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

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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, tDCS was used to assess the role of the right tempoparietal junction (rTPJ), as this brain region has been 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.

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

Keywords: vicarious, empathy for pain, rTPJ, somatosensation, somatosensory modulation

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 & Derbyshire, 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., 2015). 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 eliciting 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. We did not aim to induce *painful* vicarious sensations. Therefore, we consequently label the vicarious sensations as such and not as painful vicarious sensations. Consequently, no statements can be made regarding vicarious pain. 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 each type of stimulation of rTPJ.

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 (touch, pain, control), location of visual cue, 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. (2015), the screen on which the hands were depicted was placed in a frontal angle before the participant.

-Insert Figure 1 about here-

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). This threshold procedure was repeated in every session, before tDCS stimulation was induced.

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). Both tDCS stimulation and sham condition 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). Several intensities were used to avoid habituation and

to enhance the chance to report vicarious errors. When both hands were stimulated, the intensities were both threshold or both above threshold

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 discriminating 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. The stimulation was counterbalanced across participants.

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.

-Insert Table 1 about here-

-Insert Figure 2 about here-

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). This categorization is based upon previous work on vicarious touch (Banissy & Ward, 2007) and vicarious somatosensory sensations in general (Vandenbroucke et al., 2013, 2014a,b, 2015). 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— $100 \times (eB - 1)$ —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 ‘tDCS stimulation’ (anodal versus cathodal versus sham) as predictor. In a third model both video category and tDCS 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 tDCS 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 tDCS 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 tDCS 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 tDCS 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, ‘tDCS stimulation’ (anodal versus cathodal versus sham) was added as predictor. In a third model both video category and tDCS 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 tDCS 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).

Pain scenes. 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).

Touch scenes. 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).

Control scenes. 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) (see table 1).

-Insert table 2 about here-

-Insert figure 3 about here-

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 $p > .27$).

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

Detection accuracy and reaction times

A 2 (congruency: congruent versus incongruent) x 3 (type of tDCS 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 tDCS stimulation was found ($F(2,42) = 1.08$, $p = .35$). A trend was found regarding the video x tDCS stimulation interaction ($F(4,84) = 2.34$, $p = .06$). When exploring this trend by comparing tDCS 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 (see figure 4 and 5).

-Insert figure 4 and 5 about here-

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 tDCS stimulation was added as a predictor. Results showed that the number of neglect errors was independent of type of tDCS stimulation (all $p > .48$). In a third model, both type of video and tDCS stimulation were added as predictors. No interaction occurred between video category and tDCS stimulation (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 intensity 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., 2015), our results show that participants reported more vicarious somatosensory experiences when pain-related videos were 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., 2015). Our results suggest that the different video categories (touch, pain, control) may modulate somatosensation differently. We designed our videos to be as similar as possible, in terms of visual features as well as of the represented actions. For that reason, the control videos consisted of a hand approaching another hand without holding an object. Morrison, Tipper, Fenton-Adams, and Bach (2013) showed that separate somatosensory regions responded more strongly when the observed action targeted noxious rather than 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 or the absence of an approaching object, the type of object could also have played a role in our study (e.g., cotton swab vs. needle), in that a needle could have been more salient.

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 tDCS stimulation and video, in which facilitation implied *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.

Participants reported in incongruent trials, the correct side of the somatosensory stimulation far more often than they reported feeling tactile stimulation at the side of the visual touch or pain (see Table 1). This illustrates that participants relied much more upon the actual somatosensory input than the visual information. In the direct comparison between congruent and incongruent trials, we see a higher proportion of detected vibrotactile stimuli in congruent compared with incongruent trials. This may suggest that the visual system could 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). 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.

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. The decrease was even stronger for observing touch. This negative relationship between the number of vicarious errors and hypervigilance for pain is in contrast to the model of Fitzgibbon et al. (2010b) which predicts a positive relation between the two variables. The negative relationship between hypervigilance for pain and the number of vicarious errors in this study is consistent with previous research in our lab in a group of pain responders (Vandenbroucke et al., 2013; study 1; Vandenbroucke et al., 2014b). These latter studies 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 to 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.

A different number of neglect errors occurred between the observation of pain-related versus control scenes. 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., 2015). In general we can say that observing pain-related information increases the likelihood of reporting tactile stimulation, particularly at a location congruent with the pain observed in the video. Neglect errors were frequently made in comparison with vicarious errors, suggesting that the observation of pain-related information modulates somatosensory experiences, rather than induce illusory experiences.

