end, participants saw the actor being exposed to similar stimuli as themselves. Those in the high-similarity group rated the painful stimuli as more intense. At present, it is yet unclear whether taking a self-perspective (versus other-perspective) facilitates the experience of vicarious sensations. A second aim of the present study was to investigate the role of perspective taking upon vicarious somatosensory experiences and the detection accuracy of subtle vibrotactile stimuli.

In a variant of the crossmodal congruency task, participants were presented three categories of videos depicting pain-related situations (left and right hand in which one hand is being pricked), touch (left and right hand in which one is touched by cotton swab) and control situations (e.g. same motor movement of the approaching hand as in first and second category but without the painful/touching object). Participants occasionally received vibrotactile stimuli on the hand in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual stimuli, or on both hands. Participants were instructed to report as quickly as possible the spatial location of the administered somatosensory stimuli. Also trials in which no vibrotactile stimulation occurred were included as well as trials in which both hands of participants were stimulated. To investigate the effect of perspective taking, videos were presented in a first-person and a third-person perspective (videos presented upside down). False alarms (erroneously reporting a somatosensory stimulus in the same spatial location as the visual cue) in response to videos showing pain or touch were labeled 'vicarious somatosensory experiences'.

First, we hypothesized that participants would report more vicarious experiences (false alarms) in response to the observation of pain compared with touch or control videos. Second, we expected that the observation of pain-related visual scenes would result in a better detection accuracy of vibrotactile stimuli compared with touch and control videos. We furthermore expected a crossmodal congruency effect (CCE) in which more vibrotactile acuity is observed when the visual and vibrotactile stimuli are congruent (i.e. presented in the same spatial location). We hypothesized this CCE effect to be dependent upon the type of visual information (pain-related versus touch versus control). More specifically, we expected a higher CCE when pain-related videos were shown as compared to non-pain related video's (touch and control). Third, we expected that pain-related videos presented in first-person perspective would facilitate detection accuracy and increase the report of vicarious experiences compared with pain-related videos presented in third-person perspective. In addition, we also explored the presence of neglect errors (i.e. only reporting the site congruent to the visual information when both hands are stimulated) during the observation of each category of video and perspective. As in previous studies (Vandenbroucke et al, 2013, 2014a,b), we investigated the putative role of some individual difference variables upon vicarious experiences. In the model of Fitzgibbon et al. (2010b), it is suggested that individual differences in empathy and hypervigilance to pain would lead to more vicarious experiences. For that reason, we assessed both variables through self-report questionnaires and explored their role in vicarious experiences and the detection of vibrotactile stimuli.

METHOD

Participants

Undergraduate psychology students (*n* = 57) were recruited by means of an online system where they could subscribe for experiments. They were paid 10 euro for participation. Seventy-five percent were female. Seventy-nine percent of the participants were right-handed as reported by self-report. All were Caucasian. Average age of participants was 23.68 years (*SD* = 4.62). Participants rated their general health on average as 'Very good'. Sixty-three percent of the participants reported to have experienced pain during the last six months (average of 27.6 days in 6 months). Fourteen participants reported pain at present (score > 0 on a Likert scale where 0 indicated 'no pain' and 10 'worst pain ever'; assessment before the experiment), but the average intensity was low (*M* = 2.64, *SD* = 1.78). All participants gave informed consent and were informed to be free to terminate the experiment at any time. None made use of this possibility. Ethical approval was obtained from the Ethics committee of the Faculty of Psychology and Educational Sciences.

Self report measures

Vigilance to pain was assessed by the Dutch version of the Pain Vigilance and Awareness Questionnaire (PVAQ; McCracken, 1997, Roelofs et al., 2002). This questionnaire consists of 16 items assessing awareness, consciousness and vigilance to pain on a six-point scale (0 = never; 5 = always). Higher scores on the PVAQ are indicative of greater pain-related vigilance and awareness. The questionnaire can be used in both clinical (McCracken, 1997; Roelofs, Peters, McCracken, & Vlaeyen, 2003) and non-clinical (McWilliams & Asmundson, 2001; Roelofs et al., 2002) samples. The Dutch version of the PVAQ is reliable and valid (Roelofs et al., 2002; 2003). Cronbach's alpha in the present study was 0.91.

Empathic disposition was assessed by means of the Dutch version of the Interpersonal Reactivity Index (IRI; Davis, 1983; De Corte et al., 2007). The questionnaire contains 28 items and consists of 4 subscales: Perspective Taking (i.e., cognitively taking the perspective of another, e.g., "I sometimes try to understand my friends better by imagining how things look from their perspective.”), Fantasy (i.e., emotional identification with characters in books, movies etc., e.g., “When I watch a good movie, I can very easily put myself in the place of a leading character.”), Empathic Concern (i.e., feeling emotional concern for others, e.g., “I am often quite touched by things that I see happen.”) and Personal Distress (i.e., negative feelings in response to the distress of others, e.g., “When I see someone who badly needs help in an emergency, I go to pieces.”). Each item is answered on a scale ranging from 1 (‘does not describe me very well’) to 5 (‘describes me very well’). This questionnaire has shown to be reliable and valid (Davis et al., 1893; De Corte et al., 2007). Cronbach’s alpha’s in the current study were 0.78 (fantasy scale), 0.80 (personal distress), 0.64 (perspective taking) and 0.60 (empathic concern). Perspective taking and empathic concern were omitted from the analyses because of the low reliability score.

Vicarious pain experiences during daily life were measured by means of four items adapted from Banissy et al. (2009). Participants were asked to indicate on an eleven point scale (0 - 10; totally disagree - totally agree) the extent to which they agreed with the questions: “Do you feel pain in your own body when you see someone accidently bump against the corner of the table?”, “Do you have the feeling experiencing pain when you observe another person in pain?”, “Do you feel bodily pain when you observe another person in pain?”, “Do you feel a physical sensation (e.g. tingling, stabbing) when you observe another person in pain”. We have used this adapted instrument in previous studies (Vandenbroucke et al., 2013, 2014a). In the present study Cronbach’s alpha was 0.87.

Procedure

Behavioral paradigm

*Preparation phase***.** First, for each participant, the threshold intensity level for the vibrotactile stimuli was individually determined prior to the experiment. Vibrotactile stimuli (50 Hz, 50 ms) were delivered by two resonant-type tactors (C-2 tactor, Engineering Acoustics, Inc.) consisting of a housing that was 3.05 cm in diameter and 0.79 cm high, with a skin contactor that was 0.76 cm in diameter. The vibrotactile stimuli were delivered on the skin between thumb and index finger. All stimulus characteristics (amplitude, duration and frequency) were entered through a self-developed software program that was used to control the tactors. Four different series of 20 stimuli/trials (two series for each hand) were randomly administered (80 stimuli/trials in total). First, a visual stimulus “X” was presented combined with a somatosensory stimulus on the left or right hand. Participants were instructed to report whether they felt a somatosensory stimulus (“yes” or “no”), which was coded by the experimenter by pressing the corresponding response button (see Vandenbroucke et al., 2014a, 2014b). Each series started at 0.068 Watt and this intensity decreased with 0.0002W within each series when participants reported feeling a stimulus and increased with 0.0002W when no sensation was reported. After 80 trials, this resulted in a threshold intensity for each hand which was based upon the mean intensity of the last stimuli (20th) of two series for that particular hand. From this threshold intensity (threshold left hand: *M* = 0.033W, *SD* = 0.008W, range: 0.002W - 0.174W; threshold right hand: *M* = 0.038W, *SD* = 0.006W, range: 0.003W - 0.163W), 1/8 was added to the threshold (above threshold), resulting in four different intensities (threshold and above threshold, one for each hand). Several intensities were implied in order not to habituate to the intensity as well as to enhance the chance to make vicarious errors.

Second, participants were informed that during the experiment they would feel subtle stimuli, varying in intensity and length, on their left, right or both hands. Participants were instructed that different videos would be presented which they needed to watch attentively and that when a somatosensory stimulus was administered on both hands, the intensity could vary across hands and that also trials without any stimulus would be included. In reality, only two fixed predetermined intensities with a fixed duration were applied (threshold intensity and threshold intensity + 1/8).

Experiment phase. Visual stimuli consisted of three categories of videos (pain, control and touch) with a duration of 3000ms. The first, ’pain category’ included a scene depicting a left and right hand, with one of the two hands being pricked by a syringe (2000ms after video onset). The second category depicted a touch scene. A left and right hand were presented in which one of these hands was touched by a cotton swab (2000ms after video onset). The third ‘control category’ included a scene depicting a left and right hand in which one hand was approached by a hand without holding an object (same movement of the approaching hand as in the first and second category of videos). Videos were presented by INQUISIT Millisecond software (Inquisit, 2002) on a Dell screen with a 19-inch CRT-monitor. The computer screen was placed in front of the participants in a degree of approximately 22°. Participants' hands were placed underneath the screen. The left hand was placed at the left and the right to the right under the screen to make the perspective taking manipulation more salient.

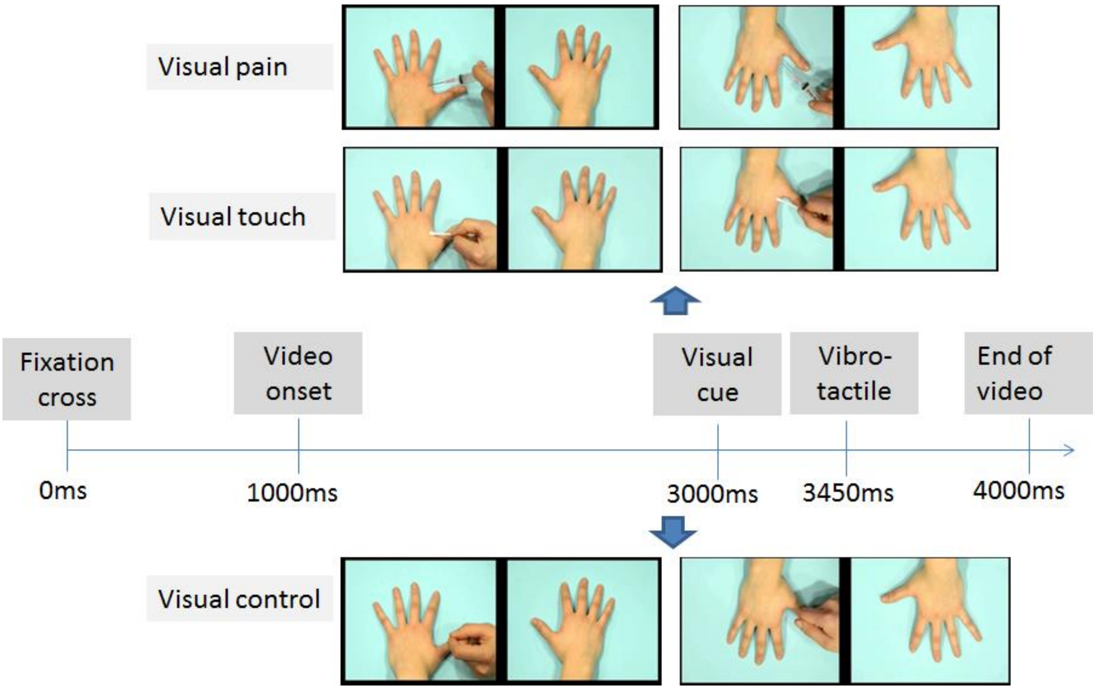


Figure 1. Time line of a trial including vibrotactile stimulation

Each trial began with a fixation cross (1000 ms duration) presented in the middle of the computer screen. Next, one of the videos was presented. In 75% of the trials, a vibrotactile stimulus was delivered 2450 ms after video onset either on the left hand, the right hand, or on both hands of the participant. In line with Banissy & Ward (2007), the somatosensory stimulus was administered with a delay (in this study 450ms) after the visual stimulus of penetration of the needle, or the touch of the cotton swab (see Vandenbroucke et al., 2014a, 2014b). For the control videos, the somatosensory stimulus was administered with a delay of 450ms after the approaching hand was closest to the resting hand (same time frame as in the other video categories). This resulted in the following trial types: congruent trials, incongruent trials, and trials in which no somatosensory stimuli were administered, or both hands of the participant received somatosensory stimuli. In congruent trials, somatosensory stimuli and visual stimuli were presented at the same spatial location (e.g., right). In incongruent trials, somatosensory stimuli and visual stimuli were presented in the opposite spatial location (e.g., left and right). The experiment started with 8 practice trials. The actual experiment phase consisted of five blocks of 96 trials, resulting in a total of 480 trials. There were 120 congruent trials, 120 incongruent trials, 120 trials without sensory stimuli and 120 trials with somatosensory stimuli at both hands. These three categories of videos were in an equal number presented in first-person perspective (240 trials; i.e. presented in same orientation as the hands of the participant) and third-person perspective (240 trials; i.e., the same videos turned upside down) (see Figure 1). The different categories, location of visual cue (touch, pain, control), congruency (congruent, incongruent, both hands stimulated, and both hand not stimulated) and perspective (first- versus third-person) were counterbalanced across videos. Order of trial types was randomized within each block. The somatosensory stimuli were equally distributed within and over each block, type of intensity (threshold and above threshold) and type of perspective (first versus third perspective).

An overview of all trial types is presented in Table 1. During each trial, participants were requested to report whether a somatosensory experience was felt by reporting as quickly as possible ‘YES’ and to discriminate the spatial location of the somatosensory stimuli by reporting “left”, “right” or “both” (see Figure 2). After the video had ended and 2000 ms had been elapsed, the Dutch word for ‘next’ was presented on the screen. Then, the experimenter coded the response by pressing the corresponding response button (left, right, both or no response) (see Figure 1). This way, the time to respond was equal for every participant. The experiment took approximately 1 hour.

Post-experiment phase. After the experiment, participants were requested to fill out self-report scales measuring hypervigilance for pain (PVAQ), empathic disposition (IRI) and the items measuring vicarious pain experiences during daily life, which took approximately 15 minutes.

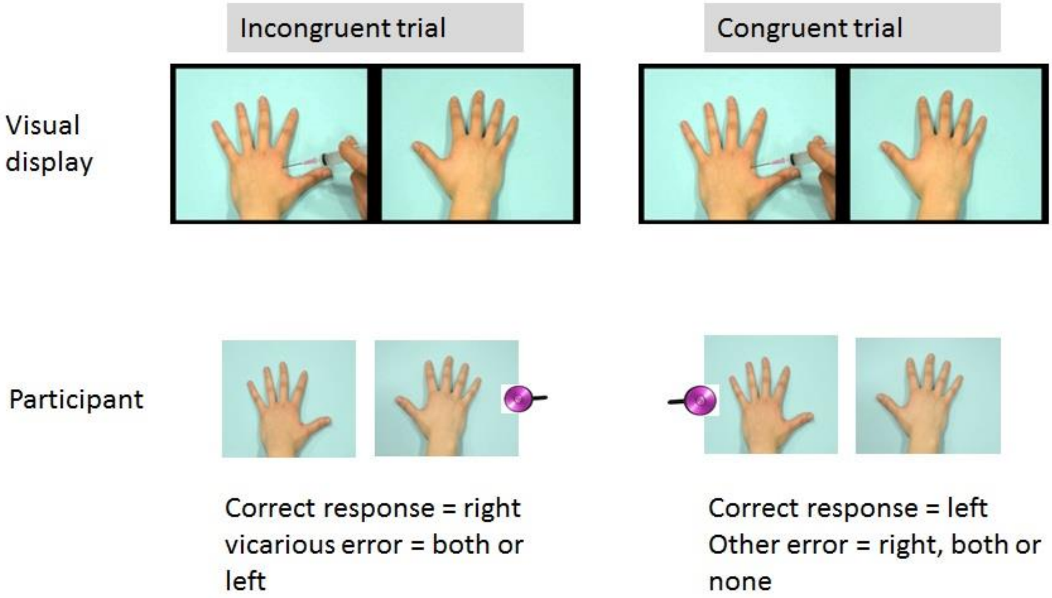


Figure 2. Example of a possible trial

Table 1

Overview of all trial types

	INCONGRUENT TRIALS				CONGRUENT TRIALS				TRIALS WITHOUT TACTILE STIMULATION				BOTH HANDS OF PARTICIPANT STIMULATED			
Reported site participant	Correct site	Opposite site (=site of visual)	Both hands	No hands	Correct site	Opposite site to visual and tactile	Both hands	No hands	Site congruent to visual	Opposite site to visual	Both hands	Correct No hands	Visual site	Opposite site to visual	Correct Both hands	No hands
Visual pain 1st perspective	59.83 %	1.84% *false alarms -vicarious experiences*	2.63% *false alarms -vicarious experiences*	35.70 %	73.86 %	0.61 %	1.23 %	24.30 %	3.51% *false alarms-vicarious experiences*	1.14 %	0.70 %	94.65 %	22.37% *neglect errors*	12.28 %	49.74 %	15.61 %
Visual control 1st perspective	50.96 %	1.40% *false alarms*	1.93% *false alarms*	45.70 %	57.37 %	0.53 %	1.75 %	40.35 %	1.58% *false alarms*	1.58 %	0.17 %	96.67 %	20.26% *neglect errors*	14.30 %	39.91 %	25.53 %
Visual touch 1st perspective	59.39 %	1.05% *false alarms-vicarious experiences*	1.32% *false alarms-vicarious experiences*	38.25 %	66.23 %	0.70 %	1.32 %	31.75 %	2.37% *false alarms-vicarious experiences*	1.49 %	0.35 %	95.79 %	20.35% *neglect errors*	14.04 %	44.39 %	21.23 %
Visual pain 3th perspective	57.98 %	2.02% *false alarms-vicarious experiences*	2.81% *false alarms-vicarious experiences*	37.19 %	69.21 %	0.44 %	1.32 %	29.04 %	3.60% *false alarms-vicarious experiences*	1.49 %	0.26 %	94.65 %	22.89% *neglect errors*	11.84 %	48.95 %	16.32 %
Visual control 3th perspective	50.53 %	1.58% *false alarms*	1.14% *false alarms*	46.75 %	52.89 %	0.26 %	.88 %	45.96 %	1.58% *false alarms*	1.32 %	0.18 %	0.97 %	17.81% *neglect errors*	15.0 %	42.11 %	25.09 %
Visual touch 3th perspective	54.04 %	1.32% *false alarms-vicarious experiences*	1.23% *false alarms-vicarious experiences*	43.42 %	60.53 %	0.53 %	1.58 %	37.37 %	2.37% *false alarms-vicarious experiences*	1.58 %	0.44 %	95.61 %	20.09% *neglect errors*	16.49 %	40.35 %	23.07 %

Statistical analysis

False alarms

The number of false alarms was calculated from the incongruent trials and from the trials without any somatosensory stimuli when erroneously a somatosensory stimulus was reported in the same spatial location as the visual cue (i.e. site of the touch/prick or approaching movement). These false alarms were labeled ‘vicarious somatosensory experiences’ when the visual stimulus contained pain or touch. To test whether category of video predicted the number of false alarms, generalized linear mixed models for count data were applied. The use of linear models is considered less appropriate (Vives et al., 2006) when the frequency of responses has a skewed distribution that violates the normality assumption. Poisson regression is the basic model to analyze count data, but the variance of counts is often larger than the mean (overdispersion). The Negative Binomial (NB) regression, a Poisson regression with an overdispersion, may therefore better fit the data (e.g., Gardner et al., 1995). As count data may additionally exhibit a lot of zero counts, zero-inflated extensions of both models, called Zero-Inflated Poisson (ZIP) and Zero-Inflated NB (ZINB) models have been developed (see Karazsia et al., 2010, Loeys et al., 2012). Deviance tests and the Vuong test were used to select the best fitting count distribution for the dependent variable. After the best fitting count model was chosen, a first model with ‘video category’ as predictor was added. In a further exploration of the data, hypervigilance for pain, and dispositional empathy and their interaction with video category were added in separate models to test whether they had a moderating role. Dummy coding was used for the categorical variables. Regression coefficients are exponentiated (eB) and called Rate Ratios (RRs). In percentages—100 x (eB -1)—RRs reflect the percentage decrease (RR < 1) or increase (RR > 1) in the expected frequency of false alarms for each 1-unit increase in the continuous predictor. In a second series of analyses, the above mentioned analyses were repeated with ‘perspective’ (first-person versus third-person) as predictor. In a third model both video category and perspective were added as predictors. R (version 2.15.1) was used to fit the count models.

