Characteristics of vicarious touch reports in a general population

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Abstract

Vicarious sensory perception occurs when one feels touch or pain while observing others experiencing these sensations. Here we examined vicarious sensory perception in a large sample of undergraduate students (N = 422) using videos from the Validated Touch-Video Database, which depict various tactile interactions and have been independently rated for hedonic qualities, arousal levels, and perceived threat. A substantial 83% of participants reported sensations such as touch, tingling, pressure when observing the touch videos, with 53% of participants reporting pain when observing painful touch. Reported sensations often mirrored the location of touch seen in the videos. Women were more inclined to report vicarious touch than men, and did so in more trials on average. There was also a modest but significant correlation between stronger vicarious touch experiences and higher emotional empathy scores. The frequency and intensity of reported sensations strongly correlated with the rated arousal of the videos, with painful videos being most arousing and eliciting the most frequent and intense responses. The valence of the reported sensations aligned with the assigned valence ratings of the touch videos. Pleasant videos typically induced sensations like ticklishness, tingling, or warmth, whereas painful videos elicited feelings of pain, pressure, or coldness. Similar sensations were reported, though less frequently, for videos depicting touch on non-human objects. Our criteria, consistent with prior research, suggested a high prevalence of potential mirror-touch (6%) and mirror-pain (20%) synaesthesia in our sample. Mirror-touch synaesthetes primarily described exteroceptive sensations like touch and pressure, contrasting with non-synaesthetes who more often reported tingling sensations. Overall, this study contributes to a deeper understanding of vicarious sensory perception in the general population with implications for understanding mirror-sensory synaesthesia and empathy.

1. Introduction

When witnessing another person being touched, some individuals perceive tactile sensations, such as touch or pain, in their own bodies. Such 'vicarious touch' (or 'mirror-touch') is thought to rely on simulation processes where seeing or inferring another person in a certain state similarly activates that state in the observer (Gallese et al., 2004; Keysers and Gazzola, 2009; Smit et al., 2023). Most of what is known about the subjective quality of such instances comes from research where participants are asked to report their experiences in response to watching images of videos depicting touch on another person. Findings suggest that a substantial proportion of the general population reports sensations such as touch, tingling, pressure, itchiness, or scratching when watching stimuli that show touch on another person's face or hand, or show individuals scratching their chest or upper arm (Li et al., 2022; Smit et al., 2023; Ward et al., 2018; Ward and Li, 2022). Likewise, approximately one-third of typical adults report sensations like tingling, aching, or shooting when observing videos of someone getting injured, such as receiving an injection, rolling an ankle, or dislocating a knee (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn & Derbyshire, 2010; Ward & Li, 2022; but see Vandenbroucke et al., 2013 for lower incidences of reportable vicarious pain in daily life). Both when it comes to vicarious touch and pain, people differ in whether they use predominantly localised and sensory descriptors (e.g., touch, sharp) or non-localised and affective descriptors (e.g., ticklish, nauseating) to describe their vicarious perception (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Vandenbroucke et al., 2013; Ward et al., 2018; Ward and Li, 2022). While women more frequently report vicarious pain than men (Grice-Jackson et al., 2017; Ward and Li, 2022), there has been no observed gender bias in the reporting of vicarious touch (Ward et al., 2018; Ward and Li, 2022). Overall, these findings indicate that vicarious sensations are fairly common in controlled settings, with variation in individual reports.

Previous research on vicarious touch has largely focused on individuals who report such experiences frequently. This is often categorised as a type of synaesthesia where *seeing* touch consistently evokes *feeling* touch; referred to as 'mirror-touch synaesthesia' (Blakemore et al., 2005; Fitzgibbon et al., 2012; Ward & Banissy, 2015 but see de Vignemont, 2017). Whereas the self-reported prevalence of mirror-touch synaesthesia is 10.8% (Banissy et al., 2009), behavioural measures indicate that the prevalence may be much lower at 1.6% (Banissy and Ward, 2007). As such, the current understanding of vicarious touch is largely derived from a very small portion of the population.

Research on mirror-touch synaesthesia suggests potential differences between this group and the general population, although evidence is mixed. Mirror-touch synaesthetes often report localised and exteroceptive sensations like touch and pressure when observing touch, whereas non-synaesthetes tend to report more generalised and interoceptive sensations like tingling and itching (Li et al., 2022; Ward et al., 2018; Ward and Li, 2022). Additionally, mirror-touch synaesthetes rate emotional stimuli more strongly, possibly suggesting increased sensitivity to emotionally arousing events (Ioumpa et al., 2019). Moreover, mirror-touch synaesthetes display more pronounced differentiation in their responses when observing touch applied to humans, including human-like objects, compared to non-synaesthetes (Holle et al., 2011; Ward et al., 2018). This suggests a potential link between vicarious touch experiences and heightened empathetic responses toward the recipient of the touch, supported by research showing increased social abilities in this group (Banissy et al., 2011; Banissy and Ward, 2007; Goller et al., 2013; Ioumpa et al., 2019; Maister et al., 2013; Martin et al., 2017; Santiesteban et al., 2015; Ward et al., 2018). While mirror-touch synaesthesia may involve distinct processes beyond shared affective or emotional states (Ward et al., 2018), categorical differences remain debated (Fitzgibbon et al., 2012; Rothen and Meier, 2013; Ward, 2019). Previous studies often feature small sample sizes, lenient inclusion criteria, and there exists substantial variation in the frequency of reported

vicarious touch experiences among individuals identified as mirror-touch synaesthetes (Holle et al., 2011). As such, it is conceivable that these samples represent a continuum of experiences rather than discrete categories.

While 'tingling' is commonly reported in response to watching videos of touch or pain (Banissy et al., 2009; Osborn and Derbyshire, 2010; Ward et al., 2018), the reason behind this frequent sensation remains unclear. This stems in part from the various circumstances under which tingling can be evoked. It could potentially result from mirrored tactile events inducing similar sensations in receivers, like soft, slow stroking. If this is the case, it should presumably be more prevalent during pleasant videos which often involves such touches (Taneja et al., 2021). However, tingling sensations can also be evoked by cognitive processes alone, such as by focusing attention on a body part, experiencing emotions, undergoing arousal, or perceiving threat (Tihanyi et al., 2018; Tihanyi and Köteles, 2017). This explanation is consistent with the frequent reports of tingling during the observation of painful stimuli (Osborn and Derbyshire, 2010). Investigating the effects of observed touch type (e.g., stroking versus pressing) and valence can provide further insight into the distinct qualities of vicarious sensations.

Previous research on vicarious sensory perception has provided insights into the subjective experiences when observing *pain* or *painful touch* (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Vandenbroucke et al., 2013; Ward et al., 2018; Ward and Li, 2022). In addition, fMRI-based neuroimaging studies have revealed variations in brain functions associated with empathetic responses to both pleasant and unpleasant tactile sensations observed in others (Lamm et al., 2015; Morrison et al., 2011; Riva et al., 2018). However, *subjective experiences* resulting from observing *pleasant* touch are less explored. This may be important in various scenarios. For example, healthcare professionals who feel their patients' pain might see it as boosting their compassionate care, yet empathetic reactions that are too strong can potentially diminish their supportive abilities

or result in burnout (Giummarra et al., 2016). Additionally, vicarious touch in virtual settings has been linked to customers feeling a greater sense of product ownership, enhancing product evaluations (Luangrath et al., 2022). Better understanding of pleasant and unpleasant vicarious touch could therefore have practical applications.

Earlier studies employed a broad range of stimuli varying in aspects like arousal, threat, valence levels, the specific body part touched, viewing perspective, and stimulus plausibility (e.g., upright vs. inverted face). While some research has examined the influence of factors like body posture on reported sensations (Holle et al., 2011; Medina and DePasquale, 2017), there are other nuances that require further exploration for a comprehensive understanding of their effects. For example, evidence suggests that stimuli portraying painful events may be more likely to elicit vicarious responses (Ward et al., 2018; Ward and Li, 2022). Further, observed touches involving threatening objects, such as a knife tip to the face, were shown to induce more frequent and intense mirrored sensations compared to those with non-threatening objects like a fingertip or feather (Holle et al., 2011; Ward et al., 2018). This suggests that stimuli perceived as unpleasant, arousing, or threatening may generally provoke stronger responses.

Here, we systematically investigate the characteristics of reported vicarious sensations in a large cohort of undergraduate students, using controlled stimuli selected from our previously developed Validated Touch-Video Database (VTD; Smit & Rich, 2023). These videos, which uniformly depict touch to a female left hand from a first-person perspective, vary in arousal, threat level, hedonic qualities, touch types, and whether touch is applied by a hand or object. This broad range of stimuli allows for a comprehensive examination of how different aspects of observed touch influence vicarious sensations. First, we examine general characteristics of vicarious sensations including prevalence, localisation, gender differences, and links to emotional empathy. Next, we assess how visual stimuli characteristics affects vicarious sensations, comparing responses to touches of varying hedonic qualities and their

correlation with arousal and threat ratings, as well as the impact of touch type and whether touch is delivered by a hand or object. Finally, we explore mirror-touch synaesthesia prevalence in our sample, using previously defined criteria, and analyse differences in experiences based on vicarious tendencies and their association with emotional empathy. Our approach thoroughly investigates vicarious sensory perception in the general population.

2. Materials and Methods

2.1. Participants

We recruited naïve undergraduate students via the Macquarie University subject pools and participants received course credit for their participation (N = 422; 292 women, 129 men; mean age = 21.17 years, SD = 5.77 years, range = 17-56 years). Students who had previously participated in our study for validating touch videos from the VTD (Smit & Rich, 2023) were not eligible to participate, as familiarity with the visual stimuli could potentially influence their experience. The study was approved by the Macquarie University Human Research Ethics committee and participants provided written consent.

2.2. Stimuli

We incorporated videos from the VTD (Smit and Rich, 2023), each featuring a female left hand against a dark backdrop, viewed in first-person with the palm down. These videos, previously validated by an independent group of participants, display varying levels of arousal, threat, hedonic qualities, types of touch, and either object- or human-induced touch. Touch videos were rated on their hedonic quality, perceived arousal, and threat. Using the validation data, we selected ten videos representing each hedonic category (neutral, pleasant, unpleasant, painful; 40 total). Further, we included five additional (non-validated) videos depicting touch to or near an object (white block), filmed under the same controlled conditions as the hand videos.

2.3. Experimental procedure

After participants signed up to our study, they were given a link to an online questionnaire hosted on Qualtrics. We instructed participants to complete the task remotely on their own devices and to use a desktop computer or laptop instead of a phone or tablet. The questionnaire included the 45 touch videos presented in randomised order. To ensure that participants were ready and paid full attention to the entire video, we disabled auto-play, and the first frame of each video was a white screen with the text "Press play to start video". After watching each video, participants were asked the following questions:

Q1: *While watching the video, did you experience a tactile sensation on YOUR body?* [Yes/No]. If participants answered 'No', they would go on to the next video. If they answered 'Yes', they would be presented with these follow-up questions:

Q2: *Which of these options describes the sensation on YOUR body?* (multiple answers allowed) [answer: Touch, Pain, Tingling, Pressure, Scratching, Ticklish, Warm, Cold, Other (describe)]

Q3: *How intense was it?* [answer: 1 = not at all, 10 = extremely]

Q4: *How did it feel?* [single answer out of the following options: neutral, pleasant, unpleasant, painful]

Q5: *How __ (pleasant/unpleasant/painful; only one category was presented and depended on the previous answer) was the touch?* [answer: 1 = not at all, 10 = extremely]

Q6: *Where on YOUR body did you feel the tactile sensation?* (multiple answers allowed) [answer: Left hand, Right hand, Another body part (describe), A general feeling (describe), Other (describe)]

After finishing this part of the survey, participants were also asked five questions taken from the short Emotional Quotient (EQ) to assess emotional reactivity (Muncer and Ling, 2006).

The entire questionnaire took between 10 and 30 minutes to complete depending on how often the participant responded 'Yes' to the first question (as this resulted in five additional questions for each video).