Some limitations of this study deserve further consideration, yielding directions for future research. First, one possible explanation for the 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 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. These processes may contribute to the higher detection accuracy and the increased number of neglect errors when pain-related videos were shown compared with control videos. Further research may focus upon possible explanatory variables for our findings, for example the mediating role of arousal and attentional processes. Second, subtle tactile somatosensory stimuli were administered in this experiment. Osborn and Derbyshire (2010) found that most patients selected ‘tingling’ as a descriptor to describe the somatosensory vicarious experiences while observing pain. Consequently, we administered subtle tactile stimuli. The percentage of vicarious experiences was increased in comparison with our previous study, suggesting that the vicarious experiences were experienced as subtle rather than painful (Vandenbroucke et al., 2013). We did not aim to simulate *painful* vicarious sensations. Therefore, we consequently labeled the vicarious sensations as such and not as

painful vicarious sensations. Consequently, no statements can be made regarding vicarious pain. Third, 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. Finally, 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).

References

- Aimola-Davies, A.M., & White, R.C. (2013). A sensational illusion: vision–touch synaesthesia and the rubber hand paradigm. *Cortex*, 49, 806–818. doi:10.1016/j.cortex.2012.01.007
- Azevedo, R.T., Macaluso, E., Avenanti, A., Santagelo, V., Cazzato, V., & Aglioti, S.M. (2013). Their Pain is Not Our Pain: Brain and Autonomic Correlates of Empathic Resonance With the Pain of Same and Different Race Individuals. *Human Brain Mapping*, 34, 3168–3181. doi:10.1002/hbm.22133
- Banissy, M.J., Kadosh, R.C., Maus, G.W., Walsh, V., & Ward, J., (2009). Prevalence, characteristics and a neurocognitive model of mirror-touch synaesthesia. *Experimental Brain Research*, 198, 261–272. doi:10.1007/s00221-009-1810-9
- Banissy, M.J., & Ward, J. (2007). Mirror-touch synesthesia is linked with empathy. *Nature Neuroscience*, 10, 815–816. doi:10.1038/nn1926
- Batson, C.D., Lishner, D.A., Carpenter, A., Dulin, L., Harjusola-Webb, S., Stocks, E.L., Gale, S., Hassan, O., & Sampat, B. (2003). “... As you would have them do unto you”: Does imagining yourself in the other’s place stimulate moral action? *Pers. Soc. Psychol. Bull.* 29, 1190–1201.
- Bufalari, I., Aprile, T., Avenanti, A., Di Russo, F., & Aglioti, S.M. (2007). Empathy for pain and touch in the human somatosensory cortex. *Cerebral Cortex*, 17, 2553–2561. doi:10.1093/cercor/bhl161
- Caes, L., Uzieblo, K., Crombez, G., De Ruddere, L., Vervoort, T., & Goubert, L. (2012). Negative emotional responses elicited by the anticipation of pain in others: psychophysiological evidence. *The Journal of Pain*, 13, 467–476. doi:10.1016/j.jpain.2012.02.003
- Cardini, F., Haggard, P., & Lavadas, E. (2013). Seeing and feeling for self and other: Proprioceptive spatial location multisensory enhancement of touch. *Cognition*, 127, 84–92. doi:10.1016/j.cognition.2012.12.010
- Craig, K.D., Versloot, J., Goubert, L., Vervoort, T., & Crombez, G. (2010). Perceiving pain in others: Automatic and controlled mechanisms. *The Journal of Pain*, 11(2), 101–108. doi:10.1016/j.jpain.2009.08.008
- Davis MH. (1983). Measuring individual differences in empathy: evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, 44, 113–126. doi:10.1037//0022-3514.44.1.113