Detection accuracy

To investigate whether type of video category and type of perspective taking modulated the detection of vibrotactile stimuli, the proportion of correct responses (left versus right) for congruent and incongruent trials for each category of visual information was calculated (pain-related, touch and control). A 3 (video category: pain-related, touch versus control) x 2 (congruency: congruent versus incongruent) x 2 (perspective: first-person versus third-person) repeated measures ANOVA was performed, with congruency, video category and perspective entered as within-participant variables. In a further exploration, hypervigilance for pain and dispositional empathy were added as a covariate in separate models to test whether they had a moderating role. Repeated measure ANOVAs were conducted with an alpha < 0.05, using SPSS statistical software, version 21.0 for Windows.

Neglect errors

The number of neglect errors was calculated based upon those trials in which both hands were stimulated, defined as reporting only the site congruent to the visual information (i.e. site of the touch/prick or approaching movement) and missing the actual vibrotactile stimuli on both hands. Generalized linear mixed models for count data were applied again to test whether the number of neglect errors was dependent upon the type of video and perspective. After the best fitting count model was chosen, a first model with ‘type of video’ as predictor was added. In a further exploration, hypervigilance for pain and dispositional empathy and their interaction with type of video were added in separate models to test whether they had a moderating role. In a second series of analyses, ‘perspective’ (first-person versus third-person) was added as predictor. In a third model both video category and perspective were added as predictors. R (version 2.15.1) was used to fit the count models.

RESULTS

Descriptives

Mean scores, standard deviations and correlations are presented in Table 2. Spearman correlations were computed for the non-normally distributed variables

(Kolmogorov-Smirnoff, p < .05). Without taking type of video in account, false alarms were made in 2.94% of the incongruent trials and trials without vibrotactile stimuli (402 false alarms from a total of 13680 trials). Vicarious somatosensory errors in response to the observation of pain-related scenes were made in 4.10% of the incongruent trials and trials without vibrotactile stimuli (187 vicarious somatosensory errors from a total of 4560 trials). Of these vicarious somatosensory errors, 48.66% occurred when the pain-related video was in first-person perspective (91 from a total of 187 vicarious somatosensory errors). Vicarious somatosensory errors in response to the observation of touch scenes were made in 2.41% of the incongruent trials and trials without vibrotactile stimuli (110 vicarious somatosensory errors from a total of 4560 trials). Of these vicarious somatosensory errors, 49.09% occurred when the touch video was in first-person perspective (54 from a total of 110 vicarious somatosensory errors). In 20.63% of the trials in which both hands were stimulated, neglect errors were made (1411 neglect errors from a total of 6840 trials). Neglect errors were made in 22.63% of all trials with pain-related videos (516 neglect errors from a total of 2280 trials). Of these neglect errors, 255 (49.42%) occurred when the pain-related video was shown in first-person perspective.

Table 2

Pearson/Spearman correlations, mean scores and standard deviations of all measures

	M (SD)	2.	3.	4.	5.	6.	7.	8.
1. Vicarious somatosensory errors (pain videos-first perspective)	1.60 (2.69)	47**	.40**	.36**	.24	.07	.14	.11
2. Vicarious somatosensory errors (pain videos -third perspective)	1.68 (3.00)	-	.30*	.11	.07	.03	.03	.21
3. Neglect errors (pain videos - first perspective)	4.47 (3.06)		-	.54**	.09	.03	.02	.23
4. Neglect errors (pain videos – third perspective)	4.58 (2.32)			-	.15	.14	.02	-.05
5. Hypervigilance for pain (PVAQ)	33.95 (13.52)				-	.22	.10	-.01
6. Personal distress (IRI)	12.97 (4.62)					-	.04	.05
7. Fantasy (IRI)	19.11 (4.73)						-	.04
8. Vicarious pain daily in life (sumscore of 4 items)	15.09 (9.18)							-

Note. PVAQ=Pain Vigilance and Awareness Questionnaire; IRI=Interpersonal Reactivity Index
* $p<0.05$; ** $p<0.01$

False alarms and vicarious experiences

The NB model was found to be the best fitting count model. In a first step, video category was added as a predictor. Results showed that the number of false alarms was dependent upon type of video presented (see Table 3). The observation of pain-related videos resulted in 81% increase in false alarms compared with control videos (RR = 1.81) (*p* < .001). The observation of pain-related videos resulted in 70% increase in false alarms or vicarious experiences compared with touch videos (RR = 1.81) (*p* < .001). No significant difference was found between touch videos and control videos regarding the number of false alarms made (*p* = .70). In order to explore the role of individual differences in PVAQ and the IRI, several additional models were run with PVAQ or IRI as additional predictor to explore its modulating role. No interactions were found between type of video and PVAQ (all *p* > .18), personal distress (all *p* > .28) and fantasy scale (all *p* > .41).

In a separate model, perspective was added as a predictor. Results showed that the number of false alarms was independent of type of perspective (*p* = .89). In a third model both type of video and type of perspective were added as predictors. No interaction occurred between video category and perspective (all *p* > .64).

Table 3

Rate Ratio and Confidence Intervals for neglect errors and false alarms

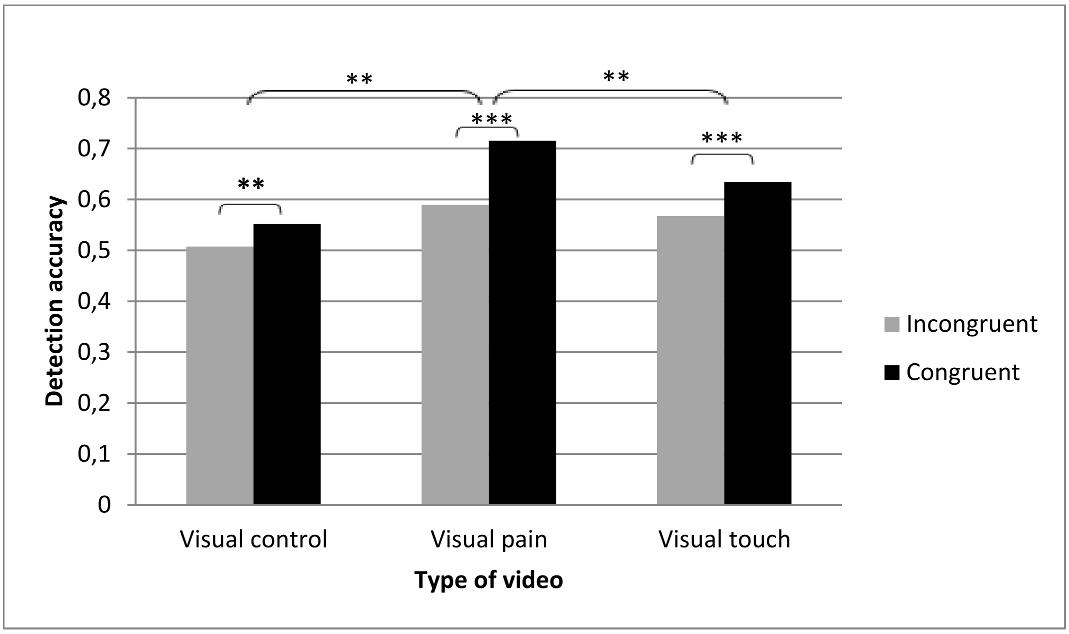
	false alarms	neglect errors
Variables	RR (e^B) (95% CI)	RR (e^B) (95% CI)
Video pain vs control	1.81*** (1.37, 2.38)	1.19** (1.05, 1.35)
Video pain vs touch	1.70*** (1.30, 2.23)	1.12 (0.99, 1.27)
Video touch vs control	0.94 (0.70, 1.27)	0.94 (0.83, 1.07)
Perspective third vs first	1.02 (0.80, 1.29)	0.97 (0.87, 1.07)

Note. RR = rate ratios*;* CI = confidence interval; * p < .05 ** *p* < .01. *** *p* < .001.

Detection accuracy

A 2 (congruency: congruent versus incongruent) x 2 (type of perspective: first-person versus third-person) x 3 (type of video: pain versus touch versus control) repeated measures ANOVA showed a main effect for type of video (*F*(2,112) = 41.49, *p* < .001). Overall, pain-related videos resulted in a better detection of vibrotactile stimuli compared with control videos (*t*(56) = 7.99, *p* < .0001, Cohen's d = 0.68, [95% CI: 0.49, 0.86]) and touch videos (*t*(56) = 4.29, *p* < .0001, Cohen's d = 0.27, [95% CI: 0.15, 0.39]). Detection accuracy while observing touch videos was significantly higher compared with observing control videos (*t*(56) = -5.48, *p* < .0001, Cohen's d = 0.37, [95% CI: 0.23, 0.51]). Also a main effect for congruency occurred (F(1,56) = 64.23, *p* < .0001, Cohen's d = 0.43, [95% CI: 0.32, 0.54]), indicating a higher detection accuracy in congruent compared to incongruent trials.

An interaction was found between congruency and type of video: the CCE was dependent on the type of video presented (*F*(2,112) = 7.42, *p* = .001). A paired sample t-test showed the CCE was present for each type of video (pain video (*t*(56) = -6.66, *p* < .0001, Cohen's d = -0.63, [95% CI: -0.84, -0.43]); control video (*t*(56) = -3.11, *p* = .003, Cohen's d = -0.23, [95% CI: -0.38, -0.08]); touch video (*t*(56) = -4.48, *p* < .0001, Cohen's d = -0.32, [95% CI: -0.47, -0.18]). The congruency effect was, however, significantly larger for pain videos compared with control videos (*t*(56) = 3.56, *p* = .001, Cohen's d = 0.65, [95% CI: 0.26, 1.05]) and touch videos (*t*(56) = 2.66, *p* = .01, Cohen's d = 0.46, [95% CI: 0.10, 0.82]). The congruency effect was not significantly different for touch videos and control videos (*t*(56) = -1.10, *p* = .28, Cohen's d = -0.21, [95% CI:-0.58, 0.16]) (see Figure 3). Also a main effect of perspective was found (*F*(1,56) = 24.59, *p* < .0001, Cohen's d = -0.20, [95% CI: -0.28, -0.12]), indicating that observing videos in first-person perspective resulted in better detection compared with videos shown in third-person perspective. No interaction was found between type of perspective and type of video category (*F*(2,112) = 1.75, *p* = .18), between type of perspective and congruency (*F*(1,56) = 2.60, *p* = .11) and between type of perspective, type of video category and congruency (*F*(2,112) = .55, *p* = .58). Centered PVAQ and IRI subscales were entered separately as covariates. No main effects were found for PVAQ, *F*(1,55) = .20, *p* = .66, fantasy scale, *F*(1,55) = .85, *p* = .36, and personal distress, *F*(1,55) = .00, *p* = .99.



**p<0.01; ***p<.001

Figure 3. The relationship between type of video and congruency

Neglect errors

The NB model was found to be the best fitting count model. In a first step, type of video was added as a predictor. Results showed that the number of neglect errors during the observation of pain-related stimuli was dependent upon video category. The observation of pain-related videos resulted in a 19% increase in neglect errors compared with control videos (RR = 1.19; *p* = .008). No difference was found between control and touch videos (*p* = .37) and between pain and touch (*p* = .08). In order to explore the role of individual differences in PVAQ and the IRI, several additional models were run with PVAQ or IRI as an additional predictor and in interaction with group to explore its modulating role. No interactions were found between video category and PVAQ (all *p* > .26) and FS (all *p* > .30). The effect of personal distress upon the number of neglect errors was significantly different for touch and pain-related videos (*p* = .01). The number of neglect errors decreased for every 1-unit increase in personal distress by 1% (RR = .99) when touch videos were presented, and increased with 2% when pain-related videos were presented (RR = 1.02). Second, in a separate model, type of perspective was added as a predictor. Results showed that the number of neglect errors was independent of type of perspective (*p* = .51). In a third model, both type of video and perspective were added as predictors. No interaction occurred between video category and perspective (all *p* > .24).

DISCUSSION

This study had two objectives. First, we investigated whether the observation of touch and pain differentially facilitated the report of vicarious experiences and the detection of subtle somatosensory stimuli during an experimental paradigm. Second, we tested whether perspective taking (first-person versus third-person) influenced these outcomes. We also explored the effects of some potential moderators as proposed by Fitzgibbon et al. (2010b, 2012), i.e., dispositional empathy and hypervigilance to pain. Participants were presented three categories of videos, showing pain-related scenes (left and right hand in which one hand is being pricked), touch scenes (left and right hand in which one is touched by cotton swab) and control situations (e.g. same approaching movement of the hand as in the other categories, but without holding any object). Videos were presented in first-person (self) perspective and third-person (other) perspective in which videos were turned upside down. Participants occasionally received vibrotactile stimuli themselves in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual cue (touch/prick or approaching movement). Participants were instructed to report as rapidly as possible the spatial location of the administered somatosensory stimuli.

The results can be readily summarized. First, observing pain in another increased the number of vicarious experiences and improved the accuracy of detecting somatosensory stimuli. Second, we did not observe an increase of vicarious experiences when pain or touch was observed in first-person perspective, compared with third-person perspective. Nevertheless, observing pain and touch in first-person perspective improved the detection accuracy of somatosensory stimuli. Third, no moderating role was found for observer's characteristics, such as hypervigilance and dispositional empathy. Our results corroborate previous findings as it shows that vicarious experiences are not frequently reported but can be measured by means of an experimental paradigm

(Vandenbroucke et al., 2013, 2014a,b). Of particular relevance to this study was whether the effects are specific for pain.

Our primary finding that participants reported more vicarious somatosensory experiences when pain-related videos were shown compared with control and touch videos indicates that vicarious experiences while observing pain are not simply due to the observation of a hand being approached or touched. It shows that vicarious experiences become more frequent when observing pain-related situations, in comparison with touch situations. No difference was obtained regarding the number of vicarious somatosensory experiences while observing touch compared with control videos. Mirams et al. (2010) found that merely viewing a hand increases the number of false alarms as compared to not viewing a hand. In our study, false alarms may have been also facilitated in the control condition as there was no condition in which no hand was seen. Also in our control videos, human features such as a hand were still present.

Detection accuracy was also affected by the type of video presented. Participants were better in detecting the vibrotactile stimuli while observing pain-related situations compared with both touch and control videos. Observing touch resulted in a better detection compared with observing control videos. In line with our hypotheses, spatially congruent visual information resulted in a better detection compared with incongruent trials. As expected, this congruency effect was present when touch and control videos were shown, although to a lesser extent compared with the presentation of pain-related videos. These effects are consistent with previous research comparing the effects of pain-related videos and control videos upon somatosensation (Vandenbroucke et al., 2014a). The increased detection accuracy while observing touch in this study is congruent with previous studies demonstrating that observing non-painful touch may facilitate somatosensory experiences (e.g. Cardini et al., 2013; Serino et al., 2008). Common pathways exist in experiencing touch and pain, such as multimodal neurons which both respond to nociceptive and non-nociceptive inputs (Mouraux and colleagues, 2011). Besides these common pathways in experiencing touch and pain, our results suggest that the different video categories (pain, touch, control) modulate somatosensation differently. This difference is consistent with the existence of different neurophysiological mechanisms of viewing painful and non-painful bodily sensations in others (Bufalari et al., 2007). One possible explanation for these results is that participants may have been more aroused when viewing the pain videos as compared to when viewing the control and touch videos. As pain captures attention and may induce threat, it may have been more arousing (in a way this is an inherent feature of pain stimuli). Another important mechanism is the involvement of attentional processes. Attention may enhance sensory processing of somatic information when observing bodily experiences in others irrespective of whether they are painful or not. Martinez-Jauand and colleagues (2012) showed enhanced P50 amplitudes by the sight of bodily sensations irrespective of whether participants were observing either a painful or non-painful bodily sensation. It suggests that images of body parts interacting with an object are able to capture participant's attention to a larger extent than images of a body without receiving stimulation. Further research may focus upon possible explanatory variables for our findings, for example the mediating role of arousal and attentional processes. Serino et al. (2008) demonstrated enhanced detection of subthreshold tactile stimuli on observers' faces when they saw a face being touched by hands rather than a face being merely approached by hands. This effect was not found for touch on a non-bodily stimulus, namely, a picture of a house. An explanation could be that because of the presentation of an inanimate object of the house, perception is already diminished independent of an approaching or touching condition. Beck and colleagues (2013) showed no modulation of detection while observing touch to monkey faces expressing different facial expressions (fearful, happy or neutral) which does occur presenting human faces, illustrating that the simple presentation of human features may influence detection accuracy. A particular strength in the present study is therefore, that even in the non-painful videos in this study, human features were still present. The effects in our study are unlikely due to the mere observation of the human body as human hands were present in all video categories.

