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

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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.

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.

FM: Fibromyalgia patients, CCE: congruency effect, TS: temporal summation

Keywords: vicarious experiences, visual enhancement, observation of pain, empathy, hypervigilance for pain

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 a 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, Enticott, Bradshaw, Giummarra, Chou, Georgiou-Karistianis, & Fitzgerald, 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, Giummarra, Georgiou-Karistianis, Enticott, & Bradshaw, 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, Oberfeld, Hiller, &Witthöft, 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.

Methods

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 0.068 W. The intensity was decreased by 0.0002 W whenever the participants reported feeling the stimulus, and increased by 0.0002 W 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, Taylor-Clarke, Kennett, & Haggard, 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, Craggs, Perlstein, Robinson, & Price, 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 .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 .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 middleof 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 measuringhypervigilance for pain (PVAQ) and empathic disposition (IRI). After a short break, the participants

continued with the temporal summation measurement.

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, Moerkerke, De Smet, &Buysse, 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.

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 (χ^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).

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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Tables

Table 1. Detection accuracy for both groups and all video types.

Table 2. Pearson/Spearman correlations of all measures.

Table 3. Mean scores and standard deviations of all measures.

Figures

Figure 1. Example of a possible trial.

Figure 2. The relationship between congruency and video.

	INCONGRUENT				CONGRUENT				NO TACTILE STIMULATION				BOT
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 tovisual	Opposite site to visual	Both hands	Correct No hands	Visua site
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%	22.5 *Neg* *erro*
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%	15.7 *Neg* *erro*
Visual control/ Control group	36.62%	.33%	.66%	62.39%	38.60%	.11%	.44%	60.86%	.88%	.55%	0%	98.58%	12.2 *Neg* *erro*
Visual control/ FM group	33.33%	.22%	.11%	66.34%	35.42%	.33%	1.21%	63.05%	.66%	.66%	.11%	98.58%	11.1 *Neg* *erro*

Table 2. Pearson/Spearman correlations of all measures.

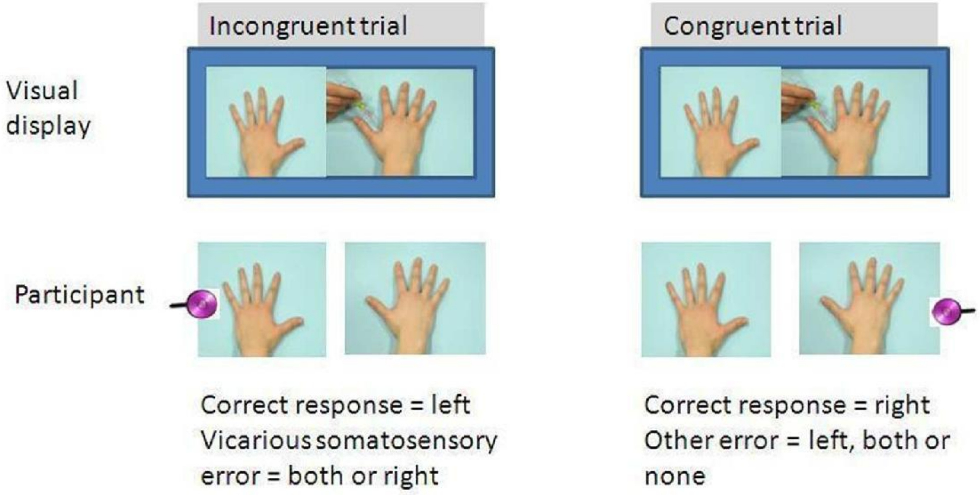
	2.	3.	4.	5.	6.	7.	8.	9.
1. Vicarioussomatosensoryerrors	.32**	-.03	-.08	.08	.10	-.00	-.02	.09
2. Neglect errors (pain-related videos)	-	-.03	-.05	.16	-.01	-.16	-.29*	-.01
3. Hypervigilance (PVAQ)		-	-.02	-.30**	-.04	.06	.40**	-.01
4. Empathic concern			-	.22	.16	-.06	.07	-.01
5. Fantasy scale				-	.14	-.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) FM group	M(SD) comparison group	M(SD) total group
1. Vicarioussomatosensoryerrors	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. Temporalsummation, (intensity last-first stimuli)	7.57 (11.18)	6.46 (6.40)	6.04 (9.22)
8. HospitalAnxietyand DepressionScale (HADS)	18.70 (7.13)	6.01 (5.03)	12.44 (8.86)
9. Vicariouspainexperiences duringdaily life	3.21 (4.86)	6.14 (8.33)	4.63 (6.89)

Note. Pain Vigilance and Awareness Questionnaire (PVAQ).



215x111mm (96 x 96 DPI)

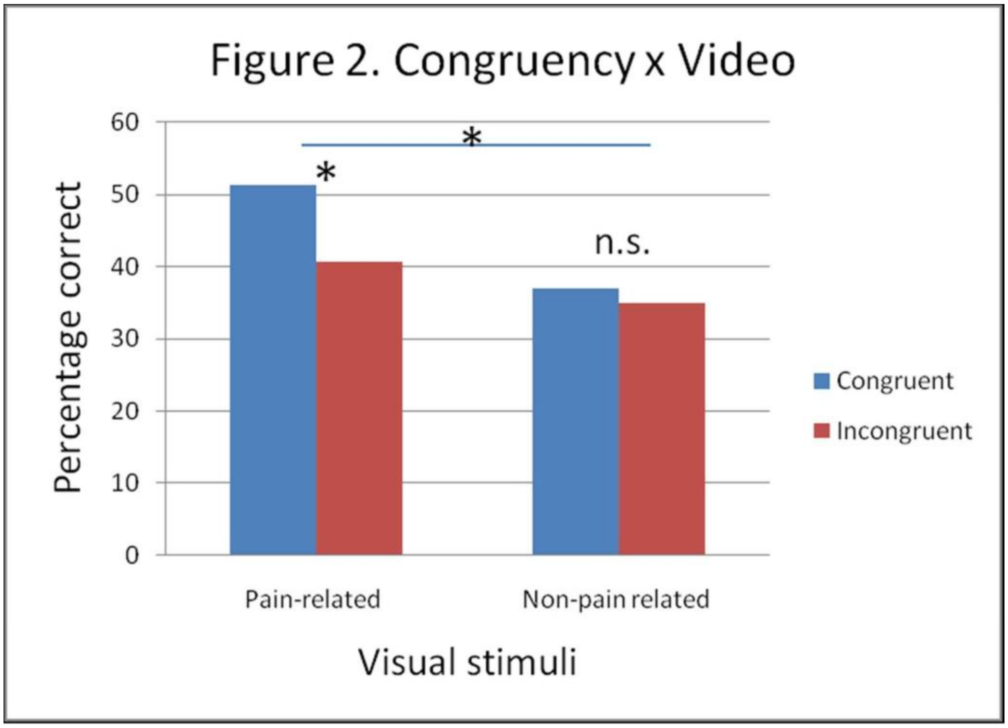


Figure 2. Congruency x Video
Percentage correct
60
50
40
30
20
10
0
*
*
n.s.
Pain-related
Non-pain related
Visual stimuli
Congruent
Incongruent