2.4. Analyses

First, we investigate the general characteristics of vicarious touch in the general population, exploring the prevalence of reported vicarious sensations, whether these are localised or general, any gender differences, and the potential link with emotional empathy. We make a distinction between exteroceptive and interoceptive sensations (as proposed by Ward et al., 2018) to see whether this impacts the results. Second, we look at the effects of various aspects of the visual stimuli on the characteristics and phenomenology of various touch experiences. Third, we test the prevalence of mirror-touch synaesthesia in our sample using a previously proposed criterion (Ward et al., 2018), and any difference in the phenomenology of experiences reported in this special population.

This study is exploratory, and we therefore take a conservative statistical approach with non-parametric testing and Bonferroni correction to adjust for multiple comparisons. For any observed null-result, we follow up with Bayes Factor (BF) analysis, using the Bayes Factor R package with the default prior and $r = 0.707$ (Morey et al., 2018). BFs can provide evidence for either the alternative hypothesis (indicated by a BF > 1) or the null hypothesis (indicated by a BF < 1). When the BF falls between 1 and 3, it is typically interpreted as insufficient evidence either way. Larger BFs, such as > 10, provide stronger evidence in favour of one hypothesis over the other (Jeffreys, 1998). All statistical analyses are performed using the R programming language (R Core Team, 2023).

3. Results

3.1. Broad characteristics: prevalence, gender differences, and empathy

3.1.1. High prevalence of vicarious touch in a general population

To examine the prevalence of reported vicarious sensations, we tallied the number of trials where a participant endorsed *any* vicarious sensation, as well as separately noting *exteroceptive* sensations (such as touch, pressure, or scratching), or *pain* (Fig. 1).

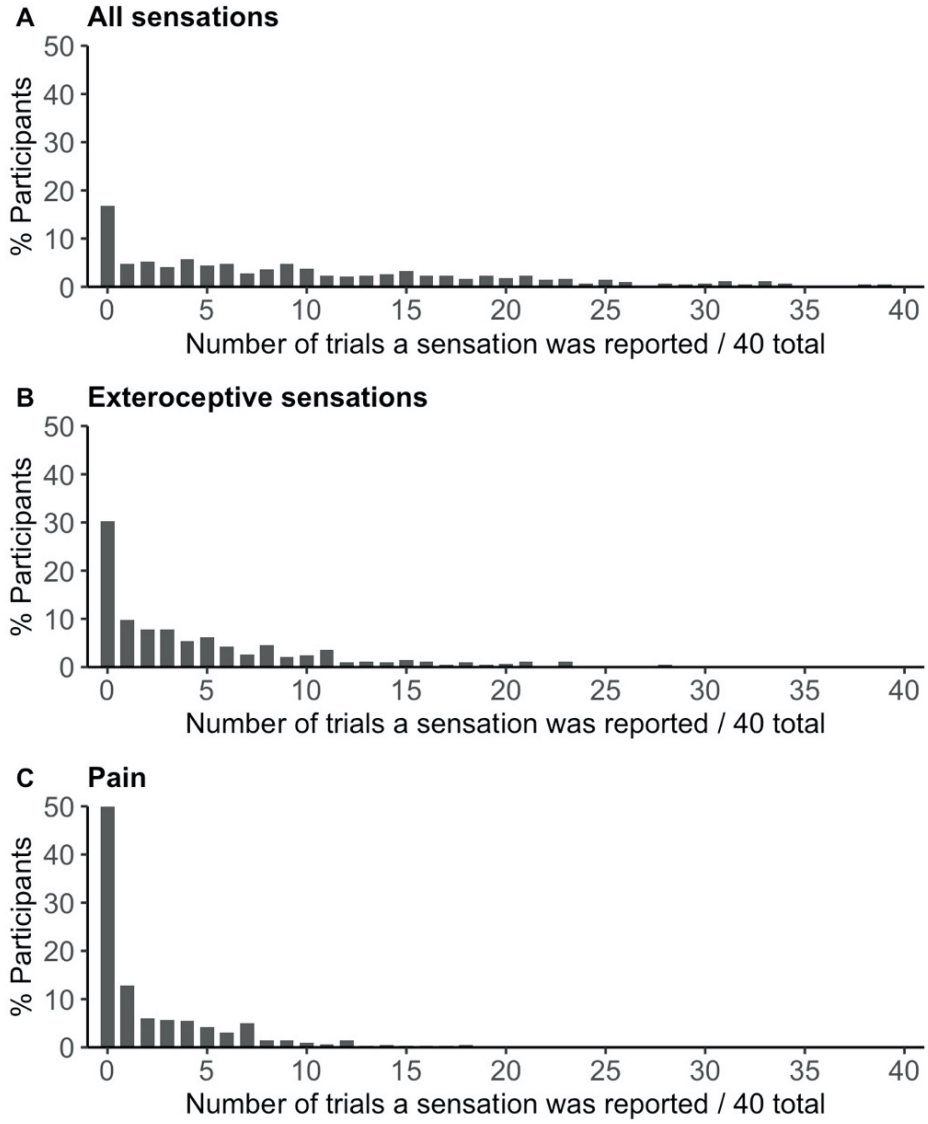

Figure 1. Prevalence of vicarious sensory perception in a general population. The bar graphs represent the number of trials (out of 40) where participants (N = 422) reported vicarious sensations after viewing 40 unique videos of a hand being touched. (A) Total reported sensations. (B) Exteroceptive

sensations, such as touch, pressure, or scratching. (C) Pain. Each bar indicates the percentage of participants who reported the sensation across the specific number of trials (videos).

Among all participants, 83% reported experiencing sensations including touch, pain, tingling, pressure, scratching, ticklish sensations, warmth, cold, or 'other' at least once while viewing the 40 videos (Fig. 1A). When we select only the exteroceptive sensations touch, pressure, and scratching (a distinction suggested by Ward et al., 2018), there is still 70% percent of participants reporting these sensations at least once (Fig. 1B). Regarding 'pain', 50% of participants reported experiencing it at least once (Fig. 1C). These findings suggest that most individuals report vicarious sensations, including pain, in response to viewing various types of tactile interactions in experimental contexts.

3.1.2. Gender differences in the frequency, but not intensity, of vicarious touch

We investigated gender differences for the average number of trials in which sensations were reported across the 40 trials, as well as in the intensity of these sensations for different types of experiences (Fig. 2).

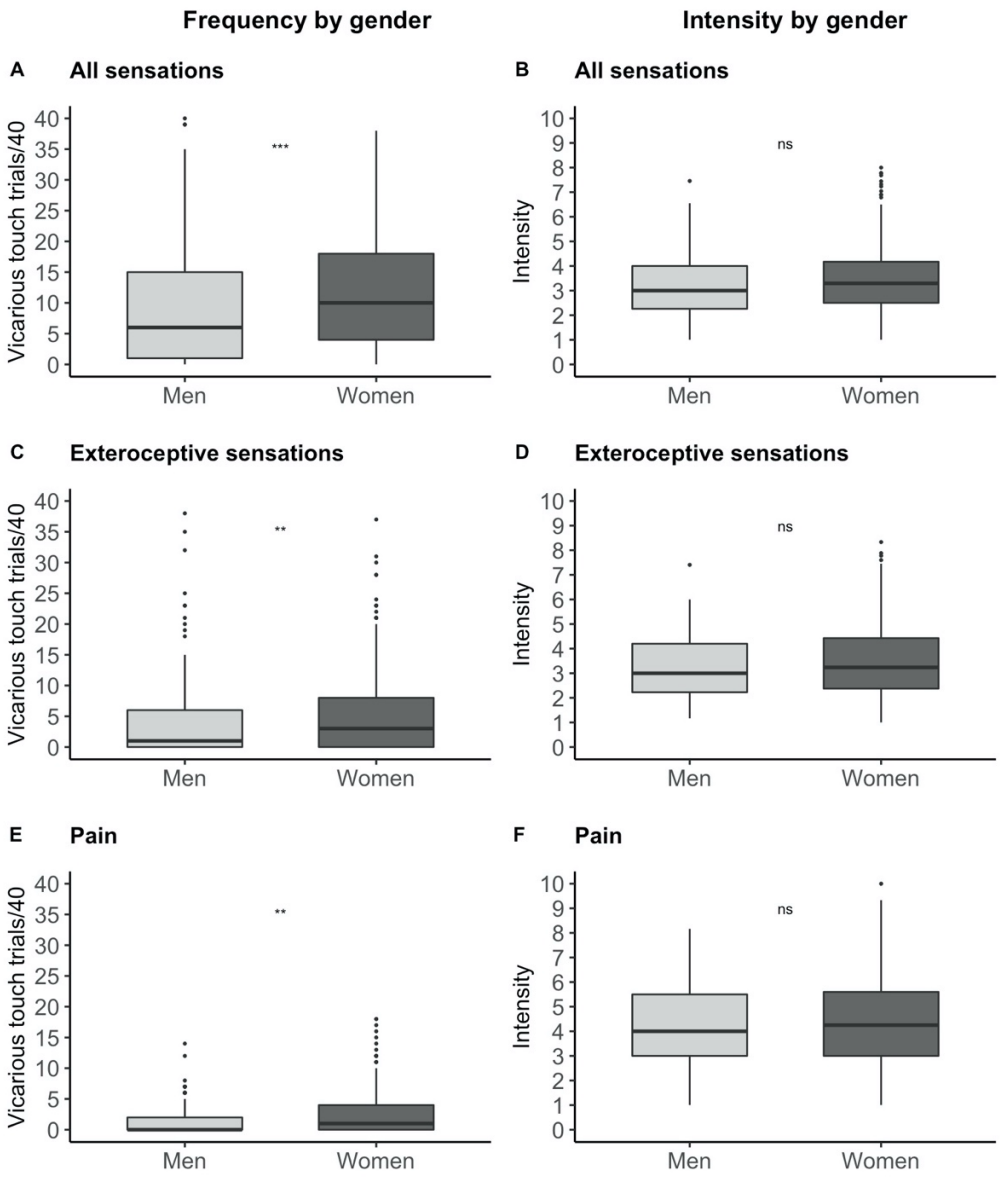

Figure 2. Gender effects in reporting vicarious sensations and their intensity. The box plots contrast the differences between men and women. (A, C, E) The distribution of the number of trials (out of 40) where vicarious sensations were reported (all sensations, exteroceptive sensations, and pain sensations respectively). (B, D, F) The distribution of intensity for these reported sensations for each sensation type. The line within each box indicates the median, the box boundaries indicate the interquartile range (IQR), and the whiskers extend to 1.5 times the IQR. Dots indicate outliers. Statistical significance of the contrast between men and women is indicated by p-values: ns = non-significant; *** $p < 0.001$, ** $p < 0.01$, all Bonferroni corrected.

Breaking it down by participants who reported each type of sensation, we observed differences between genders. Among those who reported *any* type of sensation (88% of women and 76% men), the average number of endorsed trials was 11.57 for women and 8.74 for men ($W = 14904$, $p < 0.001$). When considering *exteroceptive* sensations (74% of women and 59% of men), the average number of endorsed trials was 5.49 for women and 4.64 for men ($W = 15810$, $p < 0.01$). Similarly, among those who reported *pain* sensations (54% of women and 41% of men), the average number of trials with reported pain sensations was 2.59 for women and 1.50 for men ($W = 15724$, $p < 0.01$). Overall, more women reported sensations and on more trials than men. While there were observable differences in the frequency of sensations reported between genders, the intensity of these sensations did not differ (all p-values > 0.05; all sensations: BF = 0.444; exteroceptive sensations: BF = 0.200; pain: BF = 0.274). In sum, relatively more women report experiencing vicarious sensations than men and they also report a greater number of such sensations. However, there appears to be no difference in the intensity of these sensations between the two genders.

3.1.3. Modest significant link between emotional empathy and sensation reporting

To investigate the potential relationship between the tendency to experience vicarious touch and increased emotional empathy, we analysed the correlations between the number of trials in which vicarious touch was endorsed in the different sensation types and empathy scores (Fig. 3).