Also, type of perspective was important regarding to detection accuracy: participants were better in detecting the vibrotactile stimuli when videos were presented in first-person compared with third-person perspective. Contrary to our expectations, the role of perspective was not dependent upon the type of visual information, suggesting that any hand observed in first-person perspective compared with third-person perspective facilitated detection. The effect of perspective taking upon detection accuracy is in line with research done by Serino et al. (2009). These researchers showed that vision facilitated tactile perception mostly when self-other similarity is high (e.g. by manipulating the visual appearance and political opinions between observer and the observed person). The number of vicarious somatosensory experiences was independent of type of perspective. This suggests that perspective taking may be important but is largely dependent upon the outcome (vicarious somatosensory experiences versus general accuracy in detecting somatosensory stimuli).

In general, the effects of observing pain and touch and the role of perspective taking were stronger regarding detection accuracy compared with the experience of vicarious experiences. This is in line with the view that vicarious experiences while observing touch or pain are a more extreme variant of the modulation of somatosensory detection in a minority of people (Vandenbroucke et al., 2013, 2014b). Percentages range from 1.6% for vicarious touch (Banissy et al., 2009), 16.20% for vicarious pain in amputees (Fitzgibbon et al., 2010a), to 6.61% (Vandenbroucke et al., 2013, study 1), 22.90% (Vandenbroucke et al., 2013, study 2) and 30% for vicarious pain in a general population (Osborn & Derbyshire, 2010). The variability is probably dependent upon the criteria used for categorizing individuals as vicarious pain responders. Stability has been observed at a group level of vicarious pain responders reporting vicarious pain in daily life, but some variation may occur at the individual level (Vandenbroucke et al., 2014b). The study described in this paper has unique contributions to the literature compared with previous studies in our lab (Vandenbroucke et al., 2013, 2014a, 2014b) as it makes the direct comparison between observing pain, touch and control videos upon the report of vicarious experiences and somatosensory modulation.

Regarding the number of neglect errors, observing pain-related scenes resulted in a higher number of neglect errors compared with observing control scenes, but no differences were found between the observation of pain-related versus touch scenes. Personal distress in the context of empathy influenced the number of neglect errors differently for touch and pain-related videos. Fewer neglect errors were made when more personal distressed while observing touch videos, and vice versa regarding pain-related videos. One possible explanation may be that when observing pain-related information in combination with the experience of personal distress, people become more attentive to the site of the pain-related information, resulting in more neglect errors.

Some limitations deserve further consideration, which point to directions for future research. First, we included video clips showing hands being pricked. It may well be that these videos represent pain experiences of lower intensity than the images and movies (e.g. broken leg) used in the study of Osborn and Derbyshire (2010). Further studies have to investigate whether effects differ as a function of pain intensity. It may well be that high-intensity scenes may lead to more vicarious experiences.

Second, we designed our videos to be as similar as possible both in terms of visual features as in represented actions. For that reason, the control videos consisted of a hand approaching another hand but without holding an object. Morrison et al. (2013) showed that separate somatosensory regions responded more strongly when the observed action targeted noxious objects compared with neutral objects, irrespective of the action carried out with them. This suggests an encoding of tactile object properties independent of action properties. Besides the differential influence of the presence of absence of an approaching object, also the type of object could have played a role in our study (e.g. a cotton swab versus a needle), in which a needle could have been more salient.

Third, video clips were shown in peripersonal space as the computer screen was placed just above participants' hands. Visual cues presented near the hands may facilitate the detection of stimuli delivered on these hands compared with visual cues further away (see De Paepe et al., 2014). The fact that our video clips were presented close to the body may have overruled some hypothesized effects of perspective taking.

Fourth, in contrast to Vandenbroucke et al. (2013, 2014b), undergraduate students were participants. Future research may include participants reporting vicarious experiences in daily life (vicarious pain responders) and controls to investigate the effects of observing touch and pain upon somatosensation and vicarious experiences and their potential different impact in both groups.

Finally, future research may attempt to manipulate activity in the brain regions presumed to play a critical role in perspective taking. For example the temperoparietal junction (TPJ) is linked to self-other representations, including perspective taking (e.g., Aichhorn et al., 2006), agency discrimination (e.g., Farrer and Frith, 2002) and empathy (e.g., Völlm et al., 2006). To get further insight into the role self-other representations upon somatosensation, it would be interesting to manipulate activity of TPJ and investigating its role in somatosensation while observing touch, pain and control videos in an experimental setup as described in our study.

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CHAPTER 5

The role of the right tempoparietal junction in the elicitation of vicarious experiences and detection accuracy while observing pain and touch[6]

ABSTRACT

Objective: This study investigated the effects of observing pain and touch in others upon vicarious somatosensory experiences and the detection of subtle somatosensory stimuli. Furthermore, the role of the right tempoparietal junction (rTPJ) was investigated, by means of tDCS methodology, as this brain region is suggested to be involved in perspective taking and self-other distinction.

Methods: Undergraduates (N=22) viewed videos depicting hands being touched, hands being pricked, and control scenes (same approaching movement as in the other video categories but without the painful/touching object), while experiencing vibrotactile stimuli themselves on the left, right, or both hands. Participants reported the location at which they felt a somatosensory stimulus. Vibrotactile stimuli and visual scenes were applied in a congruent or incongruent way. During three separate testing sessions, excitability of the rTPJ was modulated with tDCS (cathodal, anodal or sham). We calculated the proportion of correct responses and false alarms (i.e., number of trials in which a vicarious somatosensory experience was reported congruent to the site of the visual information).

Results: Pain-related scenes facilitated the correct detection of tactile stimuli and augmented the number of vicarious somatosensory experiences compared with observing touch or control videos. Stimulation of the rTPJ had no reliable influence upon detection accuracy or the number of vicarious errors.

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[6] Based on: Vandenbroucke, S., Bardi, L., Brass, M., Lamm, C., & Goubert, L. (under review). The role of the right tempoparietal junction in the elicitation of vicarious experiences and detection accuracy while observing pain and touch. Experimental Brain Research

Conclusion: This study indicates that somatosensory detection is particularly enhanced during the observation of pain-related scenes compared to the observation of touch or control videos. Contrary to our expectations, the rTPJ did not modulate detection accuracy.

INTRODUCTION

Observing another in pain may elicit an empathic affective reaction in the observer, which can result in prosocial behavior (e.g. care, assistance) towards the other in pain (Goubert et al., 2005, 2013; Hein et al., 2011). Studies using functional Magnetic Resonance Imaging (fMRI) suggest that not only the affective dimension (Singer et al., 2004; Jackson et al., 2005) but also sensory-discriminative properties (Bufalari et al., 2007) of own pain and others’ pain are represented in common neural circuits. Moreover, some people even report vicarious sensations while observing another in pain or observing another being touched (Banissy & Ward, 2007; Osborn & Derbyshire, 2010; Vandenbroucke et al., 2013, 2014a, 2014b). Most cases reporting vicarious pain have been observed in amputees, who mostly have experienced chronic pain or trauma (Fitzgibbon et al., 2010a). Up to date, several studies have investigated this rare phenomenon of vicarious experiences in both clinical samples (Fitzgibbon et al., 2010a; 2012a; Vandenbroucke et al., 2014a) and the general population (Osborn & Derbyhire, 2010; Vandenbroucke et al., 2013,2014b).

Several underlying mechanisms have been proposed and investigated, such as empathy, chronic pain and hypervigilance for pain (Fitzgibbon et al., 2010b; 2012b). A mechanism that may play a role in the production of vicarious experiences is perspective taking (Fitzgibbon et al., 2010b), i.e., whether one considers the observed pain or touch from a first-person (self) versus a third-person (another’s) perspective. It has been suggested that vicarious somatosensory experiences may be enhanced when confusion between self and other is present (Fitzgibbon et al., 2010b), i.e. when a self-perspective is adopted. Interesting in this regard is a recent study by Derbyshire and colleagues (2013), which suggested that vicarious responders may have a reduced ability to distinguish their own and others' visual perspective. They presented pain responders (reporting vicarious pain) and non-pain responders an avatar on a screen. Sometimes the participant's and the avatar's perspective were consistent and sometimes inconsistent (viewing different or the same number of circles on a wall). For half of the trials the participants were asked to adopt the perspective of the avatar and for the other half they adopted their own perspective. Participants had to identify the number of circles on the wall from their adopted perspective (self or other) as quickly as possible. Regarding reaction time, the difference between consistent and inconsistent trials when adopting a self-perspective was greater for the responders compared to the non-responders. Furthermore, in a recent study, we showed that detection accuracy of somatosensory stimuli of low intensity was generally higher for videos depicted in first-person perspective compared with third-person perspective (180° angle) irrespective of the content of the video (e.g. pain-related, touch or control) (Vandenbroucke et al., resubmitted after revision). Perspective had no effect upon the number of vicarious somatosensory experiences, suggesting that the confusion between self and other may predominantly impact detection accuracy rather than installing illusionary sensations.

Several studies suggest that the right tempoparietal junction (rTPJ) is a key node for regulating representations related to the self versus others. The TPJ may modulate several low-level socio-cognitive processes such as agency discrimination (Farrer & Frith, 2002), control of imitation (Spengler, Von Cramon, & Brass, 2009) and visual perspective taking (Vogeley et al., 2004). Other high-level sociocognitive processes have also been linked with its function such as mentalizing and empathy (Spengler et al., 2009; Saxe, & Kanwisher, 2003; Decety & Lamm, 2007) and altruism (Morishima et al., 2012). Interestingly, two recent studies indicate that the rTPJ (and adjacent areas) is a prerequisite for appropriate self-other distinction. Silani et al. (2013) showed that inhibitory stimulation of rTPJ-adjacent right supramarginal gyrus using transcranial magnetic stimulation resulted in increased emotional egocentricity. Santiesteban and colleagues (2012) in turn showed that socio-cognitive abilities such as the online control of self-other representations elicited by imitation and perspective taking was improved during excitatory, anodal transcranial direct current stimulation (tDCS) of the rTPJ.

Based on these previous findings, our study had two main aims. First, we wanted to investigate whether observing pain-related, touch and control videos set up different rates of detection accuracy of subtle vibrotactile stimuli, and on top of that differentially facilitated vicarious somatosensory experiences. A second aim was to investigate whether these outcomes (detection accuracy and vicarious somatosensory experiences) could be influenced by modulation of the right TPJ using tDCS. Participants were presented three categories of videos, depicting pain-related situations (left and right hand in which one hand is being pricked by a needle), touch (left and right hand in which one is touched by a cotton swab) and control situations (e.g. same motor movement of the approaching hand as in first and second category, without the painful/touching object). Participants occasionally received vibrotactile stimuli on the hand in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual stimuli, or on both hands. Participants were instructed to report as quickly as possible the spatial location of the administered somatosensory stimuli. False alarms (erroneously reporting a somatosensory stimulus in the same spatial location as the visual cue) in response to videos showing pain or touch were labeled 'vicarious somatosensory experiences'. Also trials in which no vibrotactile stimulation occurred were included as well as trials in which both hands of participants were stimulated. While executing the task, the role of the rTPJ was investigated. During three different testing sessions participants received excitatory (anodal), inhibitory (cathodal), or sham tDCS. TDCS is a noninvasive technique that stimulates the cerebral cortex with a weak constant electric current passed between two electrodes (anodal and cathodal) on the scalp. Current flows can modulate neural activity in the cortical region under the electrodes: Anodal stimulation is thought to cause membrane depolarization and enhance cerebral excitability, while cathodal stimulation suppresses excitability via hyperpolarization (Nitsche and Paulus, 2000, 2001).

First, we hypothesized that participants would report more vicarious experiences (false alarms) in response to the observation of pain compared with touch or control videos. Second, we expected that the observation of pain-related visual scenes would result in a better detection accuracy of vibrotactile stimuli compared with touch and control videos. We furthermore expected a crossmodal congruency effect (CCE) in which more vibrotactile acuity is observed when the visual and vibrotactile stimuli are congruent (i.e. presented in the same spatial location). Third, we expected detection accuracy to be dependent upon the polarity of tDCS on the TPJ: enhancing cortical excitability in the right TPJ (anodal tDCS) is considered to improve self-other distinction and, in this way, is expected to induce higher overall detection accuracy and a lower number of vicarious somatosensory errors. For exploratory reasons, the role of dispositional empathy and hypervigilance to pain upon false alarms and detection accuracy was examined. In addition, we also explored the presence of neglect errors (i.e. only reporting the site congruent to the visual information when both hands are stimulated) during the observation of each category of video and perspective.

METHOD

Participants

Undergraduate students (n=22) were recruited by means of an online system through which they could subscribe for experiments. Only students who were Dutch-speaking and right-handed were able to subscribe. Participants were invited three times to the lab within a time period of 4 days. They were paid 75 euro for participation. Seventy-seven percent were female. Mean age of participants was 24.5 years (SD=6.75). Participants rated their general health on average as ‘very good’. Forty percent of the participants reported to have experienced pain during the last six months (average of 32 days in 6 months), but average pain intensity was moderate (M=5.33, SD=1.68) on a Likert scale where 0 indicated ‘no pain’ and 10 ‘worst pain ever’. All participants gave informed consent and were informed to be free to terminate the experiment at any time. None made use of this possibility. Ethical approval was obtained from the Ethical Committee of the Ghent University Hospital.

Apparatus and stimuli

Visual stimuli

Visual stimuli consisted of three categories of videos (pain, control and touch) with a duration of 3000ms. The first ‘pain category’ included a scene depicting a left and right hand, with one of the two hands being pricked by the needle of a syringe (2000ms after video onset). The second category depicted a touch scene. Again, the same left and right hand were presented in which one of these hands was touched by a cotton swab (2000ms after video onset). The third ‘control category’ included a scene depicting a left and right hand in which one hand was approached by a hand without holding an object (same movement of the approaching hand as in the first and second category of videos). These three categories of videos were presented in an equal number (80 trials each) (see Figure 1). The different categories, location of visual cue (touch, pain, control), and congruency (congruent, incongruent, both hands stimulated, and both hands not stimulated) were counterbalanced across videos. Videos were presented by INQUISIT Millisecond software (Inquisit, 2002) on a Dell screen with a 19-inch CRT-monitor. The computer screen was placed in front of the participants. A carton box covered the hands of the participants. In contrast to Vandenbroucke et al. (resubmitted after revision), the screen on which the hands were depicted was placed in a frontal angle before the participant.

