Atypical Bodily Self-Awareness in Vicarious Pain Responders

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Abstract

Vicarious perception refers to the ability to co-represent the experiences of others. Prior research has shown considerable inter-individual variability in vicarious perception of pain, with some experiencing conscious sensations of pain on their own body when viewing another person in pain (conscious vicarious perception / mirror-pain synaesthesia). Self-Other Theory proposes that this conscious vicarious perception may result from impairments in self-other distinction and maintaining a coherent sense of bodily self. In support of this, individuals who experience conscious vicarious perception are more susceptible to illusions of body ownership and agency. However, little work has assessed whether trait differences in bodily self-awareness are associated with conscious vicarious pain. Here we addressed this gap by examining individual difference factors related to awareness of the body, in conscious vicarious pain responders. Increased self-reported depersonalisation and interoceptive sensibility was found for conscious vicarious pain responders compared with non-responders, in addition to more internally-oriented thinking (associated with lower alexithymia). There were no significant differences in trait anxiety. Results indicate that maintaining a stable sense of the bodily self may be important for vicarious perception of pain, and that vicarious perception might also be enhanced by attention towards internal bodily states.

1. Introduction

The passive observation of touch or pain experienced by another individual elicits vicarious activity in similar brain regions as when these sensations are experienced first-hand, including somatosensory and insular cortices (see Keysers, Kaas & Gazzola, 2010; Lamm, Decety & Singer, 2011 for reviews). This evidence has led to the assertion that one way in which we are able to empathise with the sensory experiences of others is by matching them onto representations of ourselves. Vicarious perception can therefore provide a useful model for studying complex social processes such as empathy (Bird & Viding, 2014). Previous research has identified individual variability in vicarious responses to others' sensory experiences (Gillmeister, Bowling, Rigato & Banissy, 2017). For some individuals, a conscious percept is elicited on their own body purely from the observation of sensation experienced by another individual. Subtypes of this condition include mirror-touch synaesthesia (MTS) and conscious vicarious pain / mirror-pain synaesthesia (hereafter referred to as conscious vicarious pain responders). A prevalence rate of 33-34% is reported for conscious vicarious pain in healthy individuals, although this figure is based on liberal cut-offs (Giummarra et al., 2015; Osborn & Derbyshire, 2010). Grice-Jackson, Critchley, Banissy and Ward (2017) provide confirmation for this prevalence rate using a cluster analysis method, estimating the total number of responders at around 27%. This analysis also identified further sub-categories of vicarious pain perception. A Sensory-Localised responder group (estimated prevalence 17%) tended to use more sensory descriptors to describe their vicarious experience (e.g., tingling, stinging), and report that it was localised to the same body part as observed pain. An Affective-Generalised group (estimated prevalence 10%) used more affective descriptors (e.g. terrifying, gruelling) and reported a more generalised bodily sensation that was not localised to a particular body part.

While strong support for individual variability in vicarious pain has been reported, so far the mechanisms that underlie it are not as well understood. Explanations for the experience have adopted theories used to explain a related one, mirror-touch synaesthesia. In particular, Threshold Theory (Blakemore, Bristow, Bird, Frith & Ward, 2005; Ward & Banissy, 2015) proposes that conscious vicarious perception (i.e. as seen in mirror-touch synaesthesia and conscious vicarious pain) is due to overactivity in brain regions involved in mirroring the states of others (e.g. somatosensory cortex for observed touch), which boosts vicarious brain activation above a threshold for conscious perception. While there is evidence for overactive mirroring in conscious vicarious pain responders (Grice-Jackson et al., 2017; Holle, Banissy,

& Ward, 2013; Osborn & Derbyshire, 2010); further evidence suggests a broader pattern of underlying mechanisms. Conscious vicarious pain responders (both Sensory-Localised and Affective-Generalised) show reduced grey matter density in the right temporo-parietal junction (rTPJ) compared with non-responders (Grice-Jackson et al., 2017; also see Holle et al., 2013 for similar evidence in mirror-touch synaesthesia). This region has repeatedly been linked with the ability to control representations of the self and others (see Decety & Lamm, 2007; Decety & Sommerville, 2003; Santiesteban, Banissy, Catmur & Bird, 2012; Santiesteban, Banissy, Catmur & Bird, 2015). Self-Other Theory (Banissy & Ward, 2013; Ward & Banissy, 2015) provides an account for these broader differences, proposing that impairments in the ability to distinguish and switch between self- and other-relevant representations underlie conscious vicarious experience. Mechanisms relevant to maintaining a coherent sense of the bodily self also appear to be altered in conscious vicarious perception. For instance, conscious vicarious pain responders are more susceptible to the rubber-hand illusion (Derbyshire, Osborn & Brown, 2013) in which a sensation of ownership over the rubber hand is elicited without the synchronous tactile stimulation necessary for most participants. Recent evidence indicates that susceptibility to the sense of ownership on the rubber-hand illusion may be increased only for Sensory-Localised responders, and not the Affective-Generalised subgroup (Botan, Fan, Critchley & Ward, 2018). These results indicate greater plasticity of bodily self-awareness associated with conscious vicarious pain (but perhaps limited to Sensory-Localised responders). Further research is needed to establish the extent to which the sense of self is altered across conscious vicarious pain responders.

While the evidence above points towards atypical representations of the bodily self in individuals who experience conscious vicarious pain, there has thus far been little investigation into the extent to which traits related to bodily self-awareness differ between these individuals and those who do not experience conscious vicarious sensations. The current study sought to address this gap in the literature by examining trait differences in four constructs previously linked to the subjective sense of bodily self-awareness: depersonalisation, interoceptive sensibility, alexithymia and anxiety. Below we explain why each of these factors may be of theoretical interest for bodily self-awareness and conscious vicarious pain.

Depersonalisation is a clinical trait characterised by a feeling of detachment from one's own bodily self (American Psychiatric Association, 2013). In a recent study by Adler and colleagues (2016) individuals with high self-reported depersonalisation showed differences in vicarious tactile perception. Specifically, early somatosensory-evoked potential components distinguished images of the participant's own face being touched (P45) from another face (N80), and later components (P200) were attenuated in the own-face condition compared with the other-face. This distinction between self and other in vicarious somatosensory response was not present for individuals with high levels of depersonalisation. This indicates that depersonalisation is associated with reduced self-other distinction, which, as proposed by Ward and Banissy (2015) may play a key role in vicarious tactile perception. Individuals with higher levels of depersonalisation are also more susceptible to the rubber hand illusion (Kanayama, Sato & Ohira, 2009), suggesting that this construct might be interesting to examine in conscious vicarious pain responders, given prior work highlighting altered body ownership in the rubber hand illusion for this group (Botan et al., 2018; Derbyshire et al., 2013).