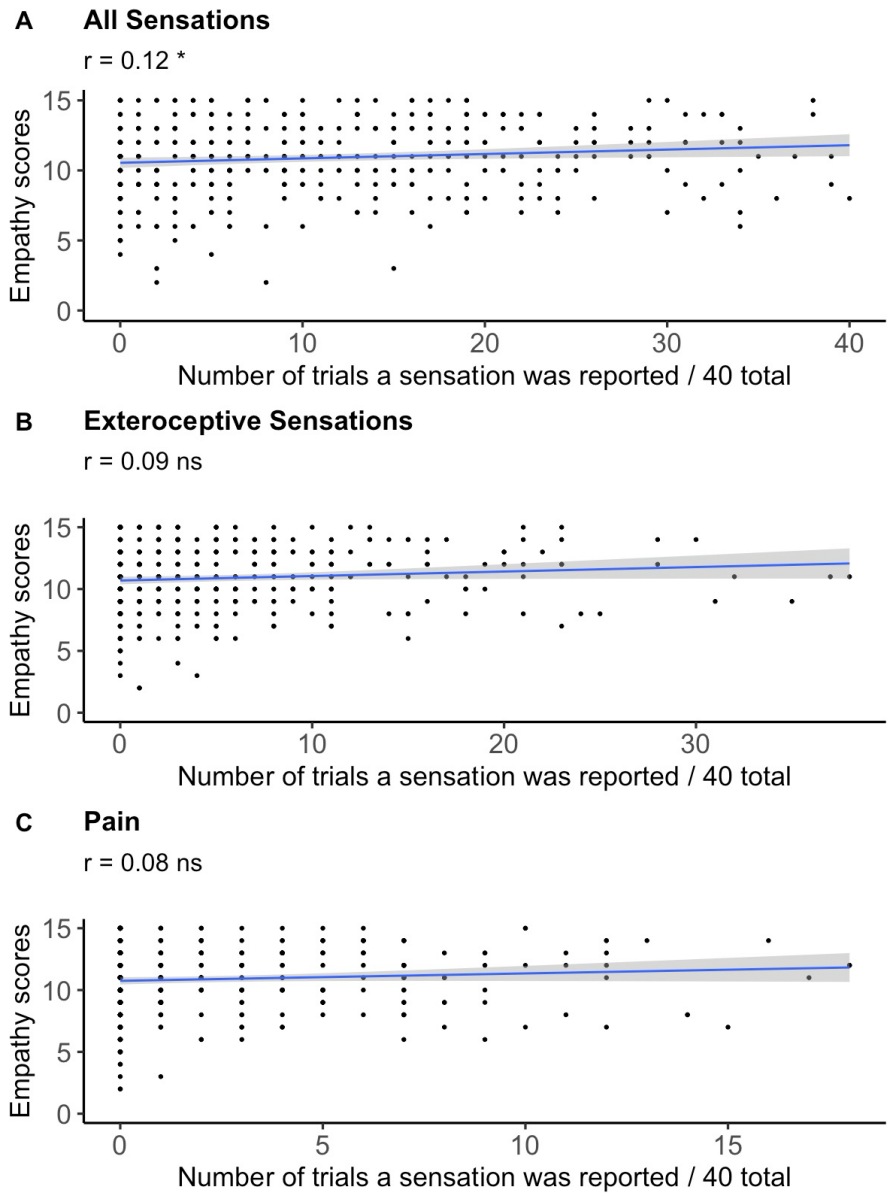

Figure 3. Correlation between empathy scores and frequency of reported sensations. Scatterplots depict the relationship between participants' empathy scores and the number of videos (out of 40) for which they reported sensations. (A) All sensations, (B) Exteroceptive sensations, and (C) Pain. Lines show linear regression with shaded 95% confidence intervals. Statistical significance is indicated by p-values: ns = non-significant; * $p < 0.05$, all Bonferroni corrected.

Our results indicate a small but statistically significant correlation between empathy scores and the number of trials in which participants reported experiencing any sensation ($r = 0.12$, $p < 0.05$). This suggests that individuals with higher empathy scores tend to report sensations

in more trials, although the correlation is small. We found no correlation between empathy scores and the frequency of reported exteroceptive (BF = 0.742) or pain sensations (BF = 0.422). A Welch two-sample t-test showed women had significantly higher empathy scores than men in our sample (mean: Women = 11.22; Men = 10.09; $t(219.61) = 3.10$, $p < 0.001$).

3.2. The influence of stimulus characteristics on vicarious touch experiences

3.2.1. Hedonic qualities of observed touch influence the frequency and intensity of vicarious touch

We assessed the average proportion of participants experiencing vicarious touch and the average intensity of these sensations for each video, categorised by their hedonic category (Fig. 4). Based on prior research, we hypothesised that videos portraying pain or threat would be particularly potent in eliciting sensory responses (Holle et al., 2011; Ward et al., 2018; Ward and Li, 2022).

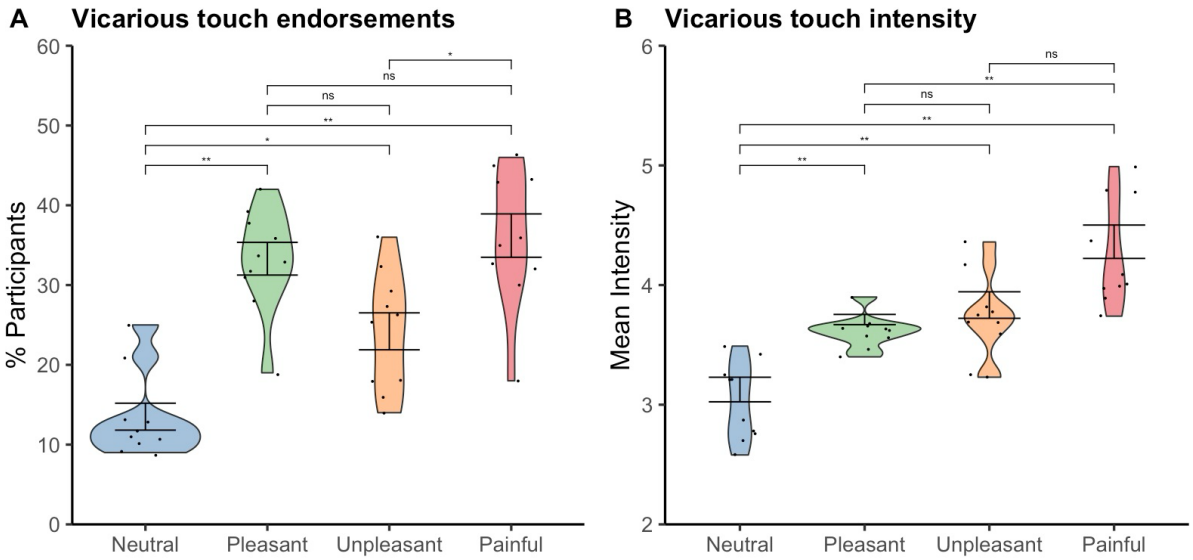

Figure 4. Vicarious touch endorsement and intensity across different hedonic categories. (A) vicarious touch endorsement; presented as a percentage of participants. (B) vicarious touch intensity; on a scale from 1-10. Violin plots convey the data distribution for each hedonic category: neutral, pleasant, unpleasant, and painful. The width of the violins indicates the density of the data, with broader

sections representing higher densities. Error bars represent the 95% CIs. Dots show ratings for the individual videos, with 10 videos per category. Statistical differences between categories are indicated by p-values: ns = non-significant; ** $p < 0.01$; * $p < 0.05$, all Bonferroni corrected.

Kruskal-Wallis tests showed significant differences in vicarious touch frequency ($X^2(3) = 25.15$, $p < 0.0001$) across hedonic categories. To delineate these differences, Wilcoxon rank-sum tests were conducted for pairwise comparisons. Painful videos were most frequently endorsed (36% of participants), with endorsement rates significantly higher than those for unpleasant (24%, $p < 0.05$) and neutral videos (13%, $p < 0.01$). Similarly, pleasant videos were endorsed by 33% of participants, with rates significantly higher than for neutral videos ($p < 0.01$). The comparison of pleasant versus unpleasant videos yielded a p-value of 0.054, which, when considered with the BF of 5.743, suggests a difference. The endorsement rate for unpleasant videos (24%) was significantly higher than that for neutral videos (13%, $p < 0.05$). The BF for the non-significant comparison between pleasant and painful videos was 0.513, and for pleasant and unpleasant videos it was 0.571, in both cases providing anecdotal evidence in favour of no difference between these categories in endorsement rates.

We also found significant differences in vicarious touch intensity ($X^2(3) = 179.47$, $p < 0.0001$). Painful videos evoked the highest average ratings (mean = 4.26), which was significantly different from the ratings for unpleasant (mean = 3.73, $p < 0.01$), pleasant (mean = 3.61, $p < 0.01$), and neutral videos (mean = 3.03, $p < 0.01$). Further, significant differences were found when comparing the intensity ratings between neutral and pleasant videos ($p < 0.01$), between neutral and unpleasant videos ($p < 0.01$), and between pleasant and painful videos ($p < 0.01$). Intensity ratings for unpleasant and painful videos yielded $p = 0.054$, which when considered with the BF of 0.571 suggests anecdotal evidence in favour of no difference in intensity ratings between the two categories.

In summary, participants indeed reported most frequent and intense vicarious sensations for painful videos, with neutral videos least likely to elicit vicarious touch and

yielding the lowest intensity when they did. These findings underscore the impact of the hedonic quality of observed touch on the frequency and intensity of vicarious touch experiences among observers.

3.2.2. Frequency and intensity of vicarious touch correlate with rated threat and arousal

Validation data from the VTD indicates that videos depicting pain are perceived as highly threatening and arousing (Smit and Rich, 2023), which might explain why they often elicit frequent and intense vicarious touch sensations. To examine this, we conducted correlation analyses between the arousal and threat scores of each of the 40 videos (as per the validation data) with both the percentage of participants reporting vicarious touch and the intensity of their experienced sensations (Fig. 5).