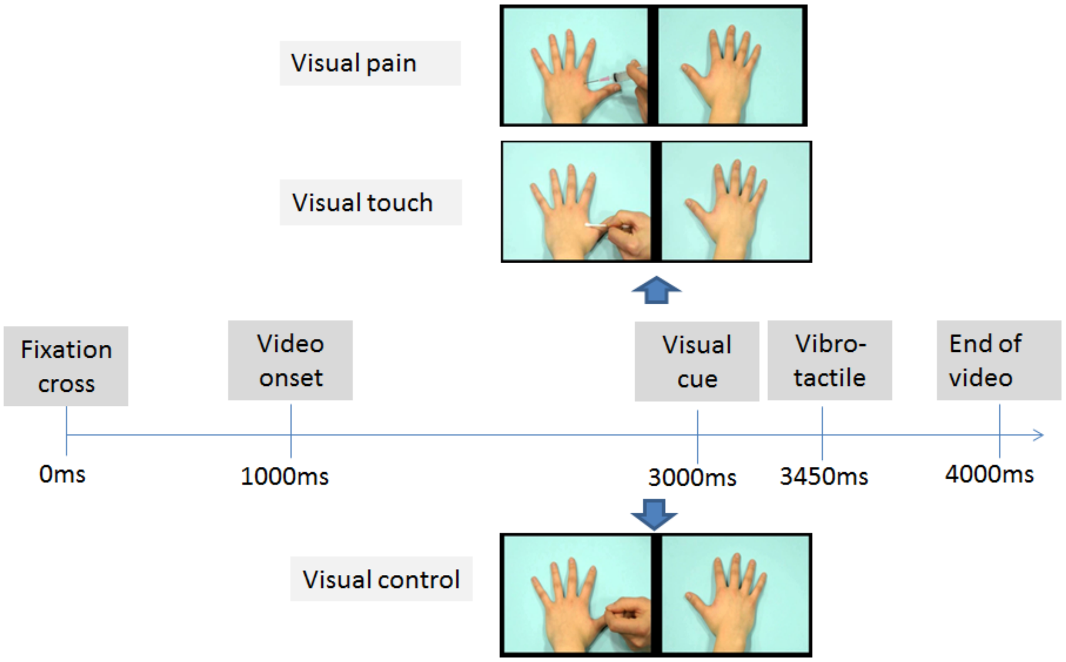

Figure 1. Time line of a trial including vibrotactile stimulation

Somatosensory stimuli

Vibrotactile stimuli (50 Hz, 50 ms) were delivered by two resonant-type tactors (C-2 tactor, Engineering Acoustics, Inc.) consisting of a housing that was 3.05 cm in diameter and 0.79 cm high, with a skin contactor that was 0.76 cm in diameter. The vibrotactile stimuli were delivered on the skin between thumb and index finger. All stimulus characteristics (amplitude, duration and frequency) were entered through a self-developed software program that was used to control the tactors. For each participant, the threshold intensity level was individually determined prior to the experiment (see Procedure-Preparation phase). Four different series of 20 stimuli/trials (two series for each hand) were randomly administered (80 stimuli/trials in total). First, a visual stimulus “X” was presented combined with a somatosensory stimulus on the left or right hand. Participants were instructed to report whether they felt a somatosensory stimulus (“yes” or “no”), which was coded by the experimenter by pressing the corresponding response button (see Vandenbroucke et al., 2014a, 2014b). Each series started at 0.068 Watt and this intensity decreased with 0.0002W within each series when participants reported feeling a stimulus and increased with 0.0002W when no sensation was reported. After 80 trials, this resulted in a threshold intensity for each hand which was based upon the mean intensity of the last stimuli (20th) of two series for that particular hand. From this threshold intensity (threshold left hand: M= .038W, SD= .002W, range: .017W-.075W; threshold right hand: M=.033W, SD=.002W, range: .014W-.082W), 1/8 was added to the threshold (above threshold), resulting in four different intensities (threshold and above threshold, one for each hand).

tDCS stimulation

A direct current of 1.5 mA intensity was delivered by a battery-driven, constant-current stimulator (Magstim, UK) through two electrodes placed in saline-soaked sponges. Previous studies have shown that this intensity of stimulation is safe in healthy volunteers (Iyer et al., 2005). A 5x7 cm electrode was applied to the right TPJ area. The reference electrode (10x10 cm) was placed over the contralateral supraorbital area. A large electrode was used for the reference in order to minimize the risk of stimulation effect in this area (Nitsche et al., 2007). TDCS stimulation lasted for 20 minutes. For anodal tDCS of the right TPJ, the anodal electrode was placed over CP6 (using the international 10/20 EEG system for electrodes placement; see Santiesteban et al., 2012) and the cathodal electrode was placed over the supraorbital area. For cathodal stimulation of TPJ, the cathode electrode was placed over CP6 and the anode over the supraorbital area. For the Sham condition, anodal or cathodal pseudo-stimulation was applied for 30 sec. In this condition, participants felt the initial itching sensation on the scalp at the beginning but received no current for the rest of the stimulation period. This procedure allowed us to blind subjects to the respective stimulation condition (Nitsche et al., 2003).

Self report measures

Vigilance to pain was assessed by the Dutch version of the Pain Vigilance and Awareness Questionnaire (PVAQ; McCracken, 1997, Roelofs et al., 2002). This questionnaire consists of 16 items assessing awareness, consciousness and vigilance to pain on a six-point scale (0 = never; 5 = always). Higher scores on the PVAQ are indicative of greater pain-related vigilance and awareness. The questionnaire can be used in both clinical (McCracken, 1997; Roelofs, Peters, McCracken, & Vlaeyen, 2003) and non-clinical (McWilliams & Asmundson, 2001; Roelofs et al., 2002) samples. The Dutch version of the PVAQ is reliable and valid (Roelofs et al., 2002; 2003). Cronbach's alpha in the present study was 0.89.

Empathic disposition was assessed by means of the Dutch version of the Interpersonal Reactivity Index (IRI; Davis, 1983; De Corte et al., 2007). The questionnaire contains 28 items and consists of 4 subscales: Perspective Taking (i.e., cognitively taking the perspective of another, e.g., "I sometimes try to understand my friends better by imagining how things look from their perspective."), Fantasy (i.e., emotional identification with characters in books, movies etc., e.g., "When I watch a good movie, I can very easily put myself in the place of a leading character."), Empathic Concern (i.e., feeling emotional concern for others, e.g., "I am often quite touched by things that I see happen.") and Personal Distress (i.e., negative feelings in response to the distress of others, e.g., "When I see someone who badly needs help in an emergency, I go to pieces."). Each item is answered on a scale ranging from 1 ('does not describe me very well') to 5 ('describes me very well'). This questionnaire has shown to be reliable and valid (Davis et al., 1893; De Corte et al., 2007). Cronbach's alpha's in the current study were 0.82 (fantasy scale), 0.86 (personal distress), 0.73 (perspective taking) and 0.84 (empathic concern).

Procedure

Behavioral paradigm

Preparation phase. First, the detection threshold was determined separately for each hand. Participants were informed that during the experiment they would feel subtle stimuli, varying in intensity and length, on their left, right or both hands. Participants were instructed that different videos would be presented which they needed to watch attentively. They were instructed that, when a somatosensory stimulus was administered on both hands, the intensity could vary across hands and that also trials without any stimulus would be included. In reality, only two fixed predetermined intensities with a fixed duration were applied (threshold intensity and threshold intensity + 1/8).

Experiment phase. Each trial began with a fixation cross (1000 ms duration) presented in the middle of the computer screen. Next, one of the videos was presented. In 75% of the trials, a vibrotactile stimulus was delivered 2450 ms after video onset either on the left hand, the right hand, or on both hands of the participant. In line with Banissy & Ward (2007), the somatosensory stimulus was administered with a delay (450ms in this study) after the visual stimulus of penetration of the needle, or the touch of the cotton swab (see Vandenbroucke et al., 2014a, 2014b). For the control videos, the somatosensory stimulus was administered with a delay of 450ms after the approaching hand was closest to the resting hand (same time frame as in the other video categories). This resulted in the following trial types: congruent trials, incongruent trials, and trials in which no somatosensory stimuli were administered, or both hands of the participant received somatosensory stimuli. In congruent trials, somatosensory stimuli and visual stimuli were presented at the same spatial location (e.g., right). In incongruent trials, somatosensory stimuli and visual stimuli were presented in the opposite spatial location (e.g., left and right). The experiment started with 8 practice trials.

The actual experiment phase consisted of five blocks of 48 trials, resulting in a total of 240 trials. There were 60 congruent trials, 60 incongruent trials, 60 trials without sensory stimuli and 60 trials with somatosensory stimuli at both hands. Order of trial types was randomized within each block. The somatosensory stimuli were equally distributed within and over each block and type of intensity (threshold and above threshold). An overview of all trial types is presented in

Table 1. During each trial, participants were requested to report whether a somatosensory experience was felt by reporting as quickly as possible ‘YES’ and to discriminate the spatial location of the somatosensory stimuli by reporting “left”, “right” or “both” (see Figure 2). Reaction times were recorded by means of a voice key. The experimenter coded the response by pressing the corresponding response button (left, right or both). The participant was instructed not to respond when no sensation was felt. In such situation a trial was considered completed when 2000ms had elapsed after the video was ended. The completion of the experiment took approximately 35 minutes. Each participant executed this procedure three times within a period of 4 days, once with anodal, once with cathodal stimulation of rTPJ and once a sham stimulation was applied.

Post-experiment phase. After the experiment at day 1, participants were requested to fill out self-report scales measuring hypervigilance for pain (PVAQ) and empathic disposition (IRI), which took approximately 15 minutes.

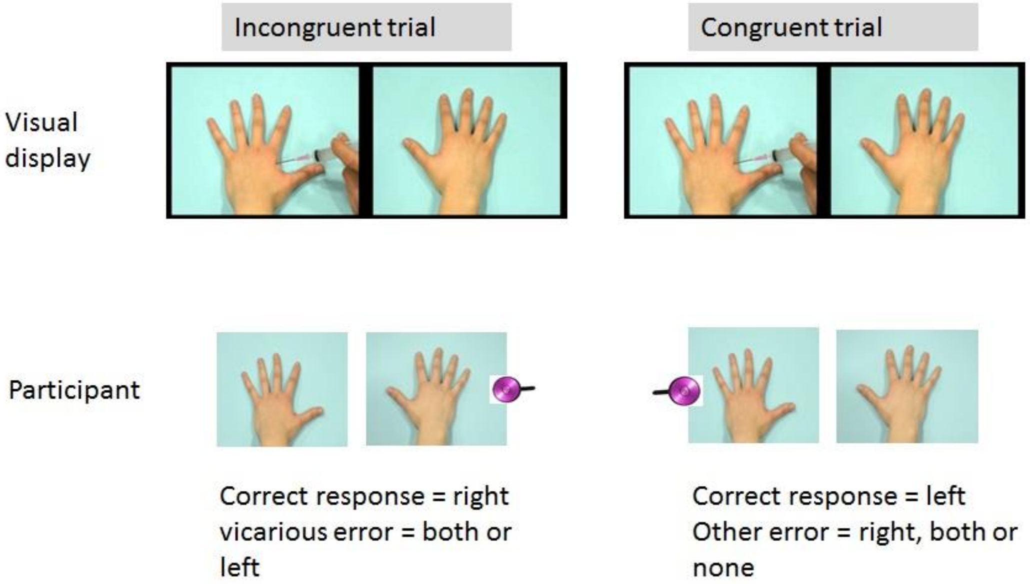

Figure 2. Example of a possible trial

Table 1

Detection accuracy for type of video

	INCONGRUENT TRIALS				CONGRUENT TRIALS				TRIALS WITHOUT TACTILE STIMULATION				BOTH HANDS OF PARTICIPANT STIMULATED			
Reported site participant	Correct site	Opposite site (=site of visual)	Both hands	No hands	Correct site	Opposite site to visual and tactile	Both hands	No hands	Site congruent to visual	Opposite site to visual	Both hands	Correct No hands	Visual site	Opposite site to visual	Correct Both hands	No hands
Visual pain facilitation	65.46 %	0.68% *false alarms -vicarious experiences*	3.86% *false alarms -vicarious experiences*	30.0 %	70.45 %	0.23 %	1.36 %	27.95 %	0.68% *false alarms-vicarious experiences*	0.45 %	0.0 %	98.87 %	12.05% *neglect errors*	10.0 %	63.64 %	14.32 %
Visual control facilitation	46.82 %	0.68% *false alarms*	1.36% *false alarms*	51.14 %	52.50 %	0.68 %	0.45 %	46.36 %	0.68% *false alarms*	0.23 %	0.0 %	99.09 %	11.14% *neglect errors*	6.59 %	49.55 %	32.73 %
Visual touch facilitation	63.18%	0.23% *false alarms-vicarious experiences*	0.91% *false alarms-vicarious experiences*	35.68 %	66.82 %	0.23 %	0.68 %	32.27 %	0.68% *false alarms-vicarious experiences*	0.45 %	0.0 %	98.86 %	11.59% *neglect errors*	10.91 %	56.82 %	20.68 %

	INCONGRUENT TRIALS				CONGRUENT TRIALS				TRIALS WITHOUT TACTILE STIMULATION				BOTH HANDS OF PARTICIPANT STIMULATED			
Reported site participant	Correct site	Opposite site (=site of visual)	Both hands	No hands	Correct site	Opposite site to visual and tactile	Both hands	No hands	Site congruent to visual	Opposite site to visual	Both hands	Correct No hands	Visual site	Opposite site to visual	Correct Both hands	No hands
Visual pain sham	72.95 %	0.68% *false alarms-vicarious experiences*	2.95% *false alarms-vicarious experiences*	23.41 %	74.77 %	0.68 %	1.82 %	22.73 %	1.14% *false alarms-vicarious experiences*	0.0 %	0.0 %	98.86 %	14.77% *neglect errors*	7.27%	66.82%	11.14 %
Visual control sham	56.14 %	0.45% *false alarms*	0.45% *false alarms*	42.95 %	56.82 %	0.45 %	1.59 %	41.14 %	0.45% *false alarms*	0.23%	0.0 %	99.32 %	8.86% *neglect errors*	8.18%	57.05%	25.91 %
Visual touch sham	64.55 %	0.0% *false alarms-vicarious experiences*	0.68% *false alarms-vicarious experiences*	34.77 %	69.77 %	0.23 %	0.91 %	29.09 %	0.23% *false alarms-vicarious experiences*	0.45 %	0.23 %	99.09 %	11.59% *neglect errors*	7.95%	60.45 %	20 %
Visual pain inhibition	71.36 %	0.45% *false alarms-vicarious experiences*	2.50% *false alarms-vicarious experiences*	25.68 %	78.18 %	0.0 %	3.18 %	18.64 %	1.14% *false alarms-vicarious experiences*	0.68 %	0.0 %	98.18 %	15.45% *neglect errors*	9.55 %	66.59 %	8.41 %
Visual control inhibition	52.5 %	0.91% *false alarms*	1.14% *false alarms*	45.45 %	56.82 %	0.68 %	0.91 %	41.59 %	0.23% *false alarms*	0.23 %	0.0 %	99.55 %	9.32% *neglect errors*	9.77 %	49.77 %	31.14 %
Visual touch inhibition	60.23 %	0.23% *false alarms-vicarious experiences*	1.59% *false alarms-vicarious experiences*	37.95 %	65.45 %	0.45 %	0.45 %	33.64 %	0.45% *false alarms-vicarious experiences*	0.68 %	0.23 %	98.64 %	12.95% *neglect errors*	8.41 %	58.18 %	20.45 %

Statistical analysis

False alarms

The number of false alarms was calculated from the incongruent trials and from the trials without any somatosensory stimuli when erroneously a somatosensory stimulus was reported in the same spatial location as the visual cue (i.e. site of the touch/prick or approaching movement). These false alarms were labeled ‘vicarious somatosensory experiences’ when the visual stimulus contained pain or touch. To test whether category of video predicted the number of false alarms, generalized linear mixed models for count data were applied. The use of linear models is considered less appropriate (Vives et al., 2006) when the frequency of responses has a skewed distribution that violates the normality assumption. Poisson regression is the basic model to analyze count data, but the variance of counts is often larger than the mean (overdispersion). The Negative Binomial (NB) regression, a Poisson regression with an overdispersion, may therefore better fit the data (e.g., Gardner et al., 1995). As count data may additionally exhibit a lot of zero counts, zero-inflated extensions of both models, called Zero-Inflated Poisson (ZIP) and Zero-Inflated NB (ZINB) models have been developed (see Karazsia et al., 2010, Loeys et al., 2012). Deviance tests and the Vuong test were used to select the best fitting count distribution for the dependent variable. After the best fitting count model was chosen, a first model with ‘video category’ as predictor was added. In a further exploration of the data, hypervigilance for pain, and dispositional empathy and their interaction with video category were added in separate models to test whether they had a moderating role. Dummy coding was used for the categorical variables. Regression coefficients are exponentiated (eB) and called Rate Ratios (RRs). In percentages—100 x (eB -1)—RRs reflect the percentage decrease (RR < 1) or increase (RR > 1) in the expected frequency of false alarms for each 1-unit increase in the continuous predictor. In a second series of analyses, the above-mentioned analyses were repeated with ‘stimulation’ (anodal versus cathodal versus sham) as predictor. In a third model both video category and stimulation were added as predictors. R (version 2.15.1) was used to fit the count models.

Detection accuracy and reaction times

To investigate whether type of video category and type of stimulation modulated the detection of vibrotactile stimuli, the proportion of correct responses (left versus right) for congruent and incongruent trials for each category of visual information was calculated (pain-related, touch and control). A 3 (video category: pain-related, touch versus control) x 2 (congruency: congruent versus incongruent) x 3 (stimulation: anodal versus cathodal of TPJ versus sham) repeated measures ANOVA was performed, with congruency, video category and type of stimulation entered as within-participant variables. In a further exploration, hypervigilance for pain and dispositional empathy were added as a covariate in separate models to test whether they had a moderating role.

Reaction times were calculated for correct responses in each congruent and incongruent condition. A 3 (video category: pain-related, touch versus control) x 2 (congruency: congruent versus incongruent) x 3 (TPJ stimulation: anodal versus cathodal versus sham) repeated measures ANOVA was performed, with congruency, video category and type of stimulation entered as within-participant variables. Repeated measure ANOVAs were conducted with an alpha < 0.05, using SPSS statistical software, version 22.0 for Windows.

Neglect errors

The number of neglect errors was calculated based upon those trials in which both hands were stimulated, defined as reporting only the site congruent to the visual information (i.e. site of the touch/prick or approaching movement) and missing the actual vibrotactile stimuli on both hands. Generalized linear mixed models for count data were applied again to test whether the number of neglect errors was dependent upon the type of video and stimulation. After the best fitting count model was chosen, a first model with ‘type of video’ as predictor was added. In a further exploration, hypervigilance for pain and dispositional empathy and their interaction with type of video were added in separate models to test whether they had a moderating role. In a second series of analyses, ‘stimulation’ (anodal versus cathodal versus sham) was added as predictor. In a third model both video category and stimulation were added as predictors. R (version 2.15.1) was used to fit the count models.

RESULTS

Descriptives

Mean scores, standard deviations and correlations are presented in Table 2. Spearman correlations were computed for the non-normally distributed variables (Kolmogorov-Smirnoff, $p < .05$). Without taking type of stimulation into account, false alarms were made in 1.41% of the incongruent trials and trials without vibrotactile stimuli (112 false alarms from a total of 7920 trials). Vicarious somatosensory errors in response to the observation of pain-related scenes were made in 2.35% of the incongruent trials and trials without vibrotactile stimuli (62 vicarious somatosensory errors from a total of 2640 trials). Of these vicarious somatosensory errors, 37.10% occurred when the pain-related video was during anodal tDCS of TPJ; 29.03% during cathodal tDCS; 33.87% during the sham condition (23; 18; 21 vicarious somatosensory errors from a total of 62 vicarious somatosensory errors). Vicarious somatosensory errors in response to the observation of touch scenes were made in 0.8% of the incongruent trials and trials without vibrotactile stimuli (22 vicarious somatosensory errors from a total of 2640 trials). Of these vicarious somatosensory errors, 36.36% occurred when the touch video was during anodal tDCS of TPJ; 45.45% during cathodal tDCS; 18.18% during sham condition (8; 10; 4 vicarious somatosensory errors from a total of 22 vicarious somatosensory errors). Vicarious somatosensory errors in response to the observation of control scenes were made 1.06% of the incongruent trials and trials without vibrotactile stimuli (28 vicarious somatosensory errors from a total of 2640 trials). Of these vicarious somatosensory errors, 42.86% occurred when the control video was during anodal tDCS of TPJ; 35.71% during cathodal tDCS; 21.43% in the sham condition (12; 10; 6 vicarious somatosensory errors from a total of 28 vicarious somatosensory errors).