- Derbyshire, S.W.G., Osborn, J., & Brown, S. (2013). Feeling the pain of others is associated with self-other confusion and prior pain experience. *Frontiers in Human Neuroscience*, 7, 1-8. doi:10.3389/fnhum.2013.00470
- De Corte, K., Buysse, A., Verhofstadt, L.L., Roeyers, H., Ponnet, K., & Davis, M. (2007). Measuring empathic tendencies: reliability and validity of the Dutch version of the interpersonal reactivity index. *Psychologica Belgica*, 47, 235-260.
- Decety, J., & Lamm, C. (2007). The role of the right tempoparietal junction in social interaction: How low-level computational processes contribute to meta-cognition. *Neuroscientist*, 13, 580-593. doi:10.1177/1073858407304654
- Farrer, C., & Frith, C. D. (2002). Experiencing oneself vs another person as being the cause of an action: the neural correlates of the experience of agency. *Neuroimage* 15, 596–603. doi:10.1006/nimg.2001.1009
- Fitzgibbon, B.M., Enticott, P.G., Giummarra, M.J., Thomson, R.H., Georgiou-Karistianis, N., & Bradshaw, J.L. (2012a). Atypical electrophysiological activity during pain observation in amputees who experience synaesthetic pain. *Social Cognit Affect Neurosci*, 7(3), 357-368. doi:10.1093/scan/nsr016
- Fitzgibbon, B.M., Enticott, P.G., Rich, A.N., Giummarra, M.J., Georgiou-Karistianis, N., & Bradshaw, J.L. (2012b). Mirror-sensory synaesthesia: Exploring ‘shared’ sensory experience as synaesthesia. *Neuroscience & Biobehavioral Reviews*, 36, 645-657. doi:10.1016/j.neubiorev.2011.09.006
- Fitzgibbon, B.M., Enticott, P.G., Rich, A.N., Giummarra, M.J., Georgiou-Karistianis, N., ... Bradshaw, J.L. (2010a). High incidence of ‘synaesthesia for pain’ in amputees. *Neuropsychologia*, 48, 3675-3678. doi:10.1016/j.neuropsychologia.2010.07.029
- Fitzgibbon, B.M., Giummarra, M.J., Georgiou-Karistianis, N., Enticott, P.G., & Bradshaw, J.L. (2010b). Shared pain: From empathy to synaesthesia. *Neuroscience & Biobehavioral Reviews*, 34, 500- 512. doi:10.1016/j.neubiorev.2009.10.007
- Gardner, W., Mulvey, E., & Shaw, E. (1995). Regression analyses of counts and rates: Poisson, overdispersed Poisson, and negative binomial models. *Psychological Bulletin*, 118, 392-404. doi:10.1037//0033-2909.118.3.392
- Goubert, L., Craig, K.D., Vervoort, T., Morley, S., Sullivan, M.J.L., Williams A.C.D., ... Crombez, G. (2005). Facing others in pain: the effects of empathy. *Pain*, 118, 285-288. doi:10.1016/j.pain.2005.10.025
- Goubert, L., Vervoort, T., & Crombez, G. (2009). Pain demands attention of others: the approach/avoidance paradox. *Pain*, 143, 5-6. doi:10.1016/j.pain.2009.02.023

- Goubert, L., Vervoort, T., & Craig, K.D. (2013). Empathy and Pain. In R.F. Schmidt & G.F. Gebhart (Eds.), *Encyclopedia of Pain*, Second Edition (pp. 1128-1134). Heidelberg: Springer-Verlag.
- Hein, G., Lamm, C., Brodbeck, C., & Singer, T. (2011). Skin conductance response to the pain of others predicts later costly helping. *Plos One*, 6, e22759. doi:10.1371/journal.pone.0022759
- Holle, H., Banissy, M., & Ward, J. (2013). Functional and structural brain differences associated with mirror-touch synaesthesia. *NeuroImage*, 83, 1041–1050. doi:10.1016/j.concog.2010.12.002
- Holle, H., Banissy, M., Wright, T., Bowling, N., & Ward, J. (2011). “That’s not a real body”: Identifying stimulus qualities that modulate synaesthetic experiences of touch. *Consciousness and Cognition*, 20, 720-726.
- Iyer, M.B., Mattu, U., Grafman, J., Lomarev, M., Sato, S., & Wassermann, E.M. (2005). Safety and cognitive effect of frontal DC brain polarization in healthy individuals. *Neurology*, 64(5), 872-875. doi:10.1212/01.WNL.0000152986.07469.E9
- Jackson, P.L., Meltzoff, A.N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *Neuroimage*, 24, 771–779. doi:10.1016/j.neuroimage.2004.09.006
- Karazsia, B.T., & van Dulmen, M.H.M. (2010). Modeling infrequent outcomes: Illustrations using prospective predictors of pediatric injuries. In H. Schuster & W. Metzger (Eds.), *Biometrics: Methods, applications and analyses* (pp. 1-27). New York, NY: Nova Science.
- Loeys, T., Moerkerke, B., De Smet, O., & Buysse, A. (2012). The analysis of zero-inflated count data: beyond zero-inflated Poisson regression. *British Journal of Mathematical and Statistical Psychology*, 65(1), 163-180. doi:10.1111/j.2044-8317.2011.02031.x
- Maister, L., Banissy, M.J., & Tsakiris, M. (2013). Mirror-touch synaesthesia changes representations of self-identity. *Neuropsychologia*, 51, 802-808. doi:10.1016/j.neuropsychologia.2013.01.020
- Mars, R.B., Sallet, J., Schuffelgen, U., Jbabdi, S., Toni, I., & Rushworth, M.F.S. (2011). Connectivity-based subdivisions of the human right “tempoparietal junction area”: evidence for different areas participating in different cortical networks. *Cerebral Cortex*, 22, 1894-1903. doi:10.1093/cercor/bhr268
- Mc Cracken, L. M. (1997). Attention to pain in persons with chronic pain: a behavioral approach. *Behavior Therapy*, 28, 271-284. doi:10.1016/S0005-7894(97)80047-0