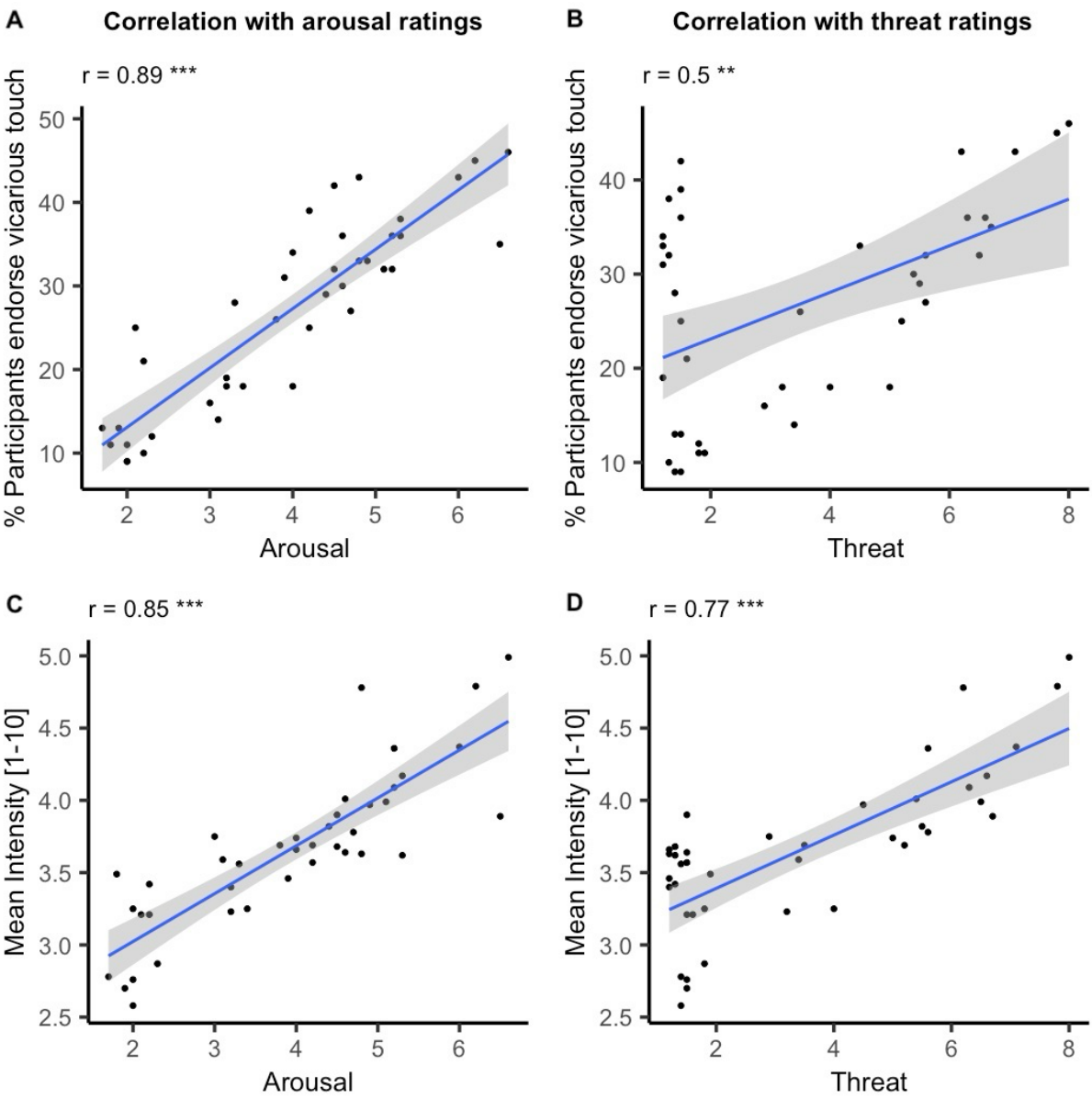

Figure 5. Correlation between arousal and threat ratings of the videos from the VTD with endorsement and intensity of the resulting vicarious touch evoked by these videos. Scatterplots depict the relationship between the independently rated (A, C) arousal and (B, D) threat (ranging from 1 to 10) from the VTD and current participants' endorsement (top) and intensity (bottom) of vicarious touch experiences. Each dot signifies the percentage of participants, or mean intensity ratings across participants, for the individual videos, with 40 videos in total. Lines show linear regression with shaded 95% confidence intervals. Statistical significance is indicated by p-values: *** $p < 0.001$, ** $p < 0.01$, all Bonferroni corrected.

The rated arousal of the touch in videos exhibited a strong correlation with both the percentage of participants that endorsed vicarious touch ($r = 0.89$, $p < .001$) and the average intensity of reported vicarious sensations ($r = 0.85$, $p < .001$). Threat ratings also showed a significant correlation with intensity ($r = 0.77$, $p < .001$) and a moderate correlation with frequency ($r = 0.50$, $p < .001$). These results suggest that arousal serves as the primary modulator determining the frequency and intensity with which vicarious touch is perceived. Both painful and pleasant videos received high arousal ratings, but only painful videos were also deemed highly threatening (Smit and Rich, 2023). This may explain the lower correlation between threat ratings and vicarious touch occurrences.

3.2.3. Sensations are felt across the body with a focus on the hands

When participants reported experiencing a sensation while watching a video (all of touch to a left hand), we asked them where they felt it (response options; left hand, right hand, another body part, a general feeling, or 'other'). Out of all participants, 82% indicated a sensation on one or both hands in at least one trial. A breakdown showed that of all trials where vicarious touch was endorsed, 86% were localised to the hands (54% in the left, 26% in the right, and 6% in both hands), 12% were felt in other body parts, 7% were described as a general feeling, and 1% were categorised as 'other'. The percentages exceed 100% because participants could indicate sensations in multiple areas during a single trial. Thus, most participants experience sensations congruent with the depicted tactile interaction—in this instance, the hand.

We examined the specificity of sensation localisation in relation to four hedonic categories (Fig. 6). Prior research suggests that mirrored painful sensations might present as localised sensory or generalised affective feelings (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Vandenbroucke et al., 2013; Ward et al., 2018; Ward

and Li, 2022). Thus, we hypothesised that painful videos would elicit both general sensations in addition to localised sensations to the hand.

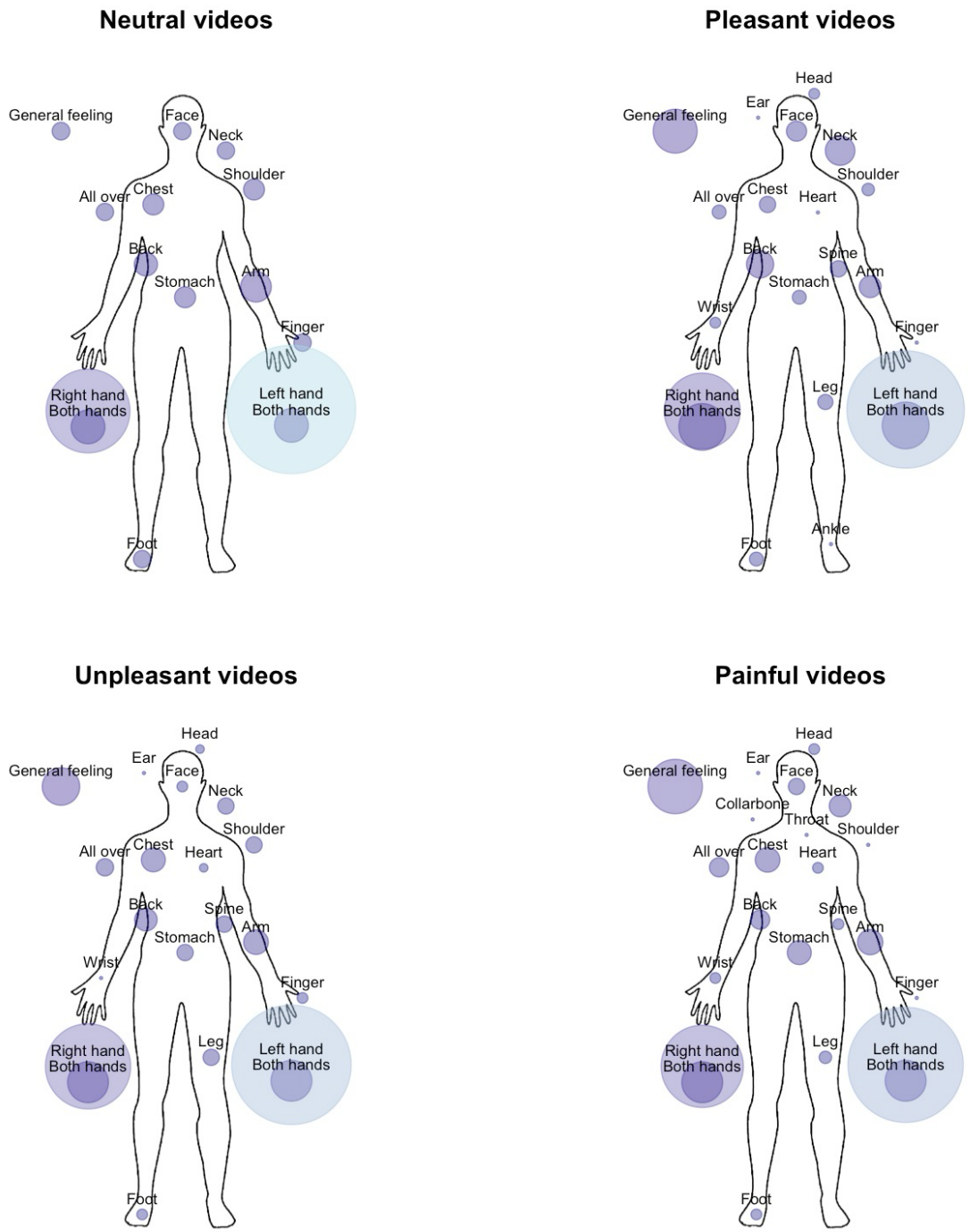

Figure 6. Location of reported sensations across different hedonic categories. Each body plot represents one of the four video categories: neutral, pleasant, unpleasant, and painful, with each category comprising 10 video trials. Note that all videos depict a left hand being touched. The body regions where sensations were felt are represented by colour-coded points. Both the size and colour

intensity of these points correlate with the frequency of sensations reported in that region. A gradient from dark purple (fewer reports) to light blue (more reports) signifies the sensation frequency.

Our data showed that out of all trials where a sensation was reported in response to watching a *painful* video, 84% was reported to be hand-localised: 52% left hand, 26% right hand, and 6% in both hands. *Neutral*, *pleasant*, and *unpleasant* videos exhibited a similar distribution, suggesting that watching any tactile interaction predominantly triggers sensations on the observer's corresponding body part. In addition, we examined the responses described when participants indicated to have felt touch on 'another body part' (neutral 5%, pleasant 14%, unpleasant 9%, painful 12%). Reported sensations are dispersed across the body, with a notable concentration in the upper body regions including the back, neck, chest, stomach, and arms. Especially for videos depicting pain, sensations were reported in many different body parts. Painful videos were also most likely to evoke a general feeling (11%), followed by pleasant (7%), unpleasant (5%), and neutral (1%) videos.

3.2.4. Different vicarious touch valences: neutral most common and pain most intense

In each trial where a vicarious sensation was reported, participants identified this vicarious sensation as being neutral, pleasant, unpleasant, or painful. We tested the valence of the reported sensations, and if this resulted in different intensities. First, we look at the percentage of all responses where vicarious touch was endorsed (Fig. 7A) and the corresponding intensity (Fig. 7B), and then we test for gender differences (Fig. 7C, D).