Interoception refers to the awareness and perception of one's own internal bodily states (Brewer, Cook & Bird, 2016). Recent work has proposed three distinct components to interoception (Garfinkel, Seth, Barrett, Suzuki and Critchley, 2015), namely interoceptive accuracy (the ability to accurately detect internal sensations, e.g., heartbeats), interoceptive sensibility (self-perception of this trait, e.g., reporting a focus on internal sensations), and interoceptive awareness (the metacognitive awareness of one's own interoceptive accuracy, e.g., knowing that you can accurately detect your own heartbeat). Detecting pain in one's own body is a key aspect of interoception (Craig, 2002). The chronic pain literature also indicates a link between pain, emotion and interoception. A recent study by Borg and colleagues (2018) finds that interoceptive accuracy is predicted by 'pain-related affect and reactions' in fibromyalgia patients, whereby more intense pain experience decreased interoceptive accuracy. Further, interoceptive sensibility was higher for individuals with more intense affective experience, suggesting a relationship between interoception and the affective qualities of pain. There is currently no direct evidence examining interoception in conscious vicarious pain responders, but neuroanatomical evidence links interoception with perceptions of others' pain. Several studies have identified the insular cortex as a key region in interoceptive processing (e.g., Craig, 2009; Critchley, Wiens, Rotshtein, Öhman & Dolan, 2004), and, as mentioned above, the insula (particularly anterior regions) is also involved in both the direct experience and passive observation of pain (e.g. Bird et al., 2010). Conscious vicarious pain responders show greater activity in anterior insula (AI) when viewing another person in pain (Osborn & Derbyshire, 2010), as well as increased grey matter density in AI compared with non-responders (Grice-Jackson et al., 2017). Structural and functional differences in this region may therefore be a contributing factor in these individuals' conscious responses to others' pain, but may also lead to differences in interoceptive processing.

Complementing earlier work on depersonalisation, which is associated with a reduction in bodily self-awareness, individuals with lower interoceptive accuracy are also more susceptible to illusions of body ownership, including the rubber hand (Tsakiris, Tajadura-Jiménez & Costantini, 2011) and enfacement illusions (Tajadura-Jiménez & Tsakiris, 2014). An implication of this is that vicarious pain perception may also be associated with reduced interoception in addition to higher depersonalisation. Although, at present there does not appear to be a direct relation between interoception and depersonalisation: Sedeño and colleagues (2014) report reduced interoceptive accuracy for a single case study of an individual with depersonalisation disorder, while Michal and colleagues (2014) find comparable interoceptive accuracy and sensibility in a larger sample of participants with high depersonalisation. Of particular relevance to the present studies, individuals with higher interoceptive accuracy show greater difficulty in inhibiting the imitation of others' actions when required (Ainley, Brass & Tsakiris, 2014). Prior work has indicated that imitation-inhibition is impaired in MTS (Santiesteban, Bird, Tew, Cioffi & Banissy, 2015), and it has been suggested that similar difficulties may be observed in conscious vicarious pain (Ward & Banissy, 2015; Derbyshire et al 2013). In addition, Grynberg and Pollatos (2015) report a link between higher interoceptive accuracy and greater empathy for pain.

The majority of previous work relevant to the relation between interoception and vicarious perception has relied on measures of interoceptive accuracy, and of these most have used those based on cardiac signals (e.g. heartbeat detection, Schandry, 1981). As noted, there are, however, at least three distinct components to interoception (Garfinkel, Seth, Barrett, Suzuki and Critchley, 2015). There is therefore a need to expand this work to address other components of interoception (i.e. sensibility, awareness). Research has demonstrated that interoceptive accuracy and sensibility are not necessarily correlated (Garfinkel et al., 2015). With this in mind, assessing interoceptive sensibility in conscious vicarious pain responders is of theoretical interest, and there is a need to identify the nature of any trait differences in interoception which may exist in conscious vicarious pain, since previous evidence leads to contradictory predictions (i.e., either improved or impaired interoceptive processing in this group).

Alexithymia is a subclinical trait encompassing difficulties with identifying and describing emotions, as well as a tendency to reduce emotional experiences and focus attention externally (Bagby, Parker & Taylor, 1994). Past research has shown that alexithymia is associated with impaired interoceptive accuracy (Herbert, Herbert & Pollatos, 2011; Shah, Hall, Catmur & Bird, 2016), but increased interoceptive sensibility (i.e., a greater focus on internal sensations; Ernst et al., 2014) as measured on the Body Perception Questionnaire (Porges, 1993). There is also evidence to suggest that individuals high in alexithymia show reduced imitation (e.g. on imitation-inhibition tasks; Sowden et al., 2016) and reduced activity in neural networks linked to empathy for pain (Bird et al., 2010). This contrasts with the profile of conscious vicarious perception, where increased imitation (e.g. hyper-imitation in imitation-inhibition tasks found in mirror-touch synaesthesia; Santiesteban et al., 2015) and greater activity in neural networks associated with empathy for pain in conscious vicarious pain responders have been reported (Osborn & Derbyshire, 2010; Grice-Jackson et al., 2017). Studying alexithymia in conscious various pain responders is therefore of importance, as based on current literature a prediction of lower alexithymia and heightened interoception in individuals that experience conscious vicarious pain would be expected.