Table 2

Pearson/Spearman correlations, mean scores and standard deviations

	M (SD)	2.	3.	4.	5.	6.	7.	8.	9.
1. Vicarious somatosensory errors (pain videos-facilitation rTPJ)	1.05(1.43)	.15	.29	.38	-.44*	-.39	-.34	-.48*	-.35
2. Vicarious somatosensory errors (pain videos-inhibition rTPJ)	0.82(1.44)	-	.26	-.09	.10	.33	-.16	.09	-.31
3. Neglect errors (pain videos-facilitation rTPJ)	2.41(1.99)		-	.51*	.20	-.05	-.23	-.37	-.32
4. Neglect errors (pain videos-inhibition rTPJ)	3.09(1.95)			-	-.07	-.07	-.03	-.25	-.04
5. Hypervigilance for pain (PVAQ)	35.40(11.15)				-	.50*	.42	.39	.29
6. Personal distress (IRI)	12.82(5.17)					-	.30	.52*	.16
7. Fantasy (IRI)	17.45(5.44)						-	.62**	.48*
8. Empathic concern (IRI)	18.36(5.14)							-	.56**
9. Perspective taking (IRI)	16.36(4.26)								-

Note. PVAQ=Pain Vigilance and Awareness Questionnaire; IRI=Interpersonal Reactivity Index
* p<0.05; **p<0.01

False alarms and vicarious experiences

The NB model was found to be the best fitting count model. In a first step, video category was added as a predictor. Results showed that the number of false alarms was dependent upon type of video presented. The observation of pain-related videos resulted in 121% increase in false alarms compared with control videos (RR = 2.21) ($p < .001$). The observation of pain-related videos resulted in 182% increase in false alarms or vicarious experiences compared with touch videos (RR = 2.82) ($p < .001$). No significant difference was found between touch videos and control videos regarding the number of false alarms made ($p = .40$). In order to explore the role of individual differences in PVAQ and the IRI, several additional models were run with PVAQ or IRI as additional predictor to explore its modulating role. No interactions were found between type of video and empathic concern (all $p > .16$), personal distress (all $p > .11$) and perspective taking (all > .27).

The effect of hypervigilance for pain upon the number of false alarms was significantly different for touch and pain-related videos ($p = .01$). The number of false alarms decreased for every 1-unit increase in hypervigilance by 1% (RR = .99) when pain-related videos were presented, and decreased with 8% when touch videos were presented (RR = .92).

The effect of fantasy scale upon the number of false alarms was significantly different for control and pain-related videos ($p < .01$). The number of false alarms increased for every 1-unit increase in fantasy scale by 9% (RR = 1.09) when control videos were presented, and decreased with 6% when pain-related videos were presented (RR = .94).

In a separate model, stimulation was added as a predictor. Results showed that the number of false alarms was independent of type of stimulation (all > .19). In a third model both type of video and type of stimulation were added as predictors. No interaction occurred between video category and stimulation (all $p > .30$).

Detection accuracy and reaction times

A 2 (congruency: congruent versus incongruent) x 3 (type of stimulation: anodal versus cathodal tDCS versus sham) x 3 (type of video: pain versus touch versus control) repeated measures ANOVA showed a main effect for type of video regarding detection accuracy (*F*(2,42) = 59.26, *p* < .0001). Overall, pain-related videos resulted in a better detection of vibrotactile stimuli compared with control videos (*t*(21) = 8.60, *p* < .0001, Cohen's d = -0.87, [95% CI: -1.11,-0.64]) and touch videos (*t*(21) = 4.74, *p* < .0001, Cohen's d = -0.37, [95% CI: -0.53,-0.21]). Detection accuracy while observing touch videos was significantly higher compared with observing control videos (*t*(21) = -8.23, *p* < .0001, Cohen's d = 0.54 [95% CI: 0.41, 0.68]). Also a main effect for congruency occurred (*F*(1,21) = 17.14, *p* < .001, Cohen's d = -0.23, [95% CI: -0.35, -0.12]), indicating a higher detection accuracy in congruent compared to incongruent trials. No interaction was found between congruency and type of video (*F*(2,42) = 0.18, *p* = .83). Also no main effect of stimulation was found (*F*(2,42) = 1.08, *p* = .35). A trend was found regarding the video x stimulation interaction (*F*(4,84) = 2.34, *p* = .06). When exploring this trend by comparing stimulation within each category of video, the anode x cathode contrast tended towards significance within the pain-related category (*p* = .09). Within the control category, the anode x sham contrast showed a trend toward significance (*p* = .08). Both trends suggested a *decreased* detection accuracy when rTPJ is facilitated. When Bonferroni correction for multiple testing was applied, these trends disappeared.

Centered PVAQ and IRI subscales were entered separately as covariates. No main effects were found for PVAQ, *F*(1,20) = .29, *p* = .60, fantasy scale, *F*(1,20) = .00, *p* = .99, personal distress, *F*(1,20) = .06, *p* = .82, empathic concern, *F*(1,20) = .01, *p* = .91 and perspective taking, *F* (1,20) = .04, *p* = .84).

A 2 (congruency: congruent versus incongruent) x 3 (type of stimulation: anodal versus cathodal tDCS versus sham) x 3 (type of video: pain versus touch versus control) repeated measures ANOVA showed a main effect for type of video upon reaction time (*F*(2,40) = 30.84, *p* < .0001). Overall, pain-related videos resulted in a faster detection of vibrotactile stimuli compared with control videos (*t*(20) = -6.56, *p* < .0001, Cohen's d = -1.03, [95% CI: -1.41, -0.66]) and touch videos (*t*(21) = -6.46, *p* < .0001, Cohen's d = -0.75, [95% CI: -1.00, -0.49]). Detecting vibrotactile stimuli while observing touch videos was significantly faster compared with observing control videos (*t*(20) = 2.66, *p* = .02, Cohen's d = 0.29, [95% CI: 0.02, 0.55]). Also a main effect of congruency occurred (*F*(1,20) = 5.91, *p* = .03, Cohen's d = 0.15, [95% CI: -0.02, 0.33]), indicating a faster detection in congruent compared to incongruent trials.

Neglect errors

The NB model was found to be the best fitting count model. In a first step, type of video was added as a predictor. Results showed that the number of neglect errors during the observation of pain-related stimuli was dependent upon video category. The observation of pain-related videos resulted in a 44% increase in neglect errors compared with control videos (RR = 1.44; $p < .01$). No difference was found between control and touch videos ($p = .09$) and between pain and touch ($p = .17$). In order to explore the role of individual differences in PVAQ and the IRI, several additional models were run with PVAQ or IRI as an additional predictor and in interaction with group to explore its modulating role. No interactions were found between video category and PVAQ (all $p > .47$), FS (all $p > .51$), PD (all $p > .75$), PT (all $p > .21$). The effect of empathic concern upon the number of neglect errors was significantly different for control and pain-related videos ($p = .04$). The number of neglect errors decreased for every 1-unit increase in empathic concern by 2% (RR = .98) when pain-related videos were presented, and increased with 3% when control videos were presented (RR = 1.03). Second, in a separate model, type of stimulation was added as a predictor. Results showed that the number of neglect errors was independent of type of stimulation (all $p > .48$). In a third model, both type of video and stimulation were added as predictors. No interaction occurred between video category and perspective (all $p > .14$).

DISCUSSION

This study investigated whether observing pain-related, touch and control videos exhibited different rates of detection accuracy of subtle vibrotactile stimuli and differentially facilitated vicarious somatosensory experiences. A second aim was to investigate whether these outcomes (vicarious somatosensory errors and detection accuracy) could be influenced by the modulation of the rTPJ. We also explored the effects of some potential moderators as proposed by Fitzgibbon et al. (2010b; 2012b), i.e. dispositional empathy and hypervigilance to pain.

Our findings show that the percentage of vicarious experiences during pain-related videos was low (2.35%). This percentage is in line with other studies using highly similar paradigms, such as 1.6% for vicarious touch (Banissy et al., 2009) and 2.5% for vicarious somatosensory experiences (Vandenbroucke et al., 2014a). As these vicarious experiences were confused with low intense tactile stimuli as administered in this study, we assume the vicarious experiences in our study to be subtle and vague. This assumption is in line with the study of Osborn & Derbyshire (2010) in which participants most often described vicarious (pain) sensations as “tingling”. The above-mentioned percentages from experimental studies are lower compared with studies questioning participants about their vicarious somatosensory (e.g., pain) experiences in daily life, with percentages ranging from 6.61% (Vandenbroucke et al., 2013, study 1), 22.9% (Vandenbroucke et al., 2013, study 2), to 8.33% (Vandenbroucke et al., 2014b) in college students, 30% in a general population sample (Osborn & Derbyshire, 2010) and 16.20% in amputees (Fitzgibbon et al., 2010a). It could be that these percentages are overestimations of the true occurrence of vicarious experiences in daily life.

In line with previous research (Vandenbroucke et al., resubmitted after revision), our results show that participants report more vicarious somatosensory experiences when pain-related videos are shown compared with control and touch videos. The presentation of touch did not enhance the report of vicarious experiences compared with control videos, illustrating the specific modulatory effects of observing pain compared with touch. Detection accuracy was also dependent upon the type of video presented. When observing pain-related situations, participants were better and faster in detecting the vibrotactile stimuli compared with touch and control videos. This is again in line with the findings of other studies demonstrating that observing somatosensation may facilitate somatosensory experiences (e.g. Cardini et al., 2013; Serino et al., 2008; Vandenbroucke et al., resubmitted after revision). Despite common pathways in experiencing touch and pain (Mouraux et al., 2011), our results suggest that the different video categories (touch, pain, control) may facilitate somatosensation differently. One possible explanation for these results is that participants may have been more aroused when viewing the pain videos as compared to when viewing the control and touch videos. As pain captures attention and has an inherent threat value (Goubert et al., 2009), it may have been more arousing. Another important mechanism is the involvement of attentional processes. Attention may enhance sensory processing of somatic information when observing bodily experiences in others irrespective of whether they are painful or not. Further research may focus upon possible explanatory variables for our findings, for example the mediating role of arousal and attentional processes.

In contrast to our expectations, enhancing or reducing cortical excitability of the rTPJ did not modulate detection accuracy or the report of vicarious experiences. A trend was found between stimulation and video, in which facilitation implied a *decreased* detection accuracy compared with inhibition, although the opposite direction was expected. Further research and more power is needed to figure out whether these changes are reliable. These results are in contrast with recent findings indicating that touch responders (those reporting vicarious touch when observing touch) show structural brain differences relative to controls within the right TPJ (namely, reduced gray matter volume; Holle et al., 2013). Holle et al. (2013) state that this area may contribute to atypical self-other processing found in touch responders (e.g. Aimola-Davies and White, 2013; Maister et al., 2013), which in turn may modulate vicarious experiences. Santiesteban and colleagues (2012) showed that the online control of self-other representations was improved during anodal stimulation (tDCS) of the rTPJ. Although our tDCS procedure was similar to the one used by Santiesteban and colleagues (2012), no effects of stimulation occurred in our study. A possible explanation could be that Santiesteban and colleagues (2012) investigated different processes. While they focused on motor mimicry and cognitive perspective taking, our study focused on somatosensory "overlap" between the observer and the observed person. Hence, self-other distinction in these domains might be supported by distinct processes and partially separate neural mechanisms/areas within the rTPJ. Indeed, recent studies consistently suggest that the TPJ is not a homogenous region but that it can be subdivided into several subregions based upon its estimated structural and functional connectivity (Mars et al., 2012; Silani et al., 2013). For example, Silani et al. (2013) showed that self-other distinction associated with egocentricity bias (i.e., the biasing of empathic judgments by one's own emotions) engages an area anterior to what has been previously referred to as rTPJ. This area was located in the supramarginal gyrus and thus anterior to the junction of parietal and temporal cortex. Moreover, the paradigm in that study also required self-other distinction based on somatosensory stimulation. Unfortunately, tDCS does not allow us to dissociate between different nearby areas as it has a relatively low spatial resolution. Future studies may adopt a different stimulation approach, Transcranial Magnetic Stimulation, which more specifically targets the supramarginal gyrus.

Our findings corroborate previous research demonstrating that spatial coincidence plays a role in multisensory integration (Spence, 2013), as sensory stimuli were detected better and faster when presented in the same spatial location. The higher proportion of detected vibrotactile stimuli in congruent compared with incongruent trials suggest that the visual system may dominate somatosensation when visual and tactile processing provide conflicting information (e.g. incongruent trials) or that vision may facilitate detection when similar information is provided (e.g. congruent trials).

In contrast to the model of Fitzgibbon et al. (2010b), hypervigilance for pain and dispositional empathy did not modulate detection accuracy. Hypervigilance for pain, however, did modulate the number of vicarious errors. The more hypervigilant for pain, the less vicarious errors were made when observing pain-related videos. This decrease was even stronger for observing touch. The inverse relationship between hypervigilance for pain and the number of vicarious errors is consistent with previous research in a group of pain responders (Vandenbroucke et al., 2013; study 1; Vandenbroucke et al., 2014b). These authors showed that for a group of pain responders, the probability of making vicarious somatosensory errors decreased when hypervigilance for pain increased. For the comparison group, the probability of making vicarious somatosensory errors increased when hypervigilance for pain increased. It could be that when being hypervigilant for pain, the attentional focus is more oriented on the own somatosensory perception (Van Damme et al., 2010), resulting in fewer errors in the pain responder group. It would be interesting to replicate the present experiment in a group of pain responders and controls (Vandenbroucke et al., 2013, 2014b) as the role of perspective taking could be more prominent in those reporting vicarious sensations in daily life.

The attentional focus may be responsible for the increased number of neglect errors when pain-related videos were shown compared with control videos. No differences were found between the observation of pain-related versus touch scenes regarding neglect errors. One possible explanation may be that when observing pain-related information, people become more attentive to the site of the pain-related information, resulting in the neglect of the incongruent site of the visual information. These results are in line with previous research demonstrating an increased number of neglect errors in which participants only report sensory experiences on the side congruent with the visual stimuli when this contained pain-related information compared with control stimuli (Vandenbroucke et al., 2014a,2014b; Vandenbroucke et al., resubmitted after revision).

Some limitations of this study deserve further consideration, yielding directions for future research. First, subtle tactile somatosensory stimuli were administered in this experiment. Consequently, no statements can be made regarding vicarious pain. We consistently labeled the vicarious experiences as vicarious somatosensory experiences and not as vicarious pain. Second, in this experiment, the pain-related videos depicting a hand being pricked presented pain of low to moderate intensity. Maybe, presenting more intense pain could facilitate the report of vicarious experiences. However, this study illustrates that vicarious somatosensory experiences can already be triggered by observing low to moderately intense pain-related visual stimuli. Third, the videos depicted only hands without the rest of the body (e.g. head, body). Holle et al. (2011) demonstrated that the intensity of vicarious touch experiences is stronger when observing touch to real bodies compared with touch to dummy bodies, pictures of bodies and disconnected dummy body parts. These results show that vicarious touch is not entirely bottom-up driven; also top-down information such as knowledge about dummy and real bodies can modulate the intensity of the vicarious experience. In future research, it could be interesting to also examine vicarious experiences to observed expressive behaviors as a reaction to pain (e.g., facial pain expressions) (Craig et al., 2010; Goubert et al., 2005). Finally, the relationship between the observer and observed person in pain is not taken into account but may be an important modulator, as well as the non-verbal communication of posture or facial expressions of the observed person (Azevedo et al., 2013; Caes et al., 2012; Goubert et al., 2005).

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GENERAL DISCUSSION

PREFACE

Pain is an inherently interpersonal experience: it is not only expressed by the one that is suffering but is also perceived by the observer (Hadjistavropoulos et al., 2011). Observing another in pain may evoke affective distress. Studies using functional Magnetic Resonance Imaging (fMRI) within the context of pain, suggest that the affective dimension of own pain and observing others' pain are represented in common neural circuits (Jackson et al., 2005; Singer et al., 2004). Besides the overlapping brain regions tapping into affective properties of pain when seeing someone else in pain, studies have provided evidence of overlapping activation of brain regions subserving the sensory-discriminative properties of pain (Bufalari et al., 2007). Some people share these sensory processes expressed by the sufferer consciously and report vicarious pain or touch. Up to date, most evidence of vicarious experiences stems from reported case studies. These studies describe the phenomenon based upon self-report in a selected sample of patients. The question remained why some individuals acquire vicarious experiences such as pain following pain-related trauma and other do not in similar circumstances. Several bottom-up variables and top-down variables seem to be important but are rarely investigated. There is little research yet available on the occurrence of vicarious experiences and underlying proposed mechanisms. Systematic research on the conditions in which vicarious experiences occur and on the underlying mechanisms is of major significance for both theory about pain as a biopsychosocial phenomenon and clinical practice. Theoretically, insight into the conditions and processes of vicarious pain may fundamentally change the view about how pain is processed, demonstrating the important role of psychosocial variables, not only in the modulation (e.g., Van Damme et al., 2010) but also as cause of pain experiences. Clinically, this might for instance shed light on potential underlying processes in "unexplained" pain conditions for which no biomedical cause can be identified. In the studies described in this PhD project, unlike some previous studies that investigated vicarious experiences, an experimental paradigm was used to measure these experiences. We tried to elicit this rare phenomenon in a more systematic way. A **first aim** was to develop an appropriate experimental paradigm allowing the measurement of vicarious experiences and somatosensory modulation. The **second aim** was to systematically investigate the effects of observing another in pain and touch upon elicitation versus modulation of somatic sensations. A **third aim** was to explore the conditions in which vicarious experiences and modulation of somatosensory input occur, such as the role of perspective taking, dispositional empathy, hypervigilance for pain, chronic pain and central sensitization. The research questions were investigated in several populations such as the general population (i.e., individuals recruited from the community and undergraduates) and chronic pain patients (fibromyalgia patients).