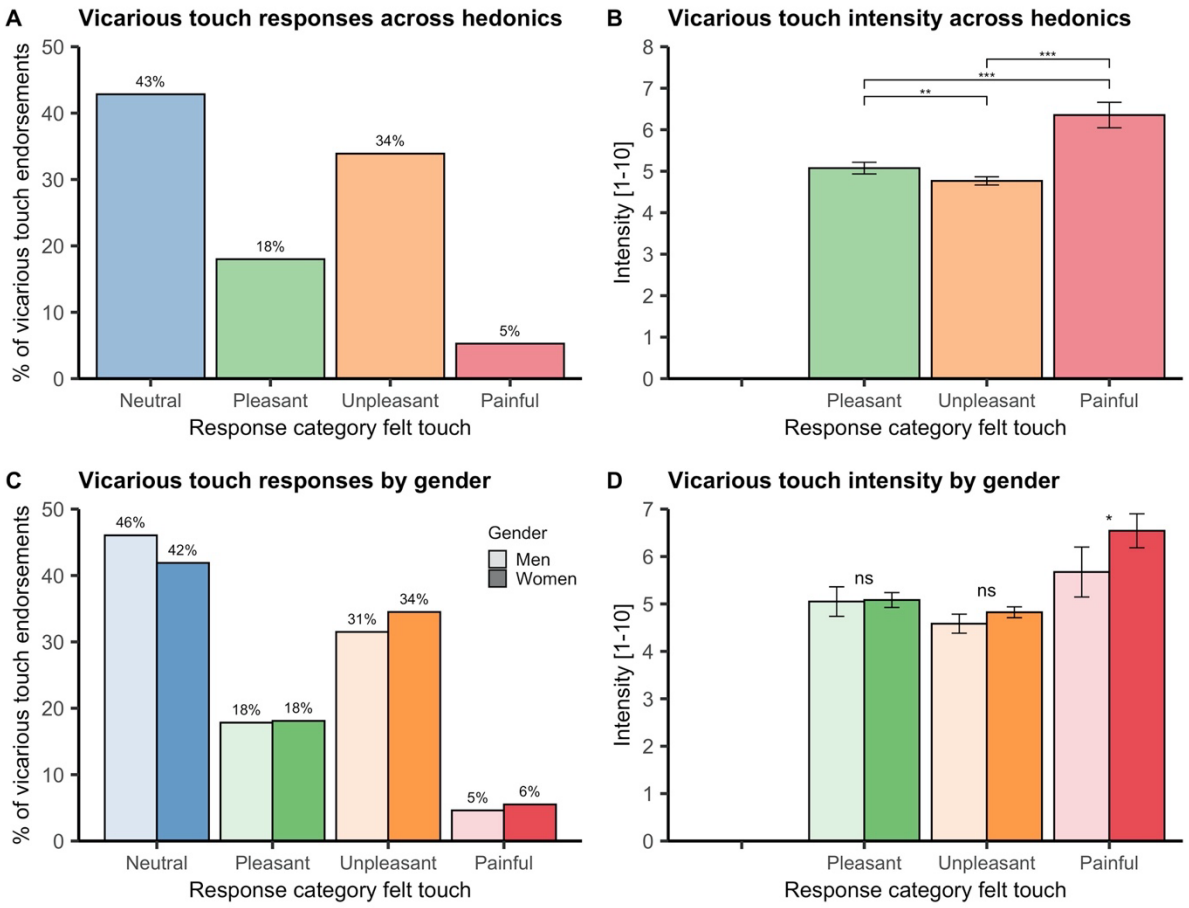

Figure 7. Vicarious touch responses with different valences. (A) The percentage of all endorsed vicarious touch trials in which participants assigned valence (neutral, pleasant, unpleasant, and painful) to the vicarious touch they experienced. (B) The corresponding average intensities for each valence (participants were only asked about intensity for valanced touch reports, i.e., not neutral). (C) Vicarious touch responses sorted by the reported valence and divided by gender (men and women). (D) Corresponding intensities of vicarious touch experiences, also divided by gender. Intensity is scored on a scale from 1 to 10, with higher values indicating stronger sensations. Error bars represent 95% confidence intervals for each category. Statistical significance is indicated by p-values: ns = non-significant; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, all Bonferroni corrected.

When considering all endorsed vicarious touch trials across all participants, most of these were categorised as 'neutral' (43%), followed by 'unpleasant' (34%), 'pleasant' (18%) and 'painful' (5%). A Pearson's Chi-squared test showed a significant difference in the distribution of vicarious touch responses across the categories ($X^2 = 30410$, $df = 4$, $p < 0.0001$). We also

analysed the perceived intensity of vicarious sensations across the sample for the different hedonic categories. The results showed that 'painful' sensations were perceived with the highest intensity (mean = 6.35), followed by 'pleasant' (mean = 5.07) and 'unpleasant' (mean = 4.77). A Kruskal-Wallis rank-sum test revealed a significant difference in intensity across the categories ($X^2(2) = 27.099$, $p < 0.0001$). Post-hoc Wilcoxon rank-sum pairwise comparisons further showed that the three categories were significantly different from one another.

When examining the distribution of response valence based on gender, a Pearson's Chi-squared test showed no significant difference in the distribution of vicarious touch responses based on gender ($X^2(3) = 6.950$, $p = 0.074$). A Kruskal-Wallis rank sum test looking at intensity scores with an interaction between gender and category showed a statistically significant difference in intensity scores across the gender-response category combinations ($X^2(5) = 104.04$, $p < 0.0001$). Post-hoc Mann-Whitney U tests showed that there was only a significant gender-related difference in the intensity of painful sensations (U = 3732, mean Women = 6.54; Men = 5.67, $p < 0.05$), with p-values > 0.05 for pleasant and unpleasant sensations. Corresponding BFs provide strong evidence for no difference between the groups in terms pleasant sensations (BF = 0.092) and anecdotal evidence for unpleasant sensations (BF = 0.498).

In sum, our analysis of the entire cohort revealed variations in the distribution of vicarious touch responses. Most vicarious sensations were reported as 'neutral', followed by 'unpleasant', while sensations with a 'painful' valence had the highest reported intensity. While no statistically significant gender differences emerged in the reported valence types across all endorsed trials, we did observe a distinction in the intensity of sensations with a painful valence, with women rating these instances as more intense than men.

3.2.5. Neutral, pleasant, and unpleasant videos evoke touch with corresponding valence

Next, we tested whether the hedonic quality of the observed touch portrayed in the videos influences the valence of reported sensations (Fig. 8).

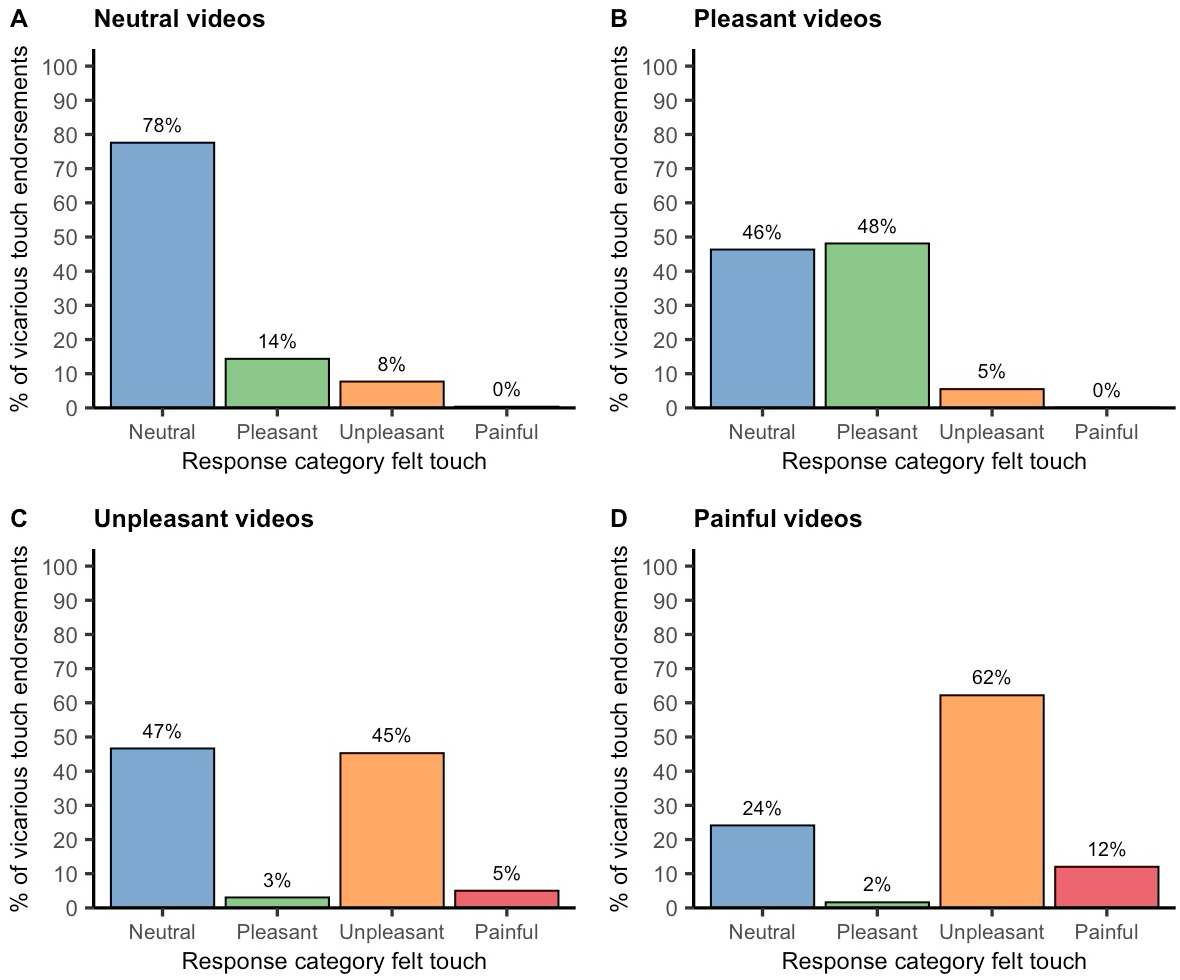

Figure 8. Impact of hedonic quality of video touch on the valence of vicarious touch sensations. The bar graphs illustrate how the hedonic quality of observed touch—(A) Neutral, (B) Pleasant, (C) Unpleasant, or (D) Painful—affects the valence of vicarious touch sensations reported by participants. Hedonic categories of the videos are predefined based on validation data from (Smit and Rich, 2023). The y-axis represents the percentage of trials where sensations were reported with a particular valence for each of the ten videos within each hedonic category.

Neutral videos predominantly evoked neutral sensations, while both pleasant and unpleasant videos frequently elicited either valence-congruent sensations or neutral ones. Notably, when

participants viewed videos showing painful touch, they predominantly reported the sensation as being unpleasant, with only 12% indicating it to be painful. This highlights that the hedonic quality is regularly mirrored with reduced valence intensity for videos depicting painful touch.

3.2.6. Strength of seen and felt touch valence are matched across hedonic categories

To explore the mirroring of touch-valence intensity further, we investigated if the valence strength of the touch videos affected participants' ratings of the valence strength in their vicarious sensations. After participants categorised their *vicarious sensations* as pleasant, unpleasant, or painful, they rated the intensity of the valence contingent upon their initial categorisation. This was compared with validation scores from the VTD (Smit and Rich, 2023), where a different cohort rated the touch displayed in the videos using an identical scale. The findings show that for videos classified as 'pleasant', the observed touch had an average rating of 6, closely paralleled by the vicarious sensation with an average of 5. A similar alignment was observed for 'unpleasant' videos, with both observed and vicarious sensations averaging at 5. For 'painful' videos, the observed touch averaged at 7, while the vicarious sensation averaged at 6. This suggests that even though participants rarely identified feeling 'pain' when viewing painful videos, on occasions when they did report feeling 'pain', the intensity of the observed and felt pain was closely aligned. This was similarly the case for both unpleasant and pleasant touch. This illustrates that when the hedonic tone of the vicarious touch corresponds with the observed touch, the strength of the valence is remarkably similar.

3.2.7. Neutral, pleasant, unpleasant, and painful videos evoke different sensations

We then investigated the type of sensation elicited by viewing touch videos of different hedonic qualities, such as whether the participants described tingling, touch, temperature, pressure and so on. To achieve this, we calculated the percentage of each type of reported sensation

relative to all reported sensations across the ten videos within each of the four categories (Fig. 9).