Conscious vicarious pain response has previously been linked with increased trait anxiety, as measured on the Depression Anxiety Stress Scale (Antony, Bieling, Cox, Enns, & Swinson, 1998; Lovibond & Lovibond, 1995; Nazarewicz, Verdejo-Garcia, & Giummarra, 2015; Young, Gandevia, & Giummarra, 2017). In the experiment by Young and colleagues, conscious vicarious pain responders also demonstrated suppression of physiological responses (slowing respiratory rate) in response to observed pain, indicative of avoidance of the threatening stimulus. The authors therefore suggest that vicarious pain sensation may be heightened by anticipatory anxiety prior to viewing a painful event. Indeed, evidence of motor inhibition when viewing others in pain (e.g. Avenanti, Bueti, Galati & Aglioti, 2005) indicates that vicarious pain perception is important for predicting and preventing potential harm to the self. Previous literature has also indicated a link between anxiety and interoception, although the nature of the relation between these constructs remains unclear. Neuroimaging evidence, for instance, has shown that the size and reactivity of AI (a region also associated with vicarious pain response, as discussed above) is linked to both heartbeat detection and to the general experience of anxiety symptoms (Paulus & Stein, 2006; Stein, Simmons, Feinstein & Paulus, 2007). At the behavioural level, there is evidence for increased interoceptive accuracy on heartbeat detection tasks for participants with higher trait anxiety (Dunn et al., 2010; Pollatos, Herbert, Matthias & Schandry, 2007; Stevens et al., 2011), indicating that anxious individuals can more accurately monitor their own heartbeats. However, this effect is not consistent, and other studies have reported either no such improvement, or even poorer accuracy (Borg et al., 2018; De Pascalis, Alberti & Pandolfo. 1984; Ehlers, Margraf, Roth, Taylor & Birbaumer, 1988). Catastrophic misinterpretation of bodily sensations is thought to play a role in anxiety disorders, particularly panic disorder (Clarke et al., 1997), suggesting that anxious individuals pay greater attention to their internal bodily signals (even if their perception is no more accurate). However, in terms of self-reported interoceptive sensibility, evidence again is inconsistent. While high anxiety has been associated with greater interoceptive sensibility (Garfinkel et al., 2016; Olatunji, Deacon, Abramowitz & Valentiner, 2007), others have reported reduced awareness of bodily signals (Brown et al., 2017; Mallorquí-Bagué et al., 2014; Mehling et al., 2012). Alexithymia has also been associated with high anxiety (Hendryx, Haviland & Shaw, 1991), adding further complication to current understanding, since alexithymia is typically associated with poor interoceptive accuracy (Herbert et al., 2011; Shah et al., 2016; see above). Regarding the inter-relation between the three constructs, Palser and colleagues (2018) suggest that the relation between interoceptive sensibility and anxiety may be mediated by alexithymia. This provides a partial explanation for previous inconsistencies, where increased interoceptive sensibility may only result in greater anxiety where there is also alexithymia, which may lead to a difficulty connecting bodily sensations to emotional states. Overall, this complex literature highlights the need for further research to clarify the relation between vicarious perception, anxiety, interoception and alexithymia.

To summarise, prior literature suggests that there may be trait differences associated with vicarious pain, which have thus far not been studied in conscious vicarious pain responders. Here, the aim was to identify differences in self-reported traits relevant to subjective bodily and emotional self-awareness in conscious vicarious pain responders for the first time. This was carried out with a view to understanding the broader traits associated with conscious vicarious pain, and informing theoretical explanations of the condition. Participants were categorised into one of three responder groups: non-responders (controls), Sensory-Localised responders, and Affective-Generalised responders. Prior work indicates that both conscious responder subgroups (Sensory-Localised and Affective-Generalised) show structural and functional brain differences in regions associated with self-other control and bodily self-awareness. Based on this evidence, both groups were predicted to show the same pattern of differences across the four measured constructs, compared with non-responders.

Comparison of trait differences in the two subgroups will nevertheless be important for informing theoretical accounts of conscious vicarious pain, identifying the extent to which atypical bodily self-awareness might be specific to Sensory-Localised responders (see Botan et al., 2018) or common to all conscious responders. On the basis of previous research, conscious vicarious pain responders (Sensory-Localised and Affective-Generalised) were predicted to report higher depersonalisation, interoceptive sensibility and trait anxiety, but lower levels of alexithymia.

2. Materials and Methods

2.1. Participants

In total 608 participants (465F, 138M; age 18-66 years, $M = 23.4$, $SD = 7.8$) took part in the experiment. This comprised a non-responder group ($N = 432$; 328F, 104M; age $M = 23.7$, $SD = 8.3$), who did not tend to report conscious vicarious experiences, a Sensory-Localised responder group ($N = 106$; 85F, 21M; age $M = 22.4$, $SD = 5.6$) who tended to report conscious vicarious experiences localised to the same body part as the observed stimulus, and use sensory descriptors, and an Affective-Generalised responder group ($N = 70$; 56F, 14M; age $M = 23.1$, $SD = 7.5$), who tended to report conscious vicarious experiences more generalised over the whole body, and to use more affective than sensory descriptors. Responder groups did not significantly differ in age (F [2,604] = 1.36, $p = .258$, $\eta_p^2 < .01$) or gender (χ^2 [2] = 1.24, $p = .537$). Normal or corrected-to-normal vision was required to participate. Five participants were removed prior to the analysis of depersonalisation data, since their total scores on the Cambridge Depersonalisation Scale were found to be extreme outliers, being more than 3 times the interquartile range above the upper quartile of the data (range of excluded scores 202-269).

2.2. Procedure

Testing was conducted online using Qualtrics survey software. All participants completed the Vicarious Pain Questionnaire (VPQ; Grice-Jackson et al., 2017) to assess and categorise their vicarious pain response. Participants also completed the Cambridge Depersonalisation Scale (CDS; Sierra & Berrios, 2000) to measure depersonalisation, the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling, 2012) to examine interoceptive sensibility, the Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994) as a measure of alexithymia, and the trait component of the State-Trait Anxiety Inventory (STAI-T; Spielberger, 1983) to assess trait anxiety. Data was collected across three recruitment phases. In one phase participants completed all self-report scales in one online questionnaire (*n* = 102). In a second phase participants first completed the VPQ, CDS, MAIA and TAS-20 in one questionnaire (*n* = 186), and 14 of these participants also completed the STAI-T in a later session. In a third phase participants who had previously completed the VPQ were recruited to complete the CDS (*n* = 320).

2.2.1. Vicarious Pain Questionnaire

To examine the subjective experience of vicarious pain, participants were required to view 16 short (10-13 second) videos of painful events occurring to another person. Videos were displayed in pseudo-random order. Eight of these videos portrayed sports injuries (e.g., a cyclist falling from a bike) and eight showed injections to various parts of the body. Videos were obtained with permission from Grice-Jackson and colleagues (2017), and can be viewed using this link https://www.youtube.com/channel/UCT8goTgWGRsu14NjVaPCSGw/videos. After each video participants were asked "Did you experience any bodily sensation of pain whilst observing the [e.g., arm injection]?" All participants were also asked to rate "How unpleasant did you find the experience of watching this video?" on a 10-point scale from 1 (not unpleasant) to 10 (highly unpleasant). If the response was 'yes', three further questions appeared. As for the touch videos, participants were asked to rate the intensity and the location (generalised vs. localised) of the vicarious pain they experienced. Finally, participants could select up to 23 descriptive words (10 affective, 10 sensory, 3 cognitive) from the McGill Pain Questionnaire (Melzack, 1975) to describe their experience. If the participant felt that none were appropriate there was also an option to add their own words.

2.3. Self-Report Measures

2.3.1. Cambridge Depersonalisation Scale

The Cambridge Depersonalisation Scale (CDS; Sierra & Berrios, 2000) was administered to assess depersonalisation symptoms experienced in the past six months.