- McWilliams, L.A., & Asmundson, G.J.G. (2001). Assessing individual differences in attention to pain: psychometric properties of the pain vigilance and awareness questionnaire modified for a non-clinical pain sample. *Personality and Individual Differences*, 31, 239–246. doi:10.1016/S0191-8869(00)00132-X
- Morishima, Y., Schunk, D., Bruhin, A., Ruff, C.C., Fehr, E. (2012). Linking brain structure and activation in tempoparietal junction to explain the neurobiology of human altruism. *Neuron*, 75, 73–79. doi:10.1016/j.neuron.2012.05.021
- Morrison, I., Tipper, S.P., Fenton-Adams, W.L., & Bach, P. (2013). “Feeling others’ painful actions: the sensorimotor integration of pain and action information. *Human Brain Mapping*, 34, 1982–1998. doi:10.1002/hbm.22040
- Mouraux, A., Diukova, A., Lee, M.C., Wise, R.G., & Iannetti, G.D. (2011). A multisensory investigation of the functional significance of the “pain matrix”. *NeuroImage*, 54, 2237–2249. doi:10.1016/j.neuroimage.2010.09.084
- Nitsche, M.A., Doemkes, S., Karakose, T., Antal, A., Liebetanz, D., Lang, N., Tergau, F., & Paulus, W. (2007). Shaping the effects of transcranial direct current stimulation of the human motor cortex. *Journal of Neurophysiology*, 3109–3117.
- Nitsche, M.A., Liebetanz, D., Antal, A., Lang, N., Tergau, F., & Paulus, W. (2003). Modulation of cortical excitability by weak direct current stimulation - technical, safety and functional aspects. *Supplements to Clinical Neurophysiology*, 56, 255–276.
- Nitsche, M.A., & Paulus, W. (2000). Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation. *Journal of Physiology*, 527, 633–639.
- Nitsche, M.A., & Paulus, W. (2001). Sustained excitability elevations induced by transcranial DC motor cortex stimulation in humans. *Neurology*, 57, 1899–1901.
- Osborn, J., & Derbyshire, S.W.G. (2010). Pain sensation evoked by observing injury in others. *Pain*, 148, 268–274. doi:10.1016/j.pain.2009.11.007
- Roelofs, J., Peters, M.L., McCracken, L., & Vlaeyen, J.W.S. (2003). The pain vigilance and awareness questionnaire (PVAQ): further psychometric evaluation in fibromyalgia and other chronic pain syndromes. *Pain*, 101, 299–306. doi:10.1016/S0304-3959(02)00338-X
- Roelofs, J., Peters, M.L., Muris, P., & Vlaeyen, J.W.S. (2002). Dutch version of the pain vigilance and awareness questionnaire: validity and reliability in a pain-free population. *Behaviour Research Therapy*, 40, 1081–1090. doi:10.1016/S0005-7967(02)00008-6
- Santesteban, I., Banissy, M.J., Catmur, C., & Brid, G. (2012). Enhancing Social Ability by Stimulating Right Tempoparietal Junction. *Current Biology*, 22, 2274–2277. doi:doi:10.1016/j.cub.2012.10.018