The **first research aim** is addressed throughout several chapters: **chapter 1 and 3** (vicarious pain responders and controls), **chapter 2** (chronic pain patients and controls) and **chapter 4 and 5** (general population). To address this aim, we developed a variant of the crossmodal congruency task inspired by the work of Banissy and Ward (2007) on vicarious touch. Participants were presented a series of videos showing hands being pricked, whilst receiving occasionally pricking experiences themselves (chapter 1) or vibrotactile stimuli (chapter 2,3,4,5) in the same spatial location (congruent trials) or in the opposite location (incongruent trials) as the visual stimuli. Participants were instructed to report as rapidly as possible the spatial location of the administered somatosensory stimuli. Throughout the different chapters, the paradigm was adapted (adaptions in the type of trials, content of videos, etc..).

The **second research aim** is again addressed throughout the different chapters. **In chapter 1,** two studies are described that investigated whether vicarious pain responders and controls reported vicarious pain experiences while observing pain-related videos. In **chapter 2** vicarious experiences were assessed by means of self-report in a group of chronic pain patients and controls. In addition to chapter 1, chapter 2 not only investigated the experience of vicarious sensation while observing pain-related information but also assessed modulation of somatosensory stimuli and presented non-pain related information. In **chapter 3**, a study is described that investigated the experience of vicarious non-painful sensations in vicarious pain responders and controls and the modulation of somatosensory stimuli while observing pain-related and non-pain related information. In **chapter 4 and 5**, the effect of observing pain, touch and control videos upon vicarious experiences and modulation of somatosensory experiences in undergraduates was investigated.

Finally, throughout the several chapters, the **third research aim** in which the effect of different conditions and underlying mechanisms was investigated. In **chapters 1, 2, 3, 4 and 5** the role of hypervigilance for pain and dispositional empathy upon the experience of vicarious experiences and modulation of somatosensation was investigated. **In chapter 2**, the role of central sensitization in the experience of vicarious experiences was examined in a group of chronic pain patients by means of temporal summation of heat pulses. The study reported in **chapter 3** investigated the stability of vicarious somatosensory experiences in those experiencing vicarious pain in daily life and controls. **In chapter 4,** the impact of perspective taking upon somatosensation was investigated, by means of an adapted paradigm in which undergraduates were exposed to several types of videos (touch, pain, control) in first- and third-person perspective (videos turned upside down). In **chapter 5**, the impact of perspective taking upon the experience of vicarious sensations and somatosensory modulation while observing pain, touch and control scenes was examined by manipulating the activity in the right tempoparietal junction (rTPJ). The rTPJ is linked to self-other representations, including perspective taking (e.g., Aichhorn et al., 2006), agency discrimination (e.g., Farrer and Frith, 2002) and empathy (e.g., Völlm et al., 2006).

MAIN FINDINGS

The development of an appropriate experimental paradigm allowing the measurement of vicarious somatosensory experiences and somatosensory modulation

In all studies, a crossmodal paradigm including visual and somatosensory stimuli was used, which is a particular strength of this project. Before the start of this PhD project, some clinical cases were reported in which vicarious experiences were described, reported by some individuals or patients (Bradshaw & Mattingley, 2001; Giummarra & Bradshaw, 2008). The paradigm implemented in this project was based upon the work of Banissy and Ward (2007). Banissy and Ward (2007) investigated vicarious touch by means of an experiment in which participants were required to detect the location of touch on their own face (left, right, both or none) while observing touch to another person's face. For vicarious responders, but not for controls, the observed touch elicited a tactile sensation, whose location was either in the same spatial location as the actual touch (congruent condition) or in a different spatial location (incongruent condition). The paradigm implemented in this PhD also focuses upon vicarious errors in which the participant reports a somatosensory experience in response to the observation of pain or touch. In contrast to the paradigm of Banissy and Ward (2007), technical equipment (vibrotactile stimulators and digitimers to elicit shocks) was used to administer the actual somatosensation in the participant. This way the intensity of the administered somatosensory stimuli was equal over all trials. A second advantage is that participants did not see the motor movement of actual touch or pain as the equipment was attached to the hands. Third, the visual stimuli in this project were specifically produced in function of this PhD project. The videos depicted only the left and right hand. This improves internal validity as the observer may only decode the painful stimuli, and not the full body posture or other expressive pain behaviors such as facial pain expressions. The pain-related videos were allied to real-life situations such as a needle prick which makes it more ecological valid. The findings of this PhD project demonstrate that vicarious experiences can be measured by means of an experimental paradigm in the lab.

The effects of observing another in pain and touch upon elicitation versus modulation of somatic sensations

It was hypothesized that observing somatosensation in others would result in a higher detection accuracy of subtle somatosensory stimuli and would increase the number of vicarious experiences. First, it was hypothesized that pain responders who report vicarious pain in daily life would have a higher number of reported vicarious experiences during the observation of pain compared with non-responders. Second, we expected a higher detection accuracy of subtle somatosensory stimuli and a higher number of vicarious experiences during the presentation of visual pain-related stimuli compared with touch and compared with control videos in which no touch or pain is presented. In general, both hypotheses were confirmed.

First, in chapter 1, two studies are described that investigated whether vicarious pain responders and controls reported vicarious pain experiences while observing pain-related videos. The first study showed that the number of vicarious errors is higher in a group of pain responders compared with non-pain responders. However, the number of vicarious experiences was generally low (in 2.7% of the trials, vicarious errors were made). Pain responders were also slower to detect the painful stimuli compared with non-pain responders. Interestingly, in the subsequent chapters, the number of vicarious errors increased slightly when no longer electrocutaneous stimuli were used but subtle vibrotactile stimuli. In a second experiment, no difference in the number of vicarious errors occurred between both groups. In chapter 3, again the number of vicarious errors was larger for the group of pain responders at two different time moments compared with non-pain responders. Second, as expected, participants reported significantly more vicarious experiences and a higher detection accuracy while pain-related scenes were shown, as compared to the non-pain related category. These findings were found in patients with chronic pain (chapter 2), in pain and non-pain responders (chapter 3) and in general undergraduates (chapter 4, 5). Observing touch may even facilitate detection accuracy compared with control videos (chapter 4 and 5) but does not enhance the number of vicarious errors (chapter 4 and 5). This illustrates that observing pain and touch has different modulating qualities regarding somatosensation in the observer.

Besides these main findings, a consistent congruency effect occurred in all chapters in which participants were better or faster in detecting the somatosensory stimulus congruent to the visual stimulus.

Underlying mechanisms of vicarious experiences and somatosensory modulation

Several underlying mechanisms have been suggested in the production of vicarious experiences and modulation of somatosensation, such as hypervigilance for pain, empathy, perspective taking, central sensitisation and chronic pain (Fitzgibbon et al., 2010b). It was hypothesized that higher levels of hypervigilance for pain, more dispositional empathy, chronic pain and self-other confusion would be positively related with vicarious experiences and a decreased detection accuracy.

First, the role of *hypervigilance for pain* and *dispositional empathy* upon the experience of vicarious experiences and modulation of somatosensation was investigated. The first and second study of chapter 1, describing an experiment executed in pain and non-pain responders showed no difference in empathy scores measured by means of the interpersonal reactivity index. Also no difference between both groups regarding hypervigilance for pain was found. These findings were in contrast to the findings of chapter 3, describing a study again executed in a group of pain responders and non-pain responders. In this latter study, pain responders were more empathic concerned and more hypervigilant for pain compared with non-responders at two different time moments. The first study of chapter 1 showed, however, that for the group of pain responders, the probability of making vicarious pain errors decreased when hypervigilance for pain increased. For the comparison group, the probability of making vicarious pain errors increased when hypervigilance for pain increased. These findings were replicated in chapter 3. In chapter 3, vicarious pain responders made less vicarious errors when more hypervigilant for pain at the first testing moment. This association was not found at time 2. In chapter 2, the same trend was found (marginally significant) in which the probability of making vicarious somatosensory errors decreased when hypervigilance for pain increased in a group of chronic pain patients. In chapter 3, the number of vicarious errors was also dependent upon empathic concern. In the comparison group, the number of vicarious errors decreased; in the pain responder group, the number of vicarious errors increased with increasing levels of empathic concern. In chapter 4, no modulating role of hyperivigilance or empathic concern was found in a group of undergraduates upon the number of vicarious experiences and detection accuracy. In chapter 5, the effect of hypervigilance for pain upon the number of false alarms was significantly different for touch and pain-related videos. When pain-related videos were presented, less false alarms occurred when more hypervigilant for pain. This decrease was even steeper when touch videos were presented.

Second, the role of *chronic pain* and *central sensitization* was investigated in a group of fibromyalgia patients and controls in chapter 2. In both groups, central sensitization was measured by means of temporal summation of heat pulses. It was expected that fibromyalgia patients, experiencing pain spread over the whole body would make more vicarious errors and show a higher level of central sensitization. This way, it was expected that those patients with high levels of central sensitization would report more vicarious experiences and have a lower detection accuracy regarding vibrotactile stimuli while observing pain-related videos. In contrast to our hypothesis, both groups showed equal levels of central sensitization. Detection accuracy and the number of vicarious errors were not dependent upon temporal summation or the presence of chronic pain as both groups were as accurate in detecting the vibrotactile stimuli.

Third, another underlying mechanism that was investigated was *perspective taking*. In the study reported in chapter 4, undergraduates were exposed to several types of videos (touch, pain, control) in first- and third-person perspective (videos turned upside down). In contrary to our expectation, videos presented in first-person perspective did not inflate the number of vicarious errors. Videos in first-person perspective did, however, facilitate detection accuracy, independent upon the content of the video. This suggests that any hands presented in first-person perspective enhance detection accuracy regardless whether these hands are being touched or being pricked. In chapter 5, the impact of perspective taking upon the experience of vicarious sensations and somatosensory modulation while observing pain, touch and control scenes was examined by manipulating the activity in the right tempoparietal junction (rTPJ) as the rTPJ is linked to self-other representations. Again this modulation of rTPJ did not influence the number of vicarious errors or detection accuracy of vibrotactile stimuli while observing pain or touch. In chapter 1, we introduced the rubber hand illusion to explore the role of perspective taking. As pain responders experience bodily illusions in response to viewing another's pain, we expected that pain responders would experience a stronger rubber hand illusion than controls. Participants were asked to focus on the rubber hand. Two small paintbrushes were used to stroke the participant's hand (out of sight) and rubber hand's index fingers, synchronizing the timing of the brushing as closely as possible. In contrary to our expectations, the pain responders experienced the rubber hand illusion equally strong as the non-pain responder group. These studies indicate that perspective taking may be less important as suggested in previous literature regarding the elicitation of vicarious experiences.

Fourth, Chapter 3 investigated the *stability* of vicarious somatosensory experiences in pain responders and controls. Recruitment in research about vicarious experiences and pain is largely based upon self-report through questionnaires or interviews (Banissy & Ward, 2007). Based upon these ratings, participants are selected in a second phase, to take part for example in neuroimaging or other experimental studies. The rather implicit assumption of this selection through self-report includes that the experience of vicarious sensations is stable over time and across several situations. In chapter 3, this assumption was investigated by inviting the same pain responders and non-pain responders for participation in the experiment a second time. We hypothesized that the detection accuracy and vicarious errors would be stable over time, which was confirmed by the analyses at group level. Important to mention is, however, that on an individual level some variability in the number of vicarious errors occurred.

THEORETICAL IMPLICATIONS

Does observing someone else in pain elicits vicarious experiences and modulates somatosensation?

The findings described in the different chapters suggest that observing pain and touch may modulate detection of somatosensory stimuli and may elicit vicarious experiences. The report of vicarious experiences in our studies is consistent with research done by Banissy and Ward (2007) in which vicarious responders produced a higher percentage of vicarious errors than did controls. This pattern of errors implies that these responders can’t easily differentiate between vicarious experiences and somatosensory stimuli which is consistent with our findings. The modulatory role of observing pain or touch upon somatosensation is consistent with other research such as research done by Kirwilliam & Derbyshire (2008). They showed participants pictures of unpleasant stimuli (pain, mutilation, etc.) or neutral stimuli (everyday items) using the dot probe task. Afterwards, participants were exposed to a series of heat pulses which they were asked to score as pain or heat. Those who saw unpleasant images were more likely to report pain instead of heat. They were also more likely to report feeling a (painful) pulse, even when no pulse was administered which is consistent with the report of vicarious experiences in our studies. Our research findings are also in line with Serino et al. (2008) who showed enhanced detection of subthreshold tactile stimuli on observers’ faces when they saw a face being touched by hands rather than a face begin merely approached by hands. This effect was not found for touch on a non-bodily stimulus, namely, a picture of a house, keeping in mind that the mere observation of a body may already facilitate perception (Kennett et al., 2001). In this thesis, the effects are unlikely due to the mere observation of the human body as human hands were present in all video categories. In general, the effects of observing pain or touch were stronger regarding detection accuracy compared with the report of vicarious experiences. This is in line with the idea that vicarious experiences while observing somatosensation is a more extreme variant of the modulation of somatosensation and this in a minority of people. The low percentages of vicarious errors in this PhD are consistent with previous research done by Banissy et al. (2009) about vicarious touch and vicarious pain in amputees (Fitzgibbon et al., 2010a). The variability is dependent upon the criteria used for categorizing individuals as a responder or a non-responder. The findings in this PhD thesis also emphasize caution in the categorizing of participants as vicarious responder or not. The findings of chapter 3 show that at a group level the report of vicarious errors may be stable, but may fluctuate on an individual level. It is yet unclear how participants should be recruited as a first step is always based upon self-report: asking whether someone experiences vicarious sensations. This makes it difficult to disentangle those who report vicarious distress (which also arouses the observer) and those experiencing actual physical vicarious sensations.

The congruency effect found in all chapters of this Phd thesis is consistent with the literature in which it is stated that sensory signals that are presented simultaneously in more than one modality, tend to be detected faster (Hershenson, 1962), more accurately and at lower thresholds than the same signals presented individually (e.g., Frassinetti, Bolognini, & Làdavas, 2002; Stein, London, Wilkinson, & Price, 1996). Johnson, Burton and Ro (2006) showed that participants were more likely to detect a threshold tactile stimulus when it was presented with a visual stimulus, compared to when the touch was presented alone. However, somatosensory stimuli were always combined with visual stimuli in our studies, implying that the different impact of all types of videos upon somatosensation is not mere the effect of congruency. In some chapters this congruency effect was even dependent upon the content of the video (chapter 2, 3, 4), emphasizing that observing pain or touch may even modulate the congruency effect. Although this congruency effect is not the main research finding in this PhD thesis, it emphasizes again the important role of psychological variables in somatosensation, fitting in a biopsychosocial view on pain and touch.

Does empathy, hypervigilance for pain, central sensitization and perspective taking modulate somatosensation and the occurrence of vicarious experiences?

The findings in this PhD about the role of empathy, hypervigilance for pain, central sensitization and perspective taking upon somatosensation and the occurrence of vicarious experiences are inconclusive.

The higher scores regarding hypervigilance for pain in the pain responder group compared with non-pain responders in chapter 3 are consistent with the model of Fitzgibbon et al. (2010b) that states that vicarious experiences may be the result of hyperactivity of the somatosensation mirror system, possibly as a by-product of hypervigilance to pain cues. It seems that hypervigilance for pain may play a modulating role. In fact, in vicarious responders more hypervigilance for pain is in contrast to controls goes together with less vicarious errors (chapter 1-study 1 and chapter 3-moment 1). These results were in line with a trend towards a lower probability to make vicarious somatosensory errors in a group of chronic pain patients when more hypervigilant for pain (chapter 2). These results are inconsistent with our expectations and in contrast to the conceptual model of Fitzgibbon et al. (2010b) in which hypervigilance for pain is assumed to be positively associated with vicarious experiences. A possible explanation for these unexpected results may be that hypervigilance for pain in vicarious responders and chronic pain patients implies a larger attentional focus on the own body, resulting in less vicarious errors. Up to date it is unclear if hypervigilance for pain has a modulating role in making vicarious errors as different findings were found in the different chapters. We don't know how exactly this observer's characteristic prevents pain responders to make vicarious errors.

Regarding empathy, the results are inconsistent. In the first chapter, no difference was found between pain responders and non-pain responders regarding trait empathy. In chapter 3 however, pain responders were more empathic concerned compared with non-pain responders. In chapter 3, the number of vicarious errors decreased in the comparison group, while in the pain responder group, the number of vicarious errors increased when more empathic concerned. The latter findings are in line with the model of Fitzgibbon et al. (2010b) postulating that those experiencing vicarious pain may be affected by dysfunctional empathic processes, resulting in vicarious experiences. The inconclusive results regarding empathy in this thesis are in line with the literature where inconsistent evidence exists regarding empathy in responders and non-responders. For example, Banissy and Ward (2007) found that those experiencing vicarious touch shored higher than controls on the emotional reactivity subscale of the empathy quotient (EQ). This difference on the subscale ‘emotional reactivity’ was replicated by Goller et al. (2013) in a group of amputees with and without the experiences of vicarious sensations. In another study, no difference was found between amputees reporting vicarious pain, amputees without vicarious pain and non-amputee controls in measures of empathy measured by means of the EQ (Fitzgibbon et al., 2012; Giummarra et al., 2010). In a study of Derbyshire et al. (2013) vicarious pain experiences were associated with increased state empathy but not trait empathy. This is congruent with research done by Osborn & Derbyshire (2010) who found that those reporting vicarious pain scored higher than controls on a measure of state empathy but not regarding trait empathy. It could be important to make a distinction between both trait empathy and state empathy as most evidence for differences between vicarious responders and non-responders have been found at the level of state empathy (e.g. Derbyshire et al., 2013; Osborn & Derbyshire, 2010). Banissy and Ward (2007) stress that empathy is multifaceted and that vicarious experiences may be associated with some but not all aspects of this ability. The question remains which aspects may be important in the occurrence of vicarious errors.