Participants are presented with 29 statements, such as "Parts of my body feel as if they didn't belong to me" and should rate the frequency of this experience on a five-point scale from "never" to "all the time". Unless the participant responds "Never", they then rate the typical duration of the experience, on a six-point scale from "few seconds" to "more than a week". Possible scores range between 0 and 290, with higher scores indicating greater depersonalisation. Sierra and Berrios report good internal consistency (α = .89) and excellent split-half reliability (α = .92) for the scale as well as good validity, shown in a specific correlation (*r* = .80) with the depersonalisation subscale of the Dissociative Experiences Scale (Bernstein & Putnam, 1986). High internal consistency was also found in the current sample (α = .96).

2.3.2. Multidimensional Assessment of Interoceptive Awareness

Interoceptive sensibility was measured using the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012). The scale contains 32 items, including "When I am tense I notice where the tension is located in my body". Participants respond to indicate the extent to which the statement applies to them, on a six-point scale from "never" to "always". Scores can be combined into eight subscales, including Noticing: "awareness of uncomfortable, comfortable and neutral body sensations"; Not-Distracting: "tendency to ignore or distract oneself from sensations of pain or discomfort" (reversed), Not Worrying: "emotional distress or worry with sensations of pain or discomfort" (reversed), Attention Regulation: "ability to sustain and control attention to body sensation", Emotional Awareness: "awareness of the connection between body sensations and emotional states", Self-Regulation: "ability to regulate psychological distress by attention to body sensations", Body Listening: "actively listens to the body for insight", and Trusting: "experiences one's body as safe and trustworthy". Scores on each subscale can range between 0 and 5, with a higher score indicating greater interoceptive awareness. Mehling and colleagues demonstrate construct validity for the scale and acceptable to good internal consistency on five of the eight subscales (α = .79 - .87). However, they note that for the Noticing, Not-Distracting, and Not-Worrying subscales internal consistency was lower (α = .66 - .69) Similar results are reported in the current sample, with good internal consistency on five subscales (α = .84 - .86), and more questionable internal consistency on the Not-Distracting (α = .69) and Not-Worrying (α = .62) subscales, although for the Noticing subscale, internal consistency was acceptable (α = .73).

2.3.3. Toronto Alexithymia Scale

Alexithymia was assessed with the twenty item Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994). The questionnaire requires participants to indicate the extent which they agree with each of 20 statements on a five-point scale from "strongly disagree" to "strongly agree." Three subscales represent Difficulty Describing Feelings, e.g, "It is difficult for me to find the right words for my feelings", Difficulty Identifying Feelings, e.g., "I am often confused about what emotion I am feeling", and Externally-Oriented Thinking, e.g., "Looking for hidden meanings in movies or plays distracts from their enjoyment". Total scores range from 20 to 80, with a higher score representing greater alexithymia. Bagby and colleagues confirm the validity of the three-factor structure and report acceptable internal consistency for the Difficulty Describing Feelings ($\alpha = .75$) and Difficulty Identifying Feelings ($\alpha = .78$) subscales, although reliability for Externally-Oriented Thinking was slightly lower ($\alpha = .66$). The same pattern of results is found in the present sample ($\alpha = .61$ - $.83$).

2.3.4 State-Trait Anxiety Inventory

The State–Trait anxiety inventory (STAI; Spielberger, 1983) is a 40-item scale which assesses both state and trait anxiety. In the present study, only the 20 trait anxiety items from the STAI-T were presented. This assesses the dispositional, or more stable, trait of anxiety proneness. It contains items such as "I feel nervous and restless" or "I feel satisfied with myself". Respondents are asked to indicate to what degree the item describes their feelings on a 4-point Likert-type scale ranging from 1 = not at all and 4 = very much so. Total scores range from 20-80, where a higher score indicates greater trait anxiety. Spielberger reports that the STAI-T is reliable and valid, with internal consistency of $\alpha = .90$. Excellent internal consistency is also found in the current sample ($\alpha = .93$).

2.4. Analysis Protocol

Participants were assigned to pain responder groups on the basis of their responses on the VPQ,_using a two-step cluster analysis based on the procedure used by Botan and colleagues (2018; see also Zhang et al., 1996). This involves an initial clustering of participants to produce cluster centroids, and then categorises participants into groups based on these centroids. Since this method produces optimal results using large data sets, data was combined with previous VPQ responses from Grice-Jackson and colleagues (2017). The first step comprised a hierarchical cluster analysis using Ward's method (Ward, 1963) to identify the number of clusters and cluster centroids. This was based on three input variables: 1) Mean pain intensity (the average intensity rating across all 16 videos), 2) Sensory-Affective (the total number of sensory descriptors used to describe the pain – the total number affective descriptors, and 3) Local-General (the total number of localised pain responses – the total number of generalised responses). This step confirmed a three-factor solution, in line with prior work (Grice-Jackson et al., 2017; Botan et al., 2018). The second step involved a non-hierarchical k-means cluster analysis, which assigned participants into one of the three groups, based on the cluster centroids from the first step. Botan and colleagues report good test-retest reliability for the VPQ and for the clustering methods employed in the current paper.

Between-group differences on the remaining self-report scales (CDS, MAIA, TAS and STAI-T) were then analysed . Univariate analysis of variance (ANOVA) was applied to the CDS (including total scores, frequency and duration of experiences) and STAI-T to identify between-group effects of vicarious pain response on these scales. Where there were subscales of theoretical interest (MAIA and TAS), multivariate analysis of variance (MANOVA) was used to assess the effect of pain responder group across subscales. Post-hoc pairwise comparisons were conducted using Tukey's HSD where significant group effects were found, with the exception of the CDS. The distribution of CDS scores showed a significant positive skew (z = 11.69). This pattern is typical for the CDS when administered in the general population rather than clinical groups (Sierra & Berrios, 2000). Due to this distribution of the data bootstrapped t-tests (two-tailed, 1000 repetitions) were used to conduct post-hoc comparisons on the CDS. Additionally, Pearson's correlations were used to identify the relation between all of the above self-report measures, and Harman's single factor test was used to examine potential common-method variance.

3. Results

3.1. Relationships Between Trait Measures

Correlations between trait measures are reported in Table 1. Higher depersonalisation was associated with higher scores on the Describing Feelings and Identifying Feelings subscales of the TAS. Positive correlations were also observed between depersonalisation and components of interoceptive sensibility, specifically Noticing, Emotional Awareness and Body Listening subscales. Negative correlations, however, were found between depersonalisation and the Not-Distracting, as well as Not-Worrying subscales. No significant correlation was found between depersonalisation and trait anxiety. Between alexithymia and interoceptive sensibility, negative correlations were observed for the majority of subscales, indicating a general association between lower interoceptive sensibility and higher alexithymia. Increased trait anxiety was also associated with greater alexithymia on the Identifying and Describing Feelings subscales. There were also significant negative correlations between anxiety and interoceptive sensibility on the Self-Regulation and Trusting subscales.