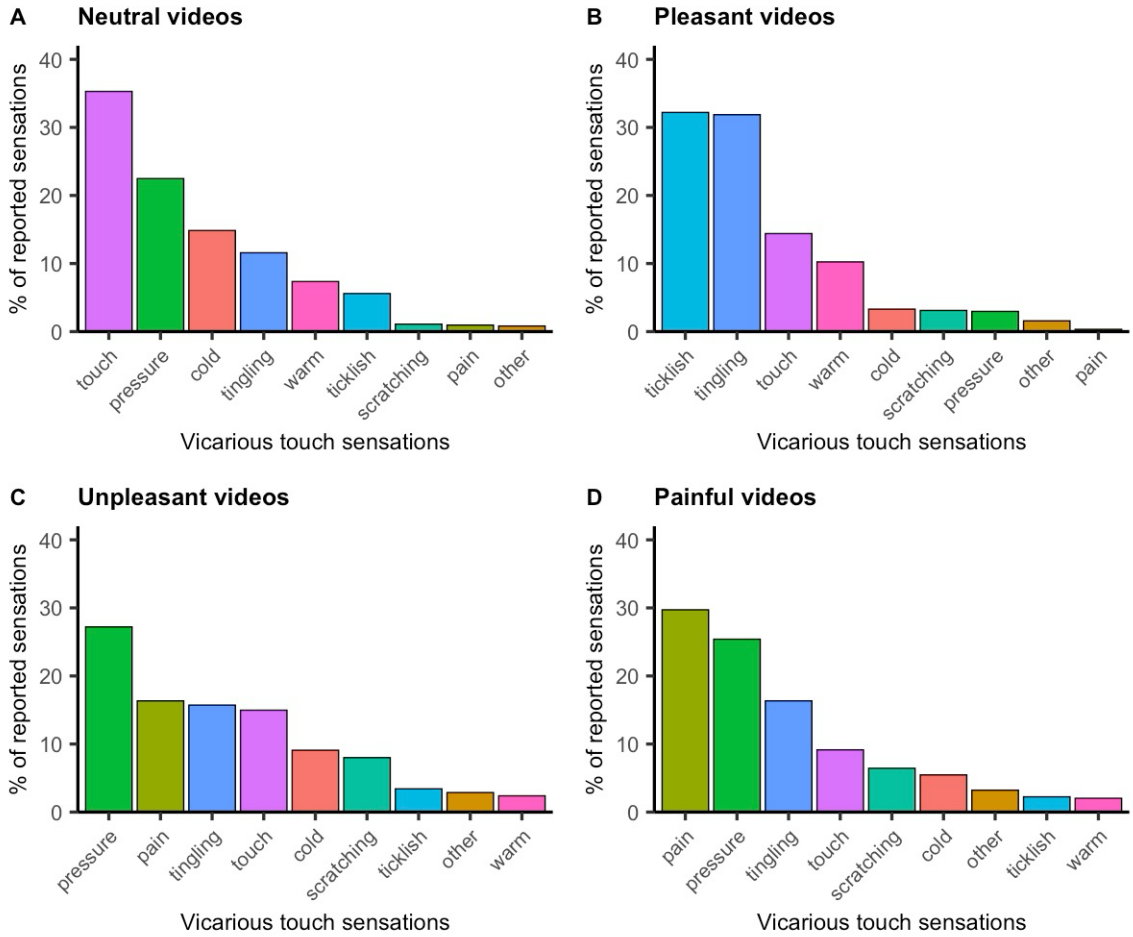

Figure 9. Differential sensation reporting across video categories. The distribution of vicarious touch sensations reported by participants following the viewing of ten videos categorised as (A) Neutral, (B) Pleasant, (C) Unpleasant, and (D) Painful. The y-axis displays the percentage of each sensation type relative to all reported sensations across the ten videos within each of the four categories.

Across all 40 videos showing touch to the hand, the most commonly reported sensations were as follows: tingling (23%), pressure (18%), pain (15%), ticklish (13%), touch (11%), cold (6%), warm (6%), scratching (5%), and other (3%). Our findings revealed distinct sensation distributions across the four hedonic video categories, aligning with the observed touch

quality. Neutral videos, often depicting a singular touch application with moderate pressure (see VTD; Smit & Rich, 2023) primarily elicited sensations of 'touch' (67%) and 'pressure' (23%). Pleasant videos, showing a gentle stroke using soft objects like brushes, fabrics, or another hand, predominantly evoked 'ticklish' (58%) and 'tingling' (32%) sensations. Conversely, unpleasant videos, where the touch generally applied significant pressure, triggered responses of 'pressure' (62%) and 'pain' (28%). In videos categorised as painful, which often portrayed touch using strong pressure or a sharp object, the predominant sensations were 'pain' (73%), and 'pressure' (20%). Collectively, these results underscore that observed touch types influences the phenomenology of the vicarious touch experience.

3.2.8. The touching object or hand, along with touch type, influences sensation quality

Considering the above results, we postulated that observers might exhibit sensations reflective of the specific touch quality. For instance, observing a hand being brushed could produce tingling or ticklish sensations, whereas viewing a finger scratch might trigger pressure, scratching, or even pain. This led us to a more fine-grained analysis, investigating sensations reported across the 40 videos (Fig. 10).

Reported vicarious touch sensation
Cold
Other
Pain
Pressure
Scratching
Ticklish
Tingling
Touch
Warm
Responses neutral videos
Responses pleasant videos
Responses unpleasant videos
Responses painful videos
Video 2: single touch with finger
Video 79: long stroke with soft brush all over
Video 62: touch top to bottom with scissors
Video 37: single stab with nail file
Video 4: slow repeated tap with finger
Video 78: single stroke top to bottom with soft brush
Video 14: repeated touch with pencil
Video 39: single stab with scissors
Video 6: single touch with flat hand
Video 88: repeated stroke with plastic brush
Video 52: touch top to bottom with hammer
Video 33: scratch top to bottom with scissors
Video 23: single push with a spoon
Video 87: single stroke top to bottom with plastic brush
Video 60: single push with tip of pencil
Video 29: single pinch with tweezers
Video 13: single touch with pen
Video 68: stroke top to bottom with shawl
Video 17: repeated touch with rolling pin
Video 12: repeated touch with nail file
Video 84: single touch with cotton bud
Video 75: long stroke with multiple fingers all over
Video 21: repeated touch with metal chopstick
Video 28: single injection with sharp needle
Video 1: fast repeated touch with finger
Video 69: stroke with soft sock
Video 41: injection with blunt syringe
Video 56: repeated touch with nail file
Video 27: single push with a plastic whisk
Video 81: single stroke top to bottom with cotton pad
Video 50: single long hard push with thumb
Video 35: single punch with hand
Video 89: single touch with plastic brush
Video 70: long stroke with finger all over
Video 57: single touch with nail file
Video 54: repeated touch with knife
Video 82: repeated touch with cotton bud
Video 85: touch top to bottom with fabric
Video 65: stroke top to bottom with stanley knife
Video 64: repeated touch with screwdriver
60%
40%
20%
0%

Figure 10. Detailed sensation distributions across hand-touch videos, highlighting the influence of touch method and type of object or hand. The relative frequencies of different vicarious touch sensations reported by participants in response to watching 40 videos. Each column represents a different category of video: neutral, pleasant, unpleasant, and painful. For each video, sensations are sorted in decreasing order of their reported frequency. Sensations are represented using different colours, and their definitions can be found in the accompanying legend. The y-axis displays the percentage of each sensation type relative to all reported sensations across the ten videos within each of the four categories.

Considering the sensations reported for each video provides insights into nuanced touch interactions and their corresponding sensations. For example, in two videos, touch was applied by scissors moving from the top to the bottom of the hand. When touch was applied with more pressure (video 62; pain category), most participants reported feeling pressure, whereas when touch was applied softly (video 33; unpleasant category), the most common response was tingling. In both cases, the second most common response was scratching, reflecting the scratching across the hand. In addition, we found that pleasant videos evoked the highest percentage of warm sensations whereas unpleasant videos evoked the highest percentage of cold sensations. This appears to capture anticipated sensations from the object that is applying the touch in the videos. For example, most of the unpleasant videos showed a 'cool' object applying the touch, including metal items such as a hammer, spoon, knife, scissors, or screwdriver, and this often resulted in cold sensations (video 23; neutral category, video 52; unpleasant category). Touching objects in the pleasant videos included soft or warm items such as a soft brush, cotton pad, a piece of fabric and a flat hand, and this commonly resulted in corresponding warm sensations (videos 69 and 85; both pleasant category). This shows that variation in pressure and the type of object used in the visual touch stimuli influences the specific character of the vicarious touch sensation.

3.2.9. Less frequent but similar vicarious sensations when viewing touch to an object versus a hand

Previous research suggests that observing touch, whether directed at humans or objects, can elicit vicarious touch sensations; notably, such responses intensify when observing touch to humans (Holle et al., 2011; Ward et al., 2018). To delve deeper into this distinction, we look at the distribution of sensations reported when participants observed videos showing touch to an object and compare the vicarious responses when the videos portray the identical touch applied either next to the object, and to the hand (Fig. 11).

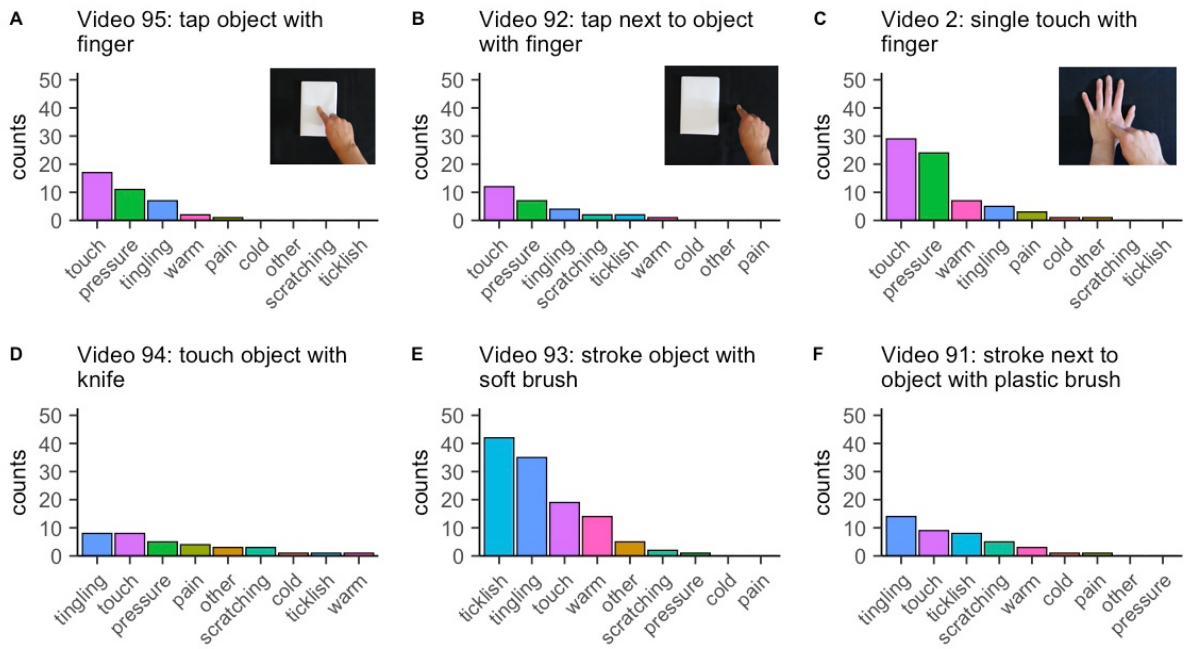

Figure 11. Distribution of vicarious touch sensations in object-touch videos. (A, B, C) Comparison of reported sensations for videos depicting identical touch interactions with an object, alongside an object, and with a hand. (D, E, F) Responses to the remaining object-touch videos (a total of 5 object videos). Please note that the y-axis represents the *total counts* of reported sensations rather than relative frequencies to illustrate the frequency of sensations for object-touch versus hand-touch videos. Sensations are ordered by the highest count.

Out of all participants, 32% reported a sensation in at least one trial (out of 5) where touch was applied to, or next-to, the object. On average, a video showing touch to the hand evoked

sensations in 27% of participants, whereas touch to the object or adjacent to the object, elicited responses in only 12% and 7% of participants, respectively. The nature of touch on the object influenced responses: a soft brush stroke on an object triggered sensations in 22% of participants (Fig. 11E; video 93), nearly three times the 8% when the object was simply touched with a finger (Fig 11A; video 95). This suggests that touches perceived as pleasant or more arousing tend to induce more pronounced vicarious sensations, regardless of whether the touch is directed at a human or an object. Participants described consistent sensations across various hand/object video types, such as observing touch with a finger, irrespective of whether it was applied to the hand, an object, or in proximity to the object. However, the percentage of total participants that reported a sensation was decreased for these object videos; 13% of participants reported a vicarious touch sensation while watching a finger touch a hand (Fig. 11C), compared to 8% when observing a similar touch to the object (Fig. 11A) or 6% in its vicinity (Fig. 11B). These findings suggest that while human touch observations have a higher propensity to elicit vicarious sensations, the nature of the touch remains consistent irrespective of the target's human or non-human attributes.