- Saxe, R., and Kanwisher, N. (2003). People thinking about thinking people: fMRI investigations of theory of mind. *Neuroimage* 9, 1835–1842. doi:10.1016/S1053-8119(03)00230-1
- Serino, A., Pizzoferrato, F., & Làdavas, E. (2008). Viewing a face (especially one's own face) being touched enhances tactile perception on the face. *Psychological Science*, 19, 434–438. doi:10.1111/j.1467-9280.2008.02105.x
- Silani, G., Lamm, C., Ruff, C.C., Singer, T. (2013). Right supramarginal gyrus is crucial to overcome emotional egocentricity bias in social judgments. *Journal of Neuroscience*, 33, 15466-15476. doi:10.1523/JNEUROSCI.1488-13.2013
- Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J., & Frith, C.D. (2004). Empathy for pain involves the affective but not the sensory components of pain. *Science*, 303, 1157-1162. doi:10.1126/science.1093535
- Spence, C., & Driver, J. (Eds.). (2004). *Crossmodal space and crossmodal attention*. Oxford: Oxford University Press.
- Spengler, S., von Cramon, D.Y., & Brass, M. (2009). Control of shared representations relies on key processes involved in mental state attribution. *Hum. Brain Mapp.* 30, 3704–3718. doi:10.1002/hbm.20800
- Van Damme, S., Legrain, V., Vogt, J., & Crombez, G. (2010). Keeping pain in mind: A motivational account of attention to pain. *Neuroscience and Biobehavioral Reviews*, 34, 204-213. doi:10.1016/j.neubiorev.2009.01.005
- 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
- Vandenbroucke, S., Crombez, G., Loeys, T., & Goubert, L. (2015). Vicarious experiences and detection accuracy while observing pain and touch: the effect of perspective taking. *Attention, Perception and Psychophysics*.
- 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
- Vandenbroucke, S., Loeys, T., Crombez, G., & Goubert, L. (2014b) Observing another in pain facilitates vicarious experiences and modulates somatosensory experiences. *Frontiers in Human Neuroscience*, 8, 631. doi:10.3389/fnhum.2014.00631

- Vives, J., Losilla, J.M., & Rodrigo, M.F. (2006). Count data in psychological applied research. *Psychological Reports*, 98, 821-835. doi:10.2466/PRO.98.3.821-835
- Vogeley, K., May, M., Ritzl, A., Falkai, P., Zilles, K., & Fink, G.R. (2004). Neural correlates of first-person perspective as one constituent of human self-consciousness. *Journal of Cognitive Neuroscience*, 16, 817-827. doi:10.1162/089892904970799

Figure legends

Figure 1. Time line of a trial including vibrotactile stimulation

Figure 2. Example of a possible trial

Figure 3. Vicarious errors for each type of video category and type of stimulation

Figure 4. Reaction times (ms) as a function of congruency (congruent and incongruent) and type of video (pain, touch and control video). Data are presented as mean $\pm$ SE (standard error).

Figure 5. Proportion correct responses as a function of congruency (congruent and incongruent) and type of video (pain, touch and control video). Data are presented as mean $\pm$ SE (standard error).

Tables

Table 1. Detection accuracy for type of video

Table 2. Pearson/Spearman correlations, mean scores and standard deviations

% Data Storage Fact Sheet

% Name/identifier study: /

% Author: Sophie Vandenbroucke

% Date: 3/12/15

1. Contact details

1a. Main researcher

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2. Information about the datasets to which this sheet applies

* Reference of the publication in which the datasets are reported:

Vandenbroucke, S., Bardi, L., & Lamm, C., Goubert, L. (in press). The role of the right tempoparietal junction in the elicitation of vicarious experiences and detection accuracy while observing pain and touch. *Experimental Brain Research*, Doi: 10.1007/s00221-015-4516-1

* Which datasets in that publication does this sheet apply to?: all data

3. Information about the files that have been stored

3a. Raw data

* Have the raw data been stored by the main researcher? ☐ YES / ☒ NO

If NO, please justify:

* On which platform are the raw data stored?

- ☒ researcher PC

- ☐ research group file server

- ☐ responsible ZAP PC

* Who has direct access to the raw data (i.e., without intervention of another person)?

- ☒ main researcher

- ☐ responsible ZAP

- ☐ all members of the research group

- ☐ all members of UGent

- ☐ other (specify): ...

3b. Other files

* Which other files have been stored?

- ☒ file(s) describing the transition from raw data to reported results. Specify: ...

-neglect_errors.R

-false_alarms.R

- ☒ file(s) containing processed data. Specify: ...

-raw_data.sav

-false_alamrs.sav

-neglect_errors.sav

-datafile.xlsx

- ☒ file(s) containing analyses. Specify: ...

-neglect_errors.R