The only self-report trait measure found to significantly correlate with age was depersonalisation, where older participants tended to report less depersonalisation (r [600] = -.131, p = .001). All other correlations with age were not significant (ps > .08). Gender differences were also observed in the data. With a Bonferroni-corrected alpha level of $p < .004$, significant effects of gender were found on the Not-Worrying (t [286] = 4.28, $p < .001$, Cohen's d = 0.57), Attention Regulation (t [286] = 3.37, p = .001, Cohen's d = 0.46) and Trusting (t [286] = 3.71, $p < .001$, Cohen's d = 0.51) subscales of the MAIA. In all cases male participants scored higher than females, indicating greater interoceptive sensibility.

To estimate common-method variance in the current data set, Harman's single factor test (Harman, 1976) was carried out. A principal components method was used to load all experimental variables onto a single factor, in order to calculate shared variance. This is generally thought to be problematic if a single factor can account for the majority of the covariance in the data (see Podsakoff, Mackenzie, Lee & Podsakoff, 2003). The analysis resulted in a single factor that accounted for 25.4% of the covariance, well below that considered to be problematic, and 14 factors with eigenvalues greater than 1.

3.2. Trait Differences associated with Vicarious Pain

3.2.1. Depersonalisation

To examine depersonalisation across the three pain responder groups (Sensory-Localised vs. Affective-Generalised vs. Non-Responder), a univariate ANOVA was carried out on total CDS scores. The main effect of responder group was significant (F [2,600] = 5.02, p

= .007, η_p^2 =.02). Bootstrapped t-tests (two-tailed, 1000 repetitions) revealed significantly greater depersonalisation in Sensory-Localised responders compared with non-responders (*t* [533] = 2.15, *p* = .032, Cohen's *d* = 0.24), with bootstrapped analysis also significant (*p* = .024, CI: 0.36, 12.33). Affective-Generalised responders also reported higher depersonalisation than non-responders (*t* [78] = 2.09, *p* = .040, Cohen's *d* = 0.30), and bootstrapped analysis also reporting a significant effect (*p* = .048, CI: 0.90, 22.12). No significant differences were found between Sensory-Localised and Affective-Generalised responders (*t* [106] = 0.72, *p* = .473, Cohen's *d* = 0.12). Mean CDS scores are displayed in Figure 1.

Two further univariate ANOVAs were used to identify whether between-group differences above reflected differences in the frequency or duration of depersonalisation experiences. Significant effects of pain responder group were found on both frequency (*F* [2,600] = 3.46, *p* = .032, η_p^2 =.01) and duration (*F* [2,600] = 5.63, *p* = .004, η_p^2 =.02) responses of the CDS. However, post-hoc comparisons show that although the frequency of depersonalisation symptoms was increased compared with non-responders, this did not reach significance for Sensory-Localised (*t* [533] = 1.43, *p* = .155, Cohen's *d* = 0.15) or Affective-Generalised (*t* [77] = 1.84, *p* = .070, Cohen's *d* = 0.27) groups. There was also no significant difference found between Sensory-Localised and Affective-Generalised responders (*t* [101] = 0.93, *p* = .357, Cohen's *d* = 0.15). In terms of duration, Sensory-Localised responders reported longer lasting experiences than non-responders (*t* [533] = 2.48, *p* = .013, Cohen's *d* = 0.27), with bootstrapped analysis also significant (*p* = .017, CI: 0.83, 8.76). The duration of Affective-Generalised responders' experiences was also longer than non-responders (*t* [79] = 2.19, *p* = .032, Cohen's *d* = 0.31), and bootstrapped analysis was also significant (*p* = .039, CI: 0.19, 13.62). No significant difference in duration was found between Sensory-Localised and Affective-Generalised responders (*t* [171] = 0.56, *p* = .575, Cohen's *d* = 0.08).

Figure 1 about here (CDS scores by pain cluster)

3.2.2. Interoceptive Sensibility

Differences in interoceptive sensibility between the pain responder groups were analysed using MANOVA. Each of the eight subscales of the MAIA were entered as dependent variables in the analysis, with pain responder group (Sensory-Localised vs. Affective-

Generalised vs. Non-Responders) as the independent variable. The analysis showed a significant effect of pain responder group on MAIA scores (*F* [16,558] = 2.72, $p < .001$, η_p^2 =.07). Using a Bonferroni-corrected alpha level of $p < .006$, significant effects were found on four of the eight subscales: Noticing (*F* [2,285] = 10.79, $p < .001$, η_p^2 =.07), Not-Distracting (*F* [2,285] = 6.32, *p* = .002, η_p^2 =.04), Emotional Awareness (*F* [2,285] = 9.94, $p < .001$, η_p^2 =.07), and Body-Listening (*F* [2,285] = 6.43, *p* = .002, η_p^2 =.04). Effects for all other subscales did not reach significance ($p > .017$).

Post-hoc pairwise comparisons, using Tukey's HSD were carried out for each subscale. The Noticing subscale demonstrated significantly higher scores for both Sensory-Localised responders (*t* [253] = 4.15, $p < .001$, Cohen's *d* = 0.71) and Affective-Generalised responders (*t* [241] = 2.71, *p* = .019, Cohen's *d* = 0.50) compared with non-responders. No significant difference was found between the Sensory-Localised and Affective-Generalised responder groups (*t* [76] = 0.76, *p* = .730, Cohen's *d* = 0.18). On the Emotional Awareness subscale, again both Sensory-Localised (*t* [253] = 3.78, *p* = .001, Cohen's *d* = 0.60) and Affective-Generalised (*t* [241] = 2.91, *p* = .011, Cohen's *d* = 0.58) responders gained higher scores than non-responders, while there was no significant difference between the two responder groups (*t* [76] = 0.33, *p* = .941, Cohen's *d* = 0.08). On the Body-Listening subscale, only the scores of Affective-Generalised responders were higher than non-responders (*t* [241] = 3.35, *p* = .003, Cohen's *d* = 0.61). No significant difference was found between Sensory-Localised responders and non-responders (*t* [253] = 1.76, *p* = .184, Cohen's *d* = 0.28), or between Sensory-Localised and Affective-Generalised responders (*t* [76] = -1.48, *p* = .302, Cohen's *d* = -0.30). Finally, on the Not-Distracting subscale, again only Affective-Generalised responders significantly differed from non-responders (*t* [241] = -3.37, *p* = .002, Cohen's *d* = -0.60), however, on this subscale, scores were lower in the Affective-Generalised group. No significant difference was observed between Sensory-Localised responders and non-responders (*t* [253] = -1.65, *p* = .228, Cohen's *d* = -0.29), or between Sensory-Localised and Affective-Generalised responders (*t* [79] = 1.57, *p* = .260, Cohen's *d* = 0.37). Means for all subscales described above are displayed in Figure 2.