We investigated the locations of sensations participants reported upon observing touch applied either to or in close proximity to an object, given the ambiguity about where observers might mirror these sensations in their bodies. We hypothesised sensations might be mirrored in the observer's finger if the displayed touch was finger-applied (Ward et al., 2018). Moreover, participants might predominantly report sensations in the hands, possibly primed by the majority of videos showing hands being touched. Analysing the five videos featuring touch directed at or adjacent to the object, we assessed the total number of trials eliciting sensations and determined the percentage of responses corresponding to each indicated body part. Reported sensations (summing to >100% as participants could report multiple areas per trial) were: **right hand** (32%), **left hand** (26%), arm (14%), back (14%), neck (14%), face (13%), chest (11%), general (10%), **finger** (8%), stomach (8%), leg (6%), both hands (5%), all over

(3%), ear (2%), head (2%), and spine (2%). Notably, in the two videos where a finger applied the touch, reported sensations were: **right hand** (48%), **finger** (38%), **left hand** (28%), leg (15%), chest (8%), head (8%), stomach (8%), both hands (5%), and general (3%). These findings suggest that some vicarious touch sensations reported during these videos may indeed mirror observed finger-applied touch. In addition, with most sensations reported in the hands, there might be a priming effect from videos featuring touch to the hand or a general propensity among participants to mirror observed touches in their hands.

3.3. Vicarious touch in mirror-touch synaesthetes and non-synaesthetes

In this final section of our results, we turn to the potential distinction between vicarious touch and mirror-touch synaesthesia. In previous research, individuals were identified as mirror-touch synaesthetes if they experienced an exteroceptive sensation during at least 7 out of 14 trials when observing another human being touched (Li et al., 2022; Ward et al., 2018; Ward and Li, 2022). This classification was supported by supplementary validation measures, which showed that those meeting this criterion also displayed heightened emotional empathy and a better skill in interpreting facial expressions (Ward et al., 2018). When examining a wider variety of videos, including those depicting itch and pain, researchers observed that individuals with a higher number of vicarious touch endorsements often reported more localised and tactile sensations. In contrast, those with fewer reports typically described more non-localised feelings, such as a general itchiness or nausea (Li et al., 2022; Ward et al., 2018; Ward and Li, 2022). Here, we explore the reliability of such a criterion using our large dataset from a general population. To do so, we adopt a similar approach with minor adaptations. First, participants are designated as potential mirror-touch synaesthetes if they report exteroceptive sensations (touch, pressure, or scratching) in at least half the trials (20 out of the 40 videos) featuring touch to a hand. This approach is consistent with Ward et al.'s standard method, which also considers half the trials (7 out of 14 videos), but that research involved fewer human

touch-video trials for assessment overall. Additionally, we delve into the nature of sensations reported by the different 'groups' created by this criterion. We also examined the types of sensations reported when categorising participants into groups based on reporting *any sensation* in a minimum of 20 out of the 40 trials. Finally, we compare the emotional empathy scores between the groups.

3.3.1. Ward et al., 2018 criterion shows 6% mirror-touch synaesthesia prevalence in our sample

We counted the number of trials a participant reported feeling either any sensation, an exteroceptive sensation, or pain. We then plotted different cut-offs, ranging from 0 to 40 with 5 trial intervals (Fig.12). Note that we only present 10 painful touch videos, so under the criterion proposed by Ward et al., 2018, we could take 5/10 as a cut-off for potentially indicating mirror-pain synaesthesia.

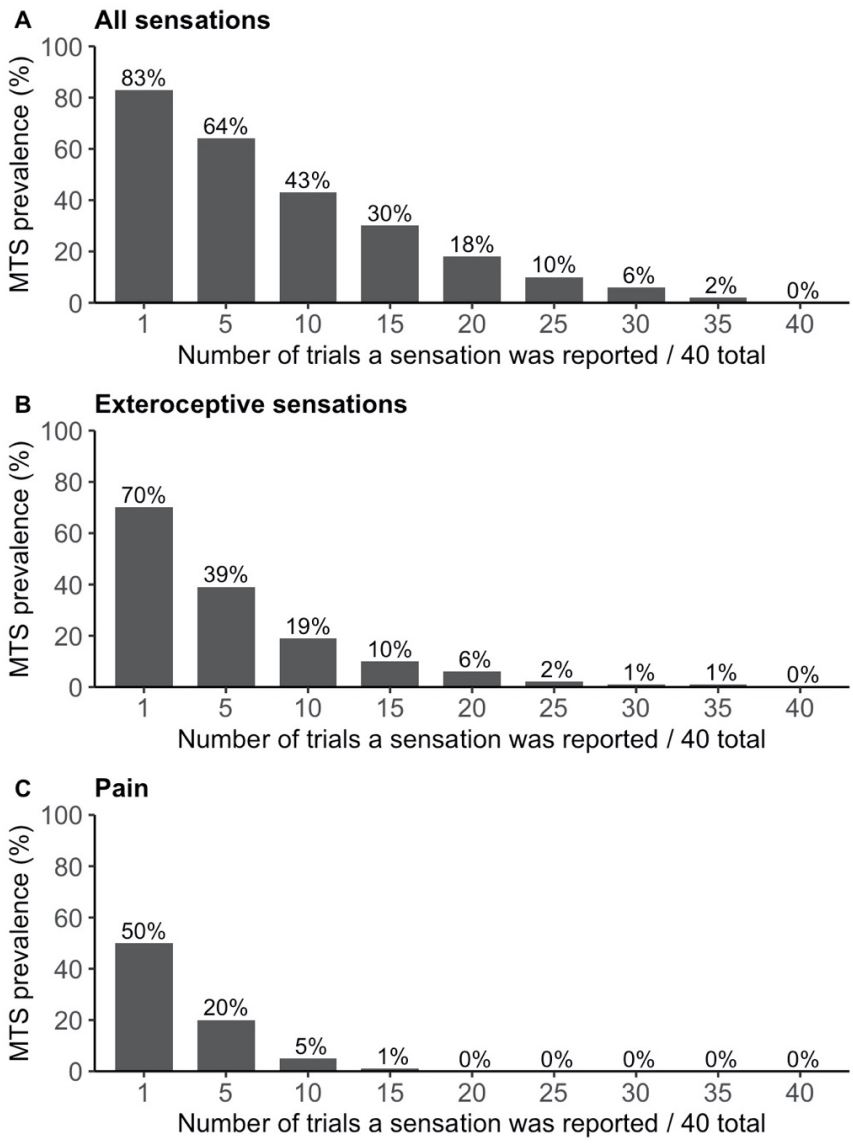

Figure 12. Prevalence of potential mirror-touch/pain synaesthesia in our sample. This figure illustrates the percentage of participants reporting various types of sensations across different cut-off options. (A) All sensations, (B) Exteroceptive sensations, and (C) Pain. These options range from experiencing a sensation in 0 to 40 trials, with 5 trial intervals.

We find that 18% of our sample report *any type of sensation* on at least half the trials and this is reduced to 6% when considering only *exteroceptive sensations*. We separately looked at reports of pain and we find that 20% of people endorse this on at least 5/10 painful videos. Of participants categorised as belonging to the mirror-touch synaesthesia group, 5% also met the threshold for potential mirror-pain synaesthesia. On average, participants in the mirror-

touch synaesthesia group localised around 96% of sensations to their hands while viewing the hand video, whereas for participants from the non-synaesthesia group, this was approximately 70% of the reported sensations.

Somewhat surprisingly given prior research (Holle et al., 2011; Ward et al., 2018), individuals in the mirror touch synaesthesia group were more likely to report vicarious sensations when witnessing touch to, or next to, the object than others. In this group, 63% indicated feeling a sensation during at least one such instance, compared to 28% in the non-synaesthete group. Additionally, the synaesthete group reported sensations for an average of 2.1 trials, with an average of 1.5 for the non-synaesthetes. This may indicate a propensity (or bias) to endorse touch videos in general in this group. However, note that we included only 5 videos showing this type of video, and results should be interpreted with some caution.

For the remaining analysis, participants reporting an exteroceptive sensation in at least 20/40 videos were classified as mirror-touch synaesthetes (N = 24), while the rest were grouped as non-synaesthetes (N = 398). It is important to mention that our classification did not account for other forms of synaesthesia in the non-synaesthete category; our distinction solely marks the absence of mirror-touch synaesthesia by our set criteria.

3.3.2. Higher vicarious touch intensity in mirror-touch synaesthetes compared to non-synaesthetes

We investigated the difference in intensity scores between the groups using a Wilcoxon rank-sum test for the comparisons. In all three examined categories, the mirror-touch synaesthete group consistently reported higher mean intensity for sensations than the non-synaesthete group. Specifically, for *all sensations*, the mean scores were 4.38 for 'synaesthetes' versus 2.81 for 'non-synaesthetes' ($p < 0.001$); for *exteroceptive sensations*, the mean scores were 4.30 for 'synaesthetes' versus 2.31 for 'non-synaesthetes' ($p < 0.001$); and for *pain sensations*, the mean scores were 5.64 for 'synaesthetes' compared to 2.02 for 'non-synaesthetes' (p <

0.001). This suggests that those individuals classified as mirror-touch synaesthetes, using our defined criterion, report more intense vicarious touch sensations compared to 'typical adults'.

3.3.3. More exteroceptive sensations in mirror-touch synaesthetes than non-synaesthetes

We then examined the distribution of reported sensations within the four hedonic categories across both groups (Fig. 13; left side). We assessed the relative proportions of all vicarious sensation types, which includes interoceptive sensations. Among those classified as mirror-touch synesthetes, 'touch' emerged as the most frequent sensation, followed by 'pressure' and 'pain'. In contrast, the non-synaesthete group predominantly described 'tingling', followed by 'pressure' and 'pain'.

In addition to using the number of exteroceptive sensations alone for classifying participants (as in Ward et al., 2018), we also categorised participants based on reporting *any sensation* in a minimum of 20 out of the 40 trials (Fig. 13; right side). Those who met this threshold were classified as 'strong responders' (N = 77), while the remaining participants were categorised as 'weak responders' (N = 345). Even without a specific criterion tied to a particular sensation type, strong responders predominantly described exteroceptive sensations, with 'pressure' being the most frequently reported, followed by 'touch' and 'pain'. In contrast, the weak responder group primarily reported 'tingling', followed by 'pressure' and 'ticklish'. Regardless of the criterion employed to divide the groups, across the four hedonic categories, 'touch' consistently emerged as a more predominant sensation among strong responders, who may be potential mirror-touch synesthetes, whereas 'tingling' was a more dominant report from weak responders.