As pain-responders experience bodily illusions in response to viewing another’s pain, we also expected them to report a stronger rubber hand illusion. In chapter 1, however, no difference was found in the strength of the experience of the rubber hand illusion between pain responders and non-pain responders. This is in contrast to a study of Derbyshire and colleagues (2013) in which two conditions of striking the participants hand were applied: synchronous and asynchronous. In general, the rubber hand illusion can be generated with asynchronous stroking but the synchronous stroking is important to feel owner over an external body part (Makin et al., 2008; Tsakiris, 2010). Pain responders tended to have greater responses than non-responders on the rubber hand illusion, largely because the responder scores remained high even during asynchronous stroking (Derbyshire et al., 2013). The reports of body ownership during asynchronous stroking suggest that for pain responders, the strong correlations between visual and tactile input are maybe less important for ownership over another person's hand. These authors suggest that it is possible that for pain responders, simply viewing the rubber hand in an anatomically appropriate position results in rapid somatotopic integration, compensating the asynchronous stroking. This idea may count for the difference found in our study and that of Derbyshire et al. (2013) as no asynchronous stroking was used in our paradigm. On the other hand, in a study of Davies & White (2013), two vicarious touch responders did not experience the rubber hand illusion in an asynchronous stroking condition, which may suggest that other processes may be important to explain the inconsistent results. Davies & White (2013) performed a rubber hand illusion paradigm in which the hidden hand of the participant was not touched or being stroked. These authors showed that vicarious touch responders experienced vicarious tactile sensations in the hidden hand and already reported the rubber hand illusion (although no stroking occurred on the hidden hand). These results are in line with the idea of Derbyshire et al. (2013) that simply viewing the rubber hand in an anatomically appropriate position may result in rapid somatotopic integration for vicarious responders. Besides the putative difference in intensity or the presence of the rubber hand illusion in both groups of responders and non-responders, it could also be that the rubber hand illusion is more easily installed in pain responders compared with pain-responders in terms of speed. Further research is needed to point this out.

In this thesis, also the role of perspective taking was investigated. In contrary to our expectation, videos (pain-related, touch) presented in first-person perspective did not inflate the number of vicarious errors (chapter 4). Videos in first-person perspective did however boost detection accuracy, independent upon the content of the video. This suggests that any hands presented in first-person perspective can enhance detection accuracy regardless whether these hands are being touched or being hurt. Our results suggest that perspective taking may be important but is largely dependent upon the outcome (vicarious experiences versus general detection accuracy). The equal number of vicarious errors when observing the videos in first- and third-person perspective is not in line with the model of Fitzgibbon et al. (2010b) suggesting that when a self-perspective is adopted, vicarious somatosensory experiences may be enhanced. The enhanced detection accuracy when videos are presented in first-person perspective is in line with a large body of studies. For example, Serino et al. (2009) showed that vision facilitated tactile perception mostly when self-other similarity is high (e.g. by manipulating the visual appearance and political opinions between observer and the observed person). Canizales et al. (2013) instructed healthy adults to rate a series of pictures depicting hands in either painful or non-painful scenarios, presented either in first-person perspective or third-person perspective (180° angle). The ratings demonstrated that the same scenarios were rated on average as more painful when observed from the first-person perspective than from the third-person perspective. Derbyshire et al. (2013) conclude that vicarious pain may involve reactivation of pain memories or pain schema that are readily integrated into a self-perspective and bodily representation. In their experiments, pain responders showed reduced ability to distinguish their own and others' visual perspective. Besides this behavioral evidence, also neural evidence exists. Saxe, Jamal, and Powell (2006) showed that viewing body parts in first-person perspective produced greater activation of the somatosensory cortex than viewing the same body parts in third-person perspective. Jackson, Meltzoff, and Decety (2006) found a similar result for both imitating and viewing actions. Activations occurring in a wide area of the sensorimotor cortex, probably including SI, were greater for first-person perspective than for third-person perspective. In chapter 5, the impact of perspective taking upon the experience of vicarious sensations and somatosensory modulation while observing pain, touch and control scenes was examined by manipulating the activity in the tempoparietal junction (rTPJ) as the rTPJ has been linked to self-other representations. This modulation of rTPJ did not influence the number of vicarious errors nor the detection accuracy of vibrotactile stimuli while observing pain or touch. These results are in contrast with recent findings indicating that touch responders (those reporting vicarious touch when observing touch) show structural brain differences relative to controls within the right TPJ (namely, reduced gray matter volume; Holle et al., 2013). Santiesteban and colleagues (2012) showed thats online control of self-other representations was improved during anodal stimulation (tDCS) of the rTPJ.

Although our tDCS procedure was similar to the one used by Santiesteban and colleagues (2012), no effects of stimulation occurred in our study. A possible explanation could be that Santiesteban and colleagues (2012) investigated different processes. While they focused on motor mimicry and cognitive perspective taking, our study focused on somatosensory "overlap" between the observer and the observed person. Hence, self-other distinction in these domains might be supported by distinct processes and partially separate neural mechanisms/areas within the rTPJ. Indeed, recent studies consistently suggest that the TPJ is not a homogenous region but that it can be subdivided into several subregions based upon its estimated structural and functional connectivity (Mars et al., 2012; Silani et al., 2013). Further research is needed to clarify the role of perspective taking in the experience of vicarious sensations.

Another underlying mechanism suggested by Fitzgibbon et al. (2010b) in the production of vicarious experiences was central sensitization and prior pain. Central sensitization is defined as an increased responsiveness of the central nervous system to a variety of stimuli and causes hyperalgesia, allodynia, referred pain and widespread pain (Cagnie et al., 2014; Meeus & Nijs, 2007; Nijs et al., 2012). In our studies, central sensitization was assessed using a temporal summation (TS) procedure (Staud, Craggs, Perlstein, Robinson, & Price, 2008b). TS refers to an increased pain experience evoked by the repeated presentation of stimuli of the same intensity. In general, no difference was found in the strength of central sensitization between fibromyalgia patients and controls. This is in contrast to previous studies, providing support for the presence of an alteration of central pain sensitivity in fibromyalgia patients (FM) (Clauw, 2009; Meeus & Nijs; 2007; Staud, Bovee, Robinson, & Price, 2008a; Williams & Gracely, 2006). The threshold intensities for vibrotactile stimuli, although individually determined, were also not significantly different for both groups in our study. This is also contrary to previous studies that have demonstrated that patients with fibromyalgia have a hypersensitivity for mechanical, cold and heat pain perception (Kosek et al., 1996; Smith et al., 2008). Our results in chronic pain patients suggest that the presence of chronic pain nor central sensitization did modulate the experience of vicarious experiences which is in contrast to the model of Fitzgibbon et al. (2010b). In addition, controls reported even more vicarious pain experiences during daily life compared with FM patients. The results are also not in line with those of Brown et al. (2010), who suggested that there might be an interrelation between illusory tactile perceptions and the degree of pseudoneurological symptoms, nor with Katzer et al. (2011) who suggested that medically unexplained symptoms might be related to touch illusions, because both groups in the present study reported a comparable number of vicarious somatosensory experiences during the experimental paradigm. The percentage of reported vicarious pain in this study is smaller than that reported in amputees (Fitzgibbon et al., 2010a), suggesting that prior traumatic events may be an important modulator instead of chronic pain.

CLINICAL IMPLICATIONS

The results of this PhD project have some clinical implications although the research is more fundamentally oriented. Insight into the conditions wherein vicarious experiences is elicited by mere observation is important not only for clinical practice but also for the theory about pain as a biopsychosocial phenomenon. The findings in this PhD that the mere observation of pain and touch may facilitate detection accuracy in the observer and may facilitate the report of illusionary experiences demonstrate the important role of psychological variables in somatosensation. Biomedical thinking is still generally accepted in both lay observers (De Ruddere et al., 2012) as health care professionals (De Ruddere et al., 2014). De Ruddere et al (2014) showed that absence of medical evidence was related to less positive evaluations of patients in general practitioners and to higher beliefs in deception. The findings in this project however show that even without the absence of medical evidence, people may exhibit somatosensory experiences or even pain. Health care professionals should be aware of these processes in order not to stigmatize patients when somatosensation such as pain fluctuates regardless of the medical status. Especially those health care practitioners working with amputees should be aware of these processes as Fitzgibbon et al. (2010a) shows that 16.2% of this population experience pain when observing or imagining pain in another. They should be aware of patients reporting phantom pain when viewing images depicting threatening pain in another such as medical programs on television, or trauma in the newspaper (Giummarra et al., 2010). These patients should be explained that some people may experience these kind of illusionary experiences following trauma and receive some explanation about the condition.

Another clinical implication may be that even the mere observation of touch compared with observing pain may already modulate detection of subtle stimuli. This has clinical implications that go beyond the field of pain. It suggests that our somatosensation is never the same and highly dependent upon the larger context in which somatosensation occurs. This may be highly important when performing painful or (non-)painful procedures as the observation of somatosensation may already enhance the intensity of these procedures. For example, when a group of school children needs vaccination, they sometimes need to queue in which the first of the row is being pricked. The observation of another in pain may already change the experience of the next one in the row.

LIMITATIONS

Several limitations of this PhD project need to be addressed. First of all, an experimental paradigm was used in this PhD project. As mentioned before, this entails several advantages regarding internal validity (e.g. the content of the videos.) However, the use of an experimental lab procedure yields also some disadvantages. First, the videos only depicted hands and no full body which may limit the ecological validity. In reality, people not only observe the painful stimuli by itself but also decode the reaction of the observer (verbal expressions and non-verbal expressions such as posture and facial expressions) which may give some information about the intensity of the painful stimuli (Goubert et al., 2005). As only hands were depicted, the relationship with the observed person was also not taken into account. We might expect that observing loved ones in pain may elicit a stronger emotional response in the observer and therefore may modulate the experience of vicarious sensations. Also the similarity between the observed pain and the history of experienced pain in the observer may modulate the experience of vicarious sensations, which was not taken into account in this PhD project.

Second, we included video clips showing hands being pricked. These videos depict low to medium intense pain. Vicarious experiences may be elicited more easily when very intense pain is observed. That said, pain responders in this study reported more vicarious somatosensory errors during the observation of a subtle injury (the needle prick) as compared with non-pain responders, indicating that vicarious experiences can also be observed with low intense pain stimuli.

Third, participants may have been more aroused when viewing the pain videos as compared to when viewing the control and touch videos. As pain captures attention and may induce threat, it may have been more arousing than the control videos (in a way this is an inherent feature of pain stimuli). Another important mechanism is the involvement of attentional processes. Attention may enhance sensory processing of somatic information when observing bodily experiences in others irrespective of whether they are painful or not.

Finally, vibrotactile stimuli instead of painful stimuli were used in almost every chapter except for chapter one. This allows us to make conclusions about vicarious experiences but not about vicarious pain. We took this in account by consequently not labeling this as vicarious pain.

FUTURE CHALLENGES

Enhancing the ecological validity

An experimental paradigm was used in this PhD project. This way, several variables could be controlled or systematically manipulated. Only hands and no full body were presented as mentioned before, which almost never happens in real life situations. Holle et al. (2011) demonstrated that the intensity of the vicarious touch is stronger when observing touch to real bodies compared with touch to dummy bodies, pictures of bodies and disconnected dummy body parts. Therefore, it could be that the strength or the number of the reported vicarious experiences in our study is diminished by not presenting the full body. Future research could instead of using videos of hands, use real life observations of actual pain related situations. For example, Osborn and Derbyhire (2010) showed participants real life images or video clips downloaded from the internet in order to investigate vicarious pain. The three movie clips included a person’s hand receiving an injection, a tennis player turning over the left ankle and a soccer player breaking the right leg.

Further, vicarious experiences may be elicited more easily when more intense pain is observed compared with the low to medium intense pain-related stimuli in this PhD. Goller et al. (2013) showed that vicarious experiences are more intense when the observed somatosensation is mildly painful (e.g. injection) relative to non-painful (e.g. feather). Further research could present touch or pain of several levels of intensity and measure its role upon the reported intensity of the vicarious sensations.

Understanding the moderating role of observed pain behaviors

In reality, people not only observe the painful stimuli by itself but also decode the reaction of the observer regarding verbal expressions and non-verbal expressions such as posture and facial expressions (Goubert et al., 2005). Several studies showed that observing facial expressions of pain activates parts of the pain matrix, associated with pain perception (Botvinick et al., 2005; Saarela et al., 2006; Simon et al., 2006). Derbyshire et al. (2013) recruited participants with and without teeth sensitivity for cold food. Those with teeth sensitivity reported higher vicarious pain in response to both observing someone eating an ice-popsicle picture expressing pain and without expressing pain. Interestingly, they reported also vicarious experiences when an image of someone expressing pain was depicted, without the painful stimuli of eating an ice-popsicle. Expressive pain behaviors may give some information to the observer about the intensity of a possible painful stimulus and make observers prone to somatosensory modulation or the report of vicarious experiences. Future research is needed to investigate the influence of pain behavior upon the experience of vicarious pain.

The moderating role of the relationship between the observer and the one in pain

In a study of Serino et al. (2009), similarity between self and other was manipulated by visual (dis)similarity (e.g. own or different ethnic group) or through mentioning political opinions of the observed person (e.g. own or to the opposite political party). This study showed that vision facilitated tactile perception mostly when self-other similarity was large. Thorough research into the moderating role of the relationship between the observer and the one in pain would be of importance. In general and also in this PhD project, research into the factors that enhance somatosensory modulation and vicarious experiences mainly focused on unknown observers or body parts of unknown observers (Banissy & Ward, 2007; Osborn & Derbyshire, 2010), but not on relatives or friends of the observer. We might expect that observing loved ones in pain or others that are similar to the observer may elicit a stronger emotional response in the observer and therefore may modulate the experience of vicarious sensations.

The role of commonly experienced pain by the observer, pain memories and somatotopic organisation

Also the similarity between the observed pain and the history of experienced pain in the observer may modulate the experience of vicarious sensations, which was not taken into account in this PhD project. Derbyshire et al. (2013) conclude that vicarious pain may involve reactivation of pain memories or pain schema that are readily integrated into a self-perspective and bodily representation. In their study, the tendency to share pain was enhanced when the observed pain was commonly experienced by the observer. Participants who reported sensitivity to pain when eating cold foods were significantly more likely to report pain sensation after observing others eating cold foods. This finding supports the idea that if we have experienced the pain ourselves, we feel the pain of others more.

Interestingly, in some cases the pain is linked with a particular history of that patient. For example, a patient reported shooting pains from the groin that radiated down the legs when hearing about others' trauma (Giummarra and Bradshaw, 2008). This woman experienced in the past a particularly distressing and painful emergency caesarean section. Phantom limb pain patients have reported experiencing heightened phantom pain when observing, thinking about, or inferring the pain of another (Fitzgibbon et al., 2010a). Goller et al. (2013) postulate that amputees with vicarious experiences differ of normal-bodied vicarious responders in one crucial respect: the mapping between observed touch and felt touch is less somatotopic but occurs in the phantom limb. It could be interesting to investigate in which body parts the reported vicarious experiences in more general populations without chronic or prior intense pain is felt. In this PhD, we implicitly agreed with the assumption of Goller et al. (2013) that vicarious experiences in normal-bodied individuals are somatotopic organized. We expected that participants would feel the vicarious experiences in their hands as in the video clips. Although vicarious experiences were felt in the hands, which resulted in more vicarious errors, some did report vicarious sensations elsewhere in the body. Although this was not systematically investigated in this PhD, some research provides indications that vicarious experiences may not be felt in the same body part as the observed person in pain. For example, in the study of Derbyshire et al. (2013), some pain responders with teeth sensitivity for cold food, reported pain in the teeth but also in the face, the head, the foot, the chest and the lower back when observing someone eating an ice popsicle. Up to date, it is unclear why some people report the vicarious sensations in the similar body part as the observer and others do not. As mentioned before, pain memories may have played a role in this particular experiment but further research is needed to clear this out.

A model that could act as a heuristic in exploring these three future directions as mentioned above (observed pain behaviors, relationship between observer and observed one in pain and commonly experienced pain) is the model developed by Goubert et al. (2005). Goubert et al. (2005) formulated an empathy model in the context of pain, which provides a related heuristic framework to better understand observer *estimates* of another individual's pain. The same processes as described in this model could be important in the experience of vicarious experiences and modulation of somatosensation. In particular, the model distinguishes bottom-up variables (variables that are related to the individual with pain him/herself such as expressive pain behavior), top-down variables (variables that are related to the observer such as catastrophizing) and contextual variables (e.g. the relationship between the patient with pain and the observer). For example, it could be that a mother with high levels of catastrophic thinking and with a history of pain is more prone to somatosensory modulation or the report of vicarious experiences while observing a high level of pain expression in her beloved child. Further research is needed to test these hypotheses.

Understanding the quality and intensity of the reported vicarious experience

Furthermore, systematically interviewing observers reporting vicarious pain with regard to the reported intensity and experienced distress would be of major significance. Several concepts and titles in the literature about vicarious pain and touch (e.g. 'mirror touch', 'mirror pain', 'I feel what you feel') may give the impression that the quality or intensity of this vicarious experience is really felt as touch or pain. Although some concepts may look attractive for a broad public, caution is necessary in creating concepts and titles. Now, it is unclear to what extent the vicarious experiences are really felt as a painful or touching experience.