Figure 2 about here (MAIA scores by pain cluster)

3.2.3. Alexithymia

TAS scores in each of the pain responder groups were also compared using MANOVA. There was a significant effect of responder group on alexithymia scores (F [6,568] = 3.12, p = .005, η_p^2 =.03). Looking at each subscale individually, significant differences were found on the Externally-Oriented Thinking subscale (F [2,285] = 7.28, p = .001, η_p^2 =.05), but not on the Identifying (F [2,285] = 0.09, p = .914, η_p^2 < .01) or Describing Feelings (F [2,285] = 1.03, p = .358, η_p^2 = .01) subscales. Post-hoc comparisons using Tukey's HSD demonstrated lower scores on the Externally-Oriented Thinking Subscale for both Sensory-Localised (t [253] = -2.707, p = .020, Cohen's d = -0.45) and Affective-Generalised responders (t [241] = -3.08, p = .006, Cohen's d = -0.60) compared with non-responders (means are displayed in Figure 3). No significant difference was found between Sensory-Localised and Affective-Generalised responders (t [76] = 0.58, p = .828, Cohen's d = 0.15).

Figure 3 about here (TAS scores by pain cluster)

3.2.4 Trait Anxiety

Univariate ANOVA compared trait anxiety scores on the STAI-T in each vicarious pain responder group. The results showed no significant difference in anxiety (F [2, 113] = 1.70, p = .188, η_p^2 = .03) between the Sensory-Localised responder group (M = 49.37, SD = 10.97), the Affective-Generalised responder group (M = 43.88, SD = 11.33) and non-responders (M = 47.29, SD = 11.67).

4. Discussion

The present study provides evidence of heightened depersonalisation and interoceptive sensibility, as well as lower externally-oriented thinking (an alexithymic trait) associated with conscious vicarious pain. These differences were found in both Sensory-Localised and Affective-Generalised responders across all traits, with the exception of the Body Listening and Not-Distracting subscales of interoceptive sensibility. However, no differences in trait anxiety levels were found between groups. The findings support hypotheses that conscious vicarious pain perception is associated with atypical bodily self-awareness.

The initial prediction that conscious vicarious perception would be associated with increased depersonalisation, as measured on the CDS, was supported. Sensory-Localised and Affective-Generalised responders reported greater experience of depersonalisation symptoms than non-responders. This result is in line with prior research linking both depersonalisation (Adler et al., 2016; Kanayama et al., 2009) and conscious vicarious pain perception (Derbyshire et al., 2013; Grice-Jackson et al., 2017) with impairments in self-other distinction and a tendency towards self-other merging of body-relevant information. No differences in depersonalisation were found between the two subgroups of conscious vicarious responders. This is of interest, given that previous research has indicated bodily self-other blurring may be limited to the Sensory-Localised group (Botan et al., 2018). This prior work found increased susceptibility to the rubber-hand illusion in Sensory-Localised responders, indicating a tendency for this group (but not Affective-Generalised responders or controls) to incorporate other bodies into their own-body representations. While the rubber-hand paradigm and the CDS both capture the stability of body representations; they reflect different aspects of this construct. Observed differences on the rubber-hand illusion relate to increased attribution of ownership over another body, but depersonalisation relates to a loss of ownership over the bodily self. In this case it may be that both subgroups of conscious vicarious responders experience detachment from the self, but only Sensory-Localised responders experience increased ownership over other body parts.

The present results also demonstrate increased interoceptive sensibility in conscious vicarious pain responders compared with non-responders. For both Sensory-Localised and Affective-Generalised groups, this difference was present on the Noticing subscale of the MAIA (Mehling et al., 2012), which refers to the “awareness of uncomfortable, comfortable and neutral body sensations” (p10) and the Emotional Awareness subscale, which Mehling and colleagues describe as the “awareness of the connection between body sensations and emotional states” (p10). Interestingly, these two subscales were both found to be positively correlated with affective intensity in a study by Borg and colleagues (2018), indicating that increased interoceptive sensibility in conscious vicarious pain responders may be related to their heightened affective experiences. Affective-Generalised responders also obtained higher scores on the Body-Listening subscale, which refers to the extent to which the participant “actively listens to the body for insight” (p10), but lower scores on the Not-Distracting subscale, suggesting that these individuals have a greater "tendency to ignore or distract oneself from sensations of pain or discomfort" (p10). Compared with Noticing and Emotional Awareness, these two components more reflect the regulation of interoception, indicating that the Affective-Generalised group have a greater tendency to try to direct attention towards or away from their body sensations, according to the positive or negative valence of these sensations. This finding provides a potential explanation for the generalised body sensations experienced by this group. Where Affective-Generalised responders are more likely to distract themselves from sensations of pain, they may find it more difficult to localise the origin of discomfort on their own body, compared with Sensory-Localised responders. Since this result was contrary to the predictions of the current study, the suggestion requires further investigation, but the results provide novel insight into the mechanisms behind different expressions of conscious vicarious perception.

Taken together, the results regarding interoceptive sensibility indicate a greater tendency for conscious vicarious pain responders to focus and control attention towards their internal bodily states and emotions. The results complement previous work reporting an association between interoceptive accuracy and difficulty inhibiting imitation, in the motor domain (Ainley et al., 2014), as well as work linking both interoception and vicarious perception in typical adults to activity in AI (Craig, 2009; Critchley et al., 2004; Grice-Jackson et al., 2017; Osborn & Derbyshire, 2010). However, it is important to note the distinction between interoceptive sensibility and accuracy. High interoceptive sensibility, referring to the tendency to focus on internal bodily states, does not necessarily imply accuracy, the ability to correctly identify these states (Garfinkel et al., 2015). Previous work has mostly used heartbeat detection tasks of interoceptive accuracy (e.g., Schandry, 1981), and therefore the present results provide interesting evidence regarding a less-studied domain of interoception. Further research is required to establish whether observed differences associated with conscious vicarious pain extend to interoceptive accuracy. This can be achieved using the classic heartbeat detection paradigm, but measures of other bodily signals (e.g. respiratory, muscular, see Garfinkel et al., 2016; Murphy, Catmur & Bird, 2018) should also be used to examine interoceptive accuracy across the whole body.

In addition to interoceptive sensibility and depersonalisation, both Sensory-Localised and Affective-Generalised responders were found to show significantly lower externally-oriented thinking (a subscale of the Toronto Alexithymia Scale) than non-responders. In other words, more internally-oriented thinking (consistent with the MAIA) and less alexithymia.

Alexithymia is another factor relevant to bodily self-awareness. Recent research has proposed that difficulties identifying and describing emotions may be caused by a lack of ability to correctly monitor body sensations (Herbert et al., 2011; Shah et al., 2016). Alexithymia is also associated with reduced activity in AI in response to others' pain (Bird et al., 2010) and so conscious vicarious pain responders appear to lie at the opposite end of this spectrum, showing lower levels of alexithymic traits, and increased vicarious representation of others' pain. Osborn and Derbyshire (2010) report that conscious vicarious pain responders show greater activity in AI than non-responders when observing others' pain. Moreover, both Sensory-Localised and Affective-Generalised responders also show increased grey matter density in this region (Grice-Jackson et al., 2017). Atypical structure and activity in AI may therefore underlie differences in bodily self-awareness, alexithymia and vicarious perception observed in conscious vicarious pain responders in the present study. As mentioned above, a similar pattern of trait depersonalisation, interoceptive sensibility and alexithymia in both Sensory-Localised and Affective-Generalised responders suggests that atypical bodily awareness is common across conscious vicarious pain responder subtypes. The specific difference in externally-oriented thinking indicates that while conscious vicarious pain responders are no better than non-responders at identifying or describing their own emotions, they have a reduced tendency to focus their attention externally. This is in line with results showing increased interoceptive sensibility in this group, and suggests a greater focus on internal bodily sensations, not only for the self but for others. While items on the interoceptive sensibility scale relate only to one's own body, on the externally-oriented thinking subscale conscious vicarious pain responders were less likely to endorse items such as "I prefer talking to people about their daily activities than their feelings", suggesting that the internal and affective experience of others is also a greater focus for conscious vicarious pain responders. Whether this is a causal factor in conscious vicarious pain experience or comes as a result of avoiding potentially painful or distressing external stimuli (e.g. when seeing another person in pain) remains to be clarified.

The collective evidence of altered bodily and emotional self-awareness in conscious vicarious pain responders adds to growing evidence that individuals who experience conscious vicarious sensations show broader differences that extend beyond simple mirroring of sensorimotor consequences. Self-Other Theory (see Ward & Banissy, 2015) provides a potential framework from which to understand these broader differences in self-awareness experienced by conscious vicarious pain responders. While the present results provide novel insight into the broader phenomenal experience of conscious vicarious pain, conclusions cannot be drawn regarding causal relationships from this data alone. In the case of depersonalisation, a sense of detachment from the bodily self may cause the individual to incorporate other-relevant information into the self-concept, leading to the conscious percept of pain when observing another person in pain. However, it is also conceivable that the shared experience of vicarious pain could lead to a self-other blurring (similar to that induced by synchronous touch in the rubber hand and enfacement illusions – Botvinick & Cohen, 1998; Tsakiris, 2008), and that this could increase feelings of detachment from the self. Similarly, a greater focus on internal bodily states (interoceptive sensibility) could lead to increased detection of physical sensations induced by observing pain, leading to a conscious vicarious percept. Alternatively, individuals that experience vicarious pain may be more likely to attend to bodily states, due to increased sensation from both self- and other-focused stimulation. Future aims should be to establish the causal mechanisms underlying the associations between depersonalisation, interoceptive sensibility and vicarious pain that are seen here. This could be examined by directly manipulating the control of attention towards bodily states, through contemplative training for instance, which has been shown to increase interoceptive sensibility as measured on the MAIA (Bornemann, Herbert, Mehling & Singer, 2015). Depersonalisation is perhaps more difficult to directly manipulate, but future work could attempt to induce disconnection from the bodily self through out-of-body illusions. For instance, an illusion developed by Guterstam and Ehrsson (2012) allows the viewer to see their own body as if from outside of it. The authors show that this experience reduces ownership over the viewer's own body, as indexed by reduced skin conductance response to bodily threat. The impact of these manipulations could then be assessed using the VPQ, to clarify causal mechanisms in conscious vicarious pain perception.

Contrary to predictions, no differences in trait anxiety were found between vicarious pain responder groups. The current results show that conscious vicarious pain was associated with atypicality in certain dimensions of interoceptive sensibility (i.e., Noticing, Emotional Awareness, Not-distracting, Body-Listening), while high anxiety was associated with low interoceptive sensibility in a different set of dimensions (Trusting, Self-Regulation). These results contrast with some previous reports, which have suggested that anxiety scores on the STAI-T are negatively correlated with all eight dimensions of interoceptive sensibility on the MAIA (Mehling et al., 2012), and suggest that trust in one's own body sensations, as well as the ability to reduce psychological distress in relation to these sensations, are most crucial for reducing anxiety. In these dimensions conscious vicarious pain responders were similar to non-responders. This provides a potential explanation for why anxiety was not increased in the conscious vicarious pain responder groups. This finding does contrast with previous evidence of heightened anxiety in conscious vicarious pain (Nazarewicz et al., 2015; Young et al., 2017). However, in this work, an alternative measure of anxiety, the anxiety component of the Depression Anxiety Stress Scale (DASS-Anxiety; Antony et al., 1998; Lovibond & Lovibond, 1995) was used. This scale contains items such as "I was aware of dryness of my mouth", which involve an element of bodily awareness, in contrast with STAI-T items such as "I feel nervous and restless" (Spielberger, 1983). While both the STAI-T and DASS-Anxiety are negatively correlated with the Trusting subscale of the MAIA, the DASS-Anxiety is also positively correlated with Noticing (Valenzuela-Moguillansky, Reyes-Reyes & Gaete, 2017), which is here shown to be elevated in conscious vicarious pain responders. It is possible that higher DASS-Anxiety scores are found in the conscious vicarious pain group due to this interoceptive component.

The limitations of the current study should be noted. Measurement of the trait dimensions of interest relied on subjective reports on self-report scales, which can be susceptible to bias. For instance, since some questionnaire items relate to mental health, social desirability bias may have influenced participants' responses. The fact that all data for this experiment was collected online provides some protection against this bias. No participant came into contact with the experimenter at any point, providing an extra layer of anonymity, and because of this, online tests are thought to promote more honest self-disclosure (Joinson, 1999). However, the fact that all data analysed in this experiment was collected in one online questionnaire could present an issue with common-method variance. There is a concern that when the same method (e.g. online questionnaire) is used to assess different variables, this will lead to systematic error variance that is shared between the variables and attributable to the measurement method rather than the constructs of interest (Podsakoff et al., 2003). For this reason, Harman's (1976) single factor test was used to estimate common-method variance in the data set. The results indicated that this potential source of bias is not a cause for concern in the current experiment.