First of all, along several chapters in this PhD, pain responders erroneously take the vicarious experiences for an administered vibrotactile stimulus. This may suggest that the vicarious sensations are predominantly not painful but rather vague, subtle sensations. This in line with research done by Osborn & Derbyshire (2010) describing the vicarious pain experience mostly as ‘tingling’ followed by ‘aching’, ‘sharp’, ‘shooting’, throbbing’, ‘sickening’, ‘splitting’, ‘heavy’, ‘stabbing’ and ‘tender’. In the ice popsicle experiment mentioned before, the quality of the vicarious experience was described as sharp, shooting, aching and throbbing (Derbyshire et al., 2013). The reported average intensity of the pain in the observer of the first mentioned study of Osborn & Derbyshire (2010) was 1.9 (SD=2.4), indicated on a VAS scale, anchored at 0 for no pain and at 10 for most pain imaginable. The average reported pain intensities in the ice popsicle experiment of Derbyshire et al. (2013) were below 1.4 on a VAS scale ranging on the same scale. The question remains whether such low intensity scores can be labeled as vicarious ‘pain’ experiences. In line with these low intensities, a study of Holle et al. (2013) suggested that the vicarious experience resembles not even the half of a touching experience. In this study, not only the intensity but also the quality of the reported vicarious experiences was measured. Participants were asked to rate the subjective intensity of any felt touch in response to viewing touch to a face, a dummy face and an object on a scale ranging from 0 (no sensation at all) to 10 (as intense as if I were the person in the video). Although vicarious experiences were stronger for observing touch to a person compared with a dummy or an object, intensities were on average below 3.5. A study of Goller et al. (2013), using the same scale as Holle et al. (2013; no sensation at all- as intense as if I were the person in the video), showed that the average of the reported intensity of the vicarious experiences was below 1.5. Again, this study suggests that the vicarious experience is not the same as what is observed. The above mentioned studies suggest that the intensities of vicarious experiences are rather low, and of such quality that it nearly resembles a touching or painful experience as what is observed in the other.

Second, when feeling a vicarious non-painful experience, people are probably not inclined to indicate an extreme of 0 on a scale ranging from no pain to most pain imaginable as vicarious experiences that are not painful can’t be indicated on such a scale. First asking whether the participant felt anything on the body (or phantom) with a binary Yes/No option, could be a better option. When ‘no’ is chosen, the intensity can be scored as 0. This way of scoring may already reduce some false positives. Second, as the experience of pain is a subjective and emotional experience (International Association for the Study of Pain Task Force on Taxonomy, 1994, p. 210), comparisons between pain intensity scores are difficult to make. The scale measuring the intensity of the vicarious experiences as used by Holle et al. (2013) and Goller et al. (2013) ranging from ‘no sensation’ to ‘feeling as if you were the person in the video’ may give us more information about the quality of the experience as a mutual comparing point is used (the experience of the observed person) and it legitimizes comparisons of scores between different participants. Subsequently reporting whether this was painful or not (yes/no) allows us to conclude whether this was actually painful or not.

Derbyshire et al. (2013) suggested including some objective measures when measuring these intensities such as galvanic skin responses, alongside subjective report. Furthermore, future research may focus upon possible explanatory variables for our findings, for example the mediating role of arousal. Since pain captures attention and may induce threat (an inherent feature of pain-related stimuli), it may have been more arousing than the control videos.

Future research is needed to build the bridge between fundamental experimental studies implying few subject reports and those studies measuring vicarious experiences predominantly based upon self-report. This bridge, including picking words carefully when describing phenomena and constructing adequate scales, may be some of the future and interesting challenges.

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NEDERLANDSTALIGE SAMENVATTING

ALGEMENE INLEIDING

De meest voorkomende gezondheidsklacht is pijn (Crombie et al., 1991). De geschatte prevalentie van chronische pijn ligt vermoedelijk tussen 10 en 30% in de volwassen populatie, al wijzigen sommige studies op een nog grotere range (2 tot 55%; Breivik et al., 2006; Harstall et al., 2002; Verhaak et al., 1998). Het ervaren van chronische pijn heeft zowel een negatieve impact op het dagdagelijkse leven als op de mentale gezondheid (Breivik et al., 2006). Het biomedische perspectief, waarbij pijn gezien wordt als een gevolg van de sensoriële input (of de fysiologische schade) werd in de 20ste eeuw vervangen door het biopsychosociaal perspectief waarin psychologische en sociale factoren ook een belangrijke rol toebedeeld kregen (Gatchel et al., 2007). Pijn kan immers niet begrepen worden door enkel het biologische component in rekening te brengen. Ook psychologische (bijv. catastroferen over pijn, hypervigilantie voor pijn, operante en klassieke conditionering) en sociale factoren kennen een grote impact op hoe pijn ontstaat en tot uiting komt (bijv. Gatchel & Turk, 1999). Naast onderzoek dat zich focuste op het intrapersoonlijke aspect van pijn, kwam er meer en meer aandacht voor het interpersoonlijke luik. Mensen leven immers niet op zichzelf, maar in een context. Zo kan het observeren van een ander in pijn leiden tot heel wat emotionele onrust bij diegene die observeert (Goubert et al., 2005). Dit is te zien bij beeldvorming van de hersenen: affectieve gebieden die actief zijn bij het voelen van pijn zijn ook betrokken bij het zien van een ander met pijn (Singer et al., 2004; Jackson et al., 2005). Naast deze overlappende activatie op het affectieve domein is er steeds meer en meer onderzoek dat stelt dat ook de sensorische-discriminatieve functies actief zijn bij het voelen van en het zien van pijn bij een ander (Bufalari et al., 2007).

Bij sommige mensen kan het observeren van pijn niet enkel op emotioneel vlak beroeren, maar ook effectief tot een bewuste fysieke pijnervaring leiden. Deze ‘plaatsvervangende somatosensorische sensaties’ zijn intrigerend aangezien dit vooropstelt dat nociceptieve of somatosensorische input niet noodzakelijk zijn om fysieke pijn of aanraking te voelen. Een eerste gevalsbeschrijving in de literatuur vinden we terug bij Bradshaw en Mattingley (2001). Zij beschrijven een vrouw die rapporteerde dat haar man met hyperalgesie, pijn ervoer wanneer zij zich bezeerde. Een ander voorbeeld is beschreven door Giummarra en Bradshaw (2008) waarbij een vrouw die een zeer moeilijke en pijnlijke bevalling met spoedkeizersnede had doorgemaakt, steeds pijn ervoer in de lies wanneer iemand over een traumatische gebeurtenis vertelde. Deze voorbeelden tonen aan dat de meeste gevalstudies beschreven werden in patiënten met een geschiedenis van intense en/of traumatische pijn. Eén zo'n groep waarin heel wat gevallenstudies voorkomen is de groep van mensen met fantoom pijn als gevolg van een amputatie (zie Fitzgibbon et al., 2010b; Giummarra & Bradshaw, 2008). Fitzgibbon en collega's (2010a) schatten het voorkomen van plaatsvervangende pijn bij dergelijke patiënten op 16.2%. In een interview verricht door Giummarra en collega's (2008) in een groep van dergelijke patiënten bleek dat de fantoompijn werd getriggerd bij het denken over of het bekijken van een ander in pijn. Naast deze evidentie, is er onderzoek dat aantoont dat gezonde mensen uit de algemene populatie ook plaatsvervangende pijn kunnen rapporteren (Osborn en Derbyshire, 2010).

Fitzgibbon en collega's (2010b) hebben een model vooropgesteld met onderliggende mechanismen voor het optreden van plaatsvervangende pijn. Dit model werd in 2012 aangevuld en uitgebreid (zie Fitzgibbon et al., 2012). Deze onderzoekers gaan er vanuit dat dysfunctionele spiegelsystemen de empathische processen in de observeerder verstoren. Een disinhibitie probleem in deze systemen zou ervoor zorgen dat de hersenengebieden die normaal actief zijn in het verwerken van pijn bij zichzelf en de ander, te actief zijn. Hierbij zou de activiteit de drempel voor bewuste gewaarwording overschrijden, wat resulteert in het ervaren van pijn in diegene die observeert. De auteurs stellen dat deze verstoorde vorm van empathie waarbij het perspectief van de ander overlapt met het eigen perspectief, gemoduleerd wordt door reeds meegemaakte traumatische (pijn)ervaringen, hypervigilantie voor pijn en centrale sensitisatie. De meeste evidentie is afkomstig van zelfrapportage maar systematisch onderzoek naar dit fenomeen met bijhorende onderliggende mechanismen ontbreekt. Het is onduidelijk of deze plaatsvervangende somatosensorische sensaties systematisch onderzocht kunnen worden door middel van een experimenteel paradigma.

DOELSTELLINGEN

Dit onderzoeksproject had drie grote doelstellingen. De eerste doelstelling betrof het ontwerpen van een geschikt experimenteel paradigma om plaatsvervangende sensaties en somatosensorische modulatie (= de invloed van het observeren van pijn of aanraking bij een ander op de eigen somatosensatie) te meten. Een tweede doelstelling was om systematisch de effecten te onderzoeken van het observeren van aanraking of pijn bij een ander op de eigen somatosensorische perceptie en de ervaring van plaatsvervangende sensaties. Een derde doelstelling betrof de exploratie van condities waarin plaatsvervangende sensaties en somatosensorische modulatie optreden. Hierbij lag de focus voornamelijk op de rol van perspectiefname, dispositionele empathie, hypervigilantie voor pijn, chronische pijn en centrale sensitisatie. Deze variabelen werden als onderliggende mechanismen in het voorkomen van plaatsvervangende pijn in het model van Fitzgibbon en collega’s (2010b, 2012) vooropgesteld. Hierbij werd verwacht dat diegene die hoger scoren op maten van empathie, hypervigilantie voor pijn en centrale sensitisatie, meer plaatsvervangende sensaties vertonen bij het zien van anderen in pijn. Alsook werd verwacht dat chronische pijn patiënten meer plaatsvervangende sensaties zouden rapporteren tijdens een experimenteel opzet bij het zien van een ander in pijn.

Deze drie doelstellingen werden zowel bij een chronische pijnpopulatie (fibromyalgie patiënten) als bij een algemene populatie (studenten met en zonder de ervaring van plaatsvervangende ervaringen) vooropgesteld. Een groter inzicht in de manier waarop plaatsvervangende sensaties en somatosensorische modulatie optreden, is zowel belangrijk voor de praktijk als theorie omtrent pijn. Theoretisch gezien kan het onze kijk op hoe pijn ontstaat en verwerkt wordt, veranderen. Op klinisch vlak kan het ons sturen in het zoeken naar antwoorden waarom sommige patiënten pijn ervaren wanneer er geen biomedische oorzaak kan geïdentificeerd worden.

RESULTATEN

Het ontwikkelen van een geschikt experimenteel paradigma om plaatsvervangende ervaringen en somatosensorische modulatie te meten

Doorheen de verschillende hoofstukken werd gebruik gemaakt van hetzelfde (soms licht gewijzigde) paradigma. Dit paradigma werd grotendeels gebaseerd op het paradigma dat in het verleden werd gebruikt om plaatsvervangende aanrakingen te meten (Banissy & Ward, 2007). In dit doctoraatsonderzoek kregen participanten filmpjes te zien van een linker –en rechter hand waarbij een van de handen werd geprikt of aangeraakt. Tegelijkertijd werd op de eigen linker- of rechterhand van de participanten een somatosensorische prikkel toegediend (vibrotactiele prikkel of pijnprikkel). De locatie van de toegediende somatosensorische prikkel betrof dezelfde kant als de visuele prik of aanraking (congruente condities) of de andere kant (incongruente condities). Op deze manier kon men nagaan hoe vaak plaatsvervangende fouten optraden, namelijk hoe vaak men foutief een somatosensorische prikkel rapporteerde aan dezelfde kant als de visuele stimulus. Somatosensorische modulatie werd gemeten aan de hand van de accuraatheid van detectie van de aangeboden somatosensorische prikkels. Dit doctoraatsonderzoek toonde aan dat plaatsvervangende sensaties en somatosensorische modulatie gemeten kunnen worden aan de hand van een experimenteel paradigma.

De effecten van het observeren van aanraking of pijn bij een ander op de eigen somatosensorische perceptie en het voorkomen van plaatsvervangende somatosensorische sensaties

Dit doctoraatsonderzoek toonde aan dat er een groter aantal plaatsvervangende fouten voorkwam en een betere detectie van vibrotactiele prikkels plaatsvond, bij het observeren van pijn gerelateerde video’s vergeleken met niet pijn gerelateerde video’s. Deze resultaten kwamen zowel naar voor in een groep van chronische pijnpatiënten (hoofdstuk 2), als in een algemene groep van studenten (hoofdstuk 4 en 5), als bij mensen die plaatsvervangende pijn in het dagelijkse leven rapporteren (hoofdstuk 3). In het algemeen werden weinig plaatsvervangende ervaringen tijdens de experimenten gerapporteerd vooral wanneer de toegediende somatosensorische prikkels pijnprikkels betrof (hoofdstuk 1).

De exploratie van condities waarin plaatsvervangende sensaties en somatosensorische modulatie optreden

De verschillende gesuggereerde onderliggende mechanismen in het voorkomen van plaatsvervangende somatosensorische sensaties en somatosensorische modulatie werden onderzocht doorheen alle hoofdstukken. Wat betreft de rol van empathie en hypervigilantie voor pijn werd geen consistent verband vastgesteld doorheen alle hoofdstukken. In het algemeen kan gesteld worden dat bij participanten die plaatsvervangende pijn in het dagelijkse leven rapporteren (hoofdstuk 1 en 3) hypervigilantie voor pijn net leek samen te hangen met minder plaatsvervangende fouten. Dezelfde trend was te vinden bij een groep chronische pijnpatiënten (hoofdstuk 2). Deze bevindingen zijn in contrast met de vooropgestelde hypothesen gebaseerd op het model van Fitzgibbon en collega’s (2010b) waarbij een toename in hypervigilantie voor pijn zou samengaan met een toename van het aantal plaatsvervangende sensaties. Hoofdstuk 2 toonde aan dat de rapportering van plaatsvervangende ervaringen en somatosensorische modulatie onafhankelijk was van de aanwezigheid van chronische pijn of centrale sensitisatie. Perspectiefname had ook geen positief verband met het aantal plaatsvervangende fouten, maar was wel gerelateerd aan somatosensorische modulatie. Het tonen van handen in een eerste-persoons perspectief (handen met de vingers omhoog) faciliteerde de detectie accuraatheid van somatosensorische prikkels in vergelijking met het tonen van de handen in een derde-persoons perspectief (hand met de vingers omlaag). Dit was onafhankelijk van de inhoud van de filmpjes, namelijk al dan niet pijn gerelateerd (hoofdstuk 4). Het manipuleren van de activiteit in de rechtse tempopariëtale junctie (gerelateerd aan het maken van een onderscheid tussen ik en de ander) had eveneens geen invloed op het aantal plaatsvervangende fouten of de accuraatheid van detectie. Deze resultaten zijn in lijn met de resultaten van de rubberen hand illusie die werd uitgevoerd in hoofdstuk 1. In dit opzet werden diegene die plaatsvervangende pijn rapporteerden in het dagelijkse leven en controle personen gevraagd om zich te focussen op een rubberen hand. Twee borsteltjes wreven op synchrone wijze de vingers van de participant en de vingers van de rubberen hand. De rubberen hand illusie, waarbij de participant het gevoel krijgt dat de rubberen hand de zijne is, trad even sterk op in beide groepen. Deze resultaten lijken te suggereren dat perspectiefname zoals onderzocht in dit doctoraat minder belangrijk lijkt te zijn dan in de literatuur werd gesuggereerd.

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Dit doctoraatsonderzoek onderzocht het voorkomen van de ervaring van plaatsvervangende somatosensorische ervaringen, somatosensorische modulatie en mogelijke onderliggende mechanismen. Het meest robuuste resultaat van dit doctoraatsonderzoek is het gegeven dat plaatsvervangende sensaties en somatosensorische modulatie gemeten kunnen worden aan de hand van een experimenteel opzet. Dit ligt in lijn met vorige studies die deze fenomenen op een experimentele manier onderzochten (Banissy & Ward, 2007, 2009; Serino et al., 2008, 2009). Vervolgens toonden de resultaten in dit doctoraat ook aan dat plaatsvervangende sensaties gerapporteerd werden bij slechts een beperkte groep mensen in de algemene populatie. Dit ligt in lijn met vorig onderzoek waarbij werd aangetoond dat een minderheid dit fenomeen vertoont (Banissy & Ward, 2009; Fitzgibbon et al., 2010a; Osborn & Derbyshire, 2010). Wat betreft somatosensorische modulatie, suggereerde dit onderzoeksproject dat het observeren van pijn bij een ander de eigen detectie van subtiele somatosensorische prikkels kan faciliteren. Deze gegevens tonen aan dat pijn en somatosensatie noodzakelijk beschouwd moeten worden vanuit een biopsychosociaal perspectief waarin psychologische en sociale factoren naast medische factoren worden beklemtoond. Met betrekking tot onderliggende factoren zoals hypervigilantie voor pijn, chronische pijn, empathie, perspectief name en centrale sensitisatie werd niet altijd een even eenduidig beeld bekomen. Aangezien deze genoemde variabelen in de meeste van de studies in dit doctoraatsonderzoek werden gemeten aan de hand van zelfrapportage, is verder onderzoek nodig. Toekomstig onderzoek zou deze variabelen op systematische wijze kunnen manipuleren om hun modulerende rol te verduidelijken. Een andere belangrijke piste voor toekomstig onderzoek betreft het pijngedrag van de geobserveerde, de relatie tussen de observator en de geobserveerde en vroegere pijnervaringen van diegene die observeert. In de algemene discussie van dit proefschrift wordt dieper ingegaan op deze variabelen.

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