Evidence of atypical bodily self-awareness in conscious vicarious pain responders provides implications for understanding the mechanisms underlying vicarious perception and empathy in typical adults. For instance, the Self-Other Model of Empathy (Bird & Viding, 2014) proposes a self-other switch, necessary to direct attention away from the self and towards another person's state, in order to understand and empathise with that person. Current results support this mechanism, indicating that when an observer experiences disconnection from the self (as in depersonalisation), vicarious perception may be heightened. Bird and Viding suggest that for typical adults, the default state of the self-other switch is towards the self (leading to egocentric bias). Heightened depersonalisation at a trait level in conscious vicarious pain responders indicates that for these groups the self-other switch is biased away from the self. This evidence suggests that maintaining a coherent and stable sense of the bodily self may be necessary for down-regulating excessive empathy and vicarious perception of pain, an ability most clearly displayed by medical professionals (Cheng et al., 2007; Decety, Yang and Cheng, 2010). Of further relevance to models of empathy, increased interoceptive sensibility and decreased externally-oriented thinking here indicated a greater focus on the internal emotional and bodily signals of the self and others in conscious vicarious pain responders. Focusing on internal emotional and physical states may therefore be a factor enhancing conscious vicarious perception of pain in typical adults. Indeed, interoceptive accuracy has previously been linked to increased empathy for pain (Grynberg & Pollatos, 2015). The current evidence extends hypotheses based on this finding, suggesting that an internal focus across both one's own and other bodies may be linked to variation in vicarious pain perception.

With growing evidence of broader differences in the representation of the self and others in conscious vicarious pain and MTS (e.g. Santiesteban et al., 2015; Cioffi, Banissy & Moore, 2016; also see Ward & Banissy, 2015 for review) the extent to which these experiences can be considered a form of synaesthesia has been called into question (e.g. Fitzgibbon et al., 2012; Rothen & Meier, 2013). In synaesthesia, an experience in one sensory modality automatically triggers a percept in a second, unrelated sensory modality. At the surface level, MTS and conscious vicarious pain share these features, with touch or pain sensations automatically elicited by a visual stimulus. However, the causal mechanisms underlying conscious vicarious perception and other forms of synaesthesia appear to differ. Evidence described here shows that individuals with conscious vicarious pain also experience a general sense of detachment from their own bodies, and increased attention towards bodily states other than touch and pain. This indicates that these individuals' experiences are not limited to a pain sensation induced by a visual stimulus, but that conscious vicarious pain and MTS instead reflect broader atypicality in self-other representation, in line with Self-Other Theory (Ward & Banissy, 2015). This atypical representation is thought to elevate vicarious perception from the unconscious representation observed in neurotypicals (e.g., activity in regions associated with the first-hand experience of pain when viewing another person in pain, see Keysers et al., 2010; Lamm et al., 2011) to conscious sensation. Unlike other variants of synaesthesia (e.g., grapheme-colour), MTS and conscious vicarious pain therefore appear to reflect a heightened example of typical vicarious perception. In this case, as Meier, Lunke and Rothen (2015) argue, conscious vicarious perception may not provide a strong model for synaesthesia generally, but instead inform models of vicarious perception and social cognition in typical adults, as discussed above.

In summary, the current study demonstrates increased depersonalisation and interoceptive sensibility, and decreased externally-oriented thinking, in Sensory-Localised and Affective-Generalised conscious vicarious pain responders compared with non-responders. The results indicate a role for bodily self-awareness in modulating vicarious perception of pain, and highlight the need for theoretical accounts of vicarious perception to take a broader focus, beyond sensorimotor mirroring.

Ethics

Ethical approval for the project was granted by the Science and Technology Research Ethics Committee at the University of Sussex (C-REC), the Goldsmiths Research Ethics Committee, and the University of Cambridge. Participants gave informed consent before taking part in the study.

Data, Code and Materials

Data is available on request from the corresponding author.

Competing Interests

We have no competing interests.

Authors' Contributions

All authors contributed to the study conception and design. NCB, VB, and IS recruited participants and collected data. NCB and VB analysed the data, with advice from JW and MJB. NCB wrote the manuscript with contributions from all authors. All authors gave final approval for publication.

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Tables

Table 1: Pearson's coefficients for correlations between the self-report measures.

Self-Report Measure	1	2	3	4	5	6	7	8	9	10	11	12	13
1.CDS	-												
2.STAI-T	-.10	-											
TAS													
3. Describing Feelings	.24***	.48***	-										
4. Identifying Feelings	.28***	.62***	.63***	-									
5. Externally-Oriented Thinking	-.10	.12	.27***	.11	-								
MAIA													
6. Noticing	.17**	.05	-.01	.09	-.18**	-							
7. Not-Distracting	-.25***	-.04	-.22***	-.15**	-.05	- .16**	-						
8. Not-Worrying	-.13*	-.06	.09	-.12*	.14*	- .10	.02	-					
9. Attention Regulation	.11	-.15	-.09	-.14*	-.08	.46***	-.19**	.02	-				
10. Emotional Awareness	.26***	-.03	-.02	.19**	-.21***	.57***	-.21***	-.21***	.39***	-			
11. Self-Regulation	.04	-.46***	-.20**	-.14*	-.16**	.35***	-.09	.03	.52***	.45***	-		
12. Body Listening	.13*	-.17	-.13*	-.00	-.20**	.44**	-.11	-.13*	.42***	.57***	.54***	-	
13. Trusting	-.01	-.68***	-.23***	- .33***	-.10	.21**	-.01	.09	.38***	.19**	.52***	.38***	-

*p<.05, ** p<.01, ***p<.001

Figure Captions

Figure 1: Self-reported depersonalisation in each of the pain responder groups. Higher CDS total scores were found for Sensory-Localised and Affective-Generalised responders than for non-responders ($p < .05$; N/R, Non-Responder; S/L, Sensory-Localised Responder; A/G, Affective-Generalised Responder). Error bars represent +/- 1 S.E.M.*

Figure 2: Scores on MAIA subscales where a significant effect of pain responder group was found. Higher interoceptive sensibility was found on the Noticing and Emotional Awareness subscales for Sensory-Localised and Affective-Generalised responders compared with non-responders. Higher scores were also found on the Body Listening subscale, and lower scores on the Not-Distracting subscale, for Affective-Generalised responders compared with non-responders ($p < .05$, ** $p < .01$, *** $p < .001$; N/R, Non-Responder; S/L, Sensory-Localised Responder; A/G, Affective-Generalised Responder). Error bars represent +/- 1 S.E.M.*

Figure 3: Scores on each subscale of the TAS in each pain responder group. Lower externally-oriented thinking was found for Sensory-Localised and Affective-Generalised responders compared with non-responders. No significant effects of responder group were found on the other subscales ($p < .05$, ** $p < .01$; N/R, Non-Responder; S/L, Sensory-Localised Responder; A/G, Affective-Generalised Responder; Identifying, Identifying Feelings; Describing, Describing Feelings; EOT, Externally-Oriented Thinking). Error bars represent +/- 1 S.E.M.*