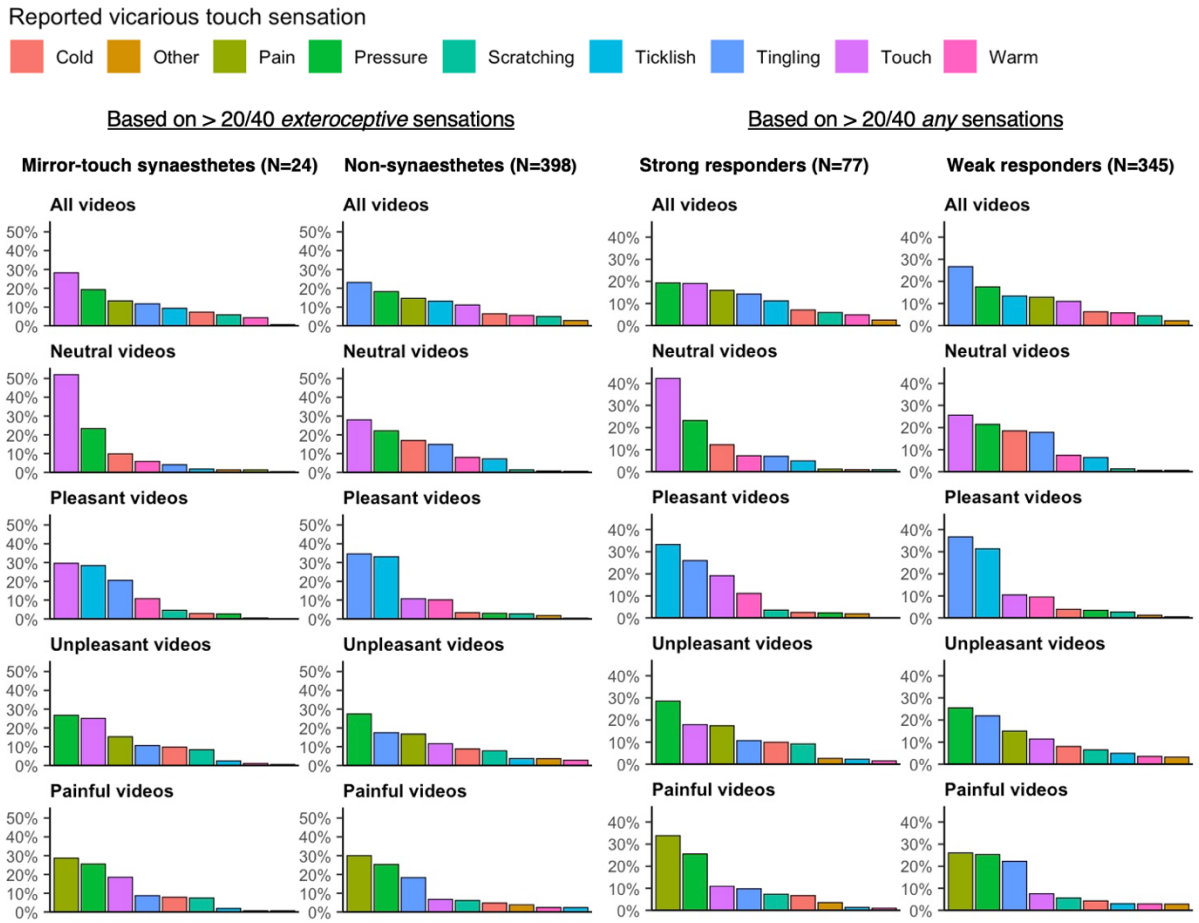

Figure 13: Distribution of reported sensations in 'mirror-touch synaesthetes'/strong responders and 'non-synaesthetes'/weak responders. On the left side, participants who reported an *exteroceptive* sensation in at least 20 of the 40 trials were categorised as mirror-touch synaesthetes. On the right side, participants who reported *any* sensation in at least 20 of the 40 trials were categorised as strong responders.

3.3.4. No difference in emotional empathy scores between mirror-touch synaesthetes and non-synaesthetes

Using the 20/40 exteroceptive criterion again (in line with Ward et al., 2018), we compared the emotional empathy scores between those classified as mirror-touch synaesthetes and non-synaesthetes (Fig. 14).

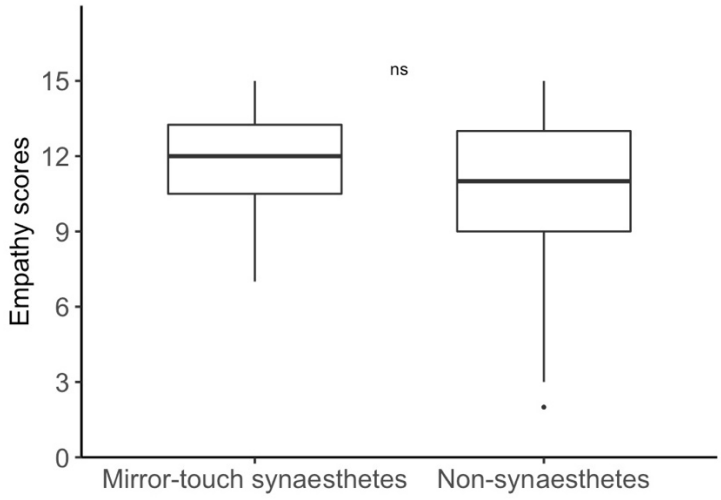

Figure 14. Empathy scores for 'mirror-touch' synaesthetes and 'non-synaesthetes'. Mirror-touch synaesthetes are defined based on reporting an exteroceptive sensations on at least 20/40 trials showing touch to a hand. Plots show the distribution of empathy scores for the two groups. The line within each box indicates the median, the box boundaries indicate the interquartile range (IQR), and the whiskers extend to 1.5 times the IQR. Dots indicate outliers. ns = non-significant.

A Wilcoxon rank-sum test comparing empathy scores between mirror-touch synaesthetes and non-synaesthetes yielded no significant difference ($p > 0.05$). The corresponding BF provided anecdotal evidence for the absence of a difference between the groups (BF = 0.498). Similarly, when comparing strong and weak vicarious touch responders, the BF suggested anecdotal to moderate evidence for the null hypothesis (BF = 0.336), indicating no difference between these groups.

4. Discussion

Previous studies suggest that a considerable proportion of the population reports experiencing vicarious touch and pain sensations when observing visual depictions of touch or pain (Giummarra et al., 2015; Grice-Jackson et al., 2017; Li et al., 2022; Osborn and Derbyshire, 2010; Smit et al., 2023; Vandenbroucke et al., 2013; Ward et al., 2018; Ward and Li, 2022).

While existing literature has provided valuable insights, it has often directed its focus towards a specific group known as 'mirror-touch synesthetes'. This small subset of individuals reportedly experiences vicarious sensations in a manner distinct from the broader population (Holle et al., 2011; Ioumpa et al., 2019; Li et al., 2022; Medina and DePasquale, 2017; Ward et al., 2018; Ward and Li, 2022). The aim of our exploratory study was to investigate the characteristics of reported vicarious sensations in a large sample of naïve undergraduate students. We used stimuli from our Validated Touch-Video Database (VTD; Smit & Rich, 2023), including a variety of touch types, hedonic qualities, arousal levels, and threat perceptions, all presented in a consistent and controlled manner. First, we examined general characteristics of vicarious sensations such as prevalence, localisation, and gender differences. Then, we assessed how various visual stimulus characteristics influenced participants' reported experiences. Lastly, we investigated the prevalence of mirror-touch synaesthesia in the sample, comparing experiences between individuals with varying vicarious touch tendencies. This overall approach allowed us to systematically explore the nuances of vicarious sensations.

4.1. Prevalence and localisation of vicarious touch

In evaluating the prevalence of reported vicarious touch sensations, our data reveal a substantial 83% of participants experienced sensations during at least one trial showing touch to a hand, with 74% of them describing exteroceptive sensations, such as touch, pressure, or scratching. Further, 53% of participants reported instances of 'pain'. The majority of reported sensations reported were hand-localised, aligning with the location of touch depicted in the videos. Our study observed a higher prevalence of reported vicarious touch compared to prior studies. Distribution score plots from earlier research indicated that only 25% of a Western undergraduate sample and 60% of a Chinese demographic reported exteroceptive sensations while viewing 14 touch videos (Li et al., 2022; Ward et al., 2018). We postulate that this

discrepancy in findings may be attributed to our study using a higher number of visual touch stimuli, including touches with varied hedonic qualities (beyond merely neutral), potentially inducing higher arousal. In addition, we demonstrate a higher prevalence of vicarious pain when observing *painful touch*, compared to observing explicit *pain* as reported in previous research (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Vandenbroucke et al., 2013; Ward et al., 2018; Ward and Li, 2022). Our results suggest that under controlled experimental conditions, the majority of individuals experience localised vicarious sensations while attentively watching videos portraying various forms of touch to a hand.

4.2. Vicarious pain

Past research indicates mirrored pain sensations can be localised and sensory or generalised and affective (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Vandenbroucke et al., 2013; Ward et al., 2018; Ward and Li, 2022). We posited that our painful touch videos would elicit both. However, most vicarious sensation endorsements were hand-localised (84% for painful videos), and this was consistent across all hedonic categories (VTD validated; Smit & Rich, 2023). Only 12% of painful video trials evoked reported sensations in 'another body part', primarily in upper body areas. While painful videos slightly increased reports of a general feeling compared to the other hedonic categories, these were still rare (11% of endorsed sensation trials; totals surpass 100% due to multiple locations reported per trial). This suggests that observed painful *touches* primarily induce localised sensory rather than generalised affective responses, which differs from observed pain without clear tactile interactions (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Vandenbroucke et al., 2013; Ward et al., 2018; Ward and Li, 2022).

4.3. Gender differences in vicarious touch and empathy

Women tended to report vicarious sensations—including all sensations, exteroceptive sensations, and pain—more frequently and in higher numbers than men, aligning with previous studies where women reported experiencing vicarious pain more often (Grice-Jackson et al., 2017; Ward and Li, 2022). This pattern also aligns with research noting stronger neural responses in women, compared to men, when they observe pain (Singer et al., 2006; Yang et al., 2009). However, this observation contrasts with other findings that showed no gender bias in reports of vicarious touch (Ward et al., 2018; Ward and Li, 2022). Notably, the BFs in our study suggest there is no difference in the intensity of these sensations between genders, particularly regarding exteroceptive sensations and pain. Further, we identified a modest but significant correlation between empathy scores and the frequency of reported vicarious sensations. Women also scored higher on emotional empathy, suggesting a potential modulating effect of empathy on vicarious touch experiences. This finding is consistent with some, but not all, prior research that has explored the connection between vicarious touch and emotional empathy (Banissy & Ward, 2007; Goller et al., 2013; Ward et al., 2018 but see Baron-Cohen et al., 2016). However, careful interpretation of these gender-related findings is necessary. Women generally self-report higher empathy levels than men do (Baez et al., 2017; Baron-Cohen and Wheelwright, 2004), a tendency that might be influenced by gender-role stereotypes (Baez et al., 2017; Eisenberg and Lennon, 1983; Löffler and Greitemeyer, 2023; Simner et al., 2006). This phenomenon could also be influencing the reports of vicarious touch, possibly skewing the data. Therefore, while our results do indicate a relationship between vicarious sensations, empathy, and gender, cautious interpretation is required due to the potential impact of inherent biases.

4.4. The influence of hedonic qualities, perceived arousal, and threat

Previous research findings also led us to anticipate a higher frequency of sensory responses to videos depicting painful or threatening touch (Giummarra et al., 2015; Grice-Jackson et al., 2017; Holle et al., 2011; Osborn and Derbyshire, 2010; Ward et al., 2018; Ward and Li, 2022). Participants did indeed frequently report vicarious sensations during painful and pleasant videos, less so during unpleasant ones, and least during neutral ones. The intensity of reported sensations followed a similar pattern: painful videos induced the most intense sensations, followed by unpleasant and pleasant ones, whereas neutral videos generated the least intensity when sensations were reported. Validation data from the VTD showed that painful and pleasant touch videos were perceived as highly arousing, with the former also being perceived as threatening (Smit and Rich, 2023), which we postulate may potentially explain these effects. We found strong correlations between arousal ratings of videos and both the frequency and intensity of vicarious sensations reported by participants. While threat ratings also correlated with these aspects, the associations were weaker. The increased arousal associated with certain visual touch stimuli could explain the common occurrence of reported vicarious pain while observing others experiencing pain (Giummarra et al., 2015; Grice-Jackson et al., 2017; Osborn and Derbyshire, 2010; Ward and Li, 2022), as well as the heightened reactions to being touched with a knife in contrast to a finger, ice cube, or feather (Holle et al., 2011; Ward et al., 2018). This emphasises the primary influence of arousal on the perception of vicarious touch and pain.

4.5. The valence of vicarious sensory experiences, including positive and negative touch

Participants primarily categorised their felt sensations as ‘neutral’, followed by ‘unpleasant’, ‘pleasant’, and ‘painful’, with no gender difference evident. While neutral videos typically induced neutral sensations, pleasant and unpleasant videos either generated neutral

sensations or those aligning with the video's valence. Painful touch videos, however, mostly resulted in sensations described as 'unpleasant' rather than 'painful'. The strength of the experienced valence was also most intense for painful experiences, followed by pleasant and unpleasant. Women reported a stronger valence for painful sensations. Validation data from the VTD (Smit and Rich, 2023) shows that women also rated the *painful videos* as more painful, potentially suggesting a general tendency to perceive observed and vicarious pain as more intense. The intensity of touch videos (based on validation data from the VTD; Smit & Rich, 2023) influenced participants' ratings, as there was a close alignment in valence-intensity between observed and vicarious sensations across hedonic categories. This suggests that observed and vicarious touches with similar hedonic tones also share similar valence intensities. Our results differ somewhat from Osborn and Derbyshire (2010), where participants assigned low intensity to vicarious pain (average 1.9, on a 0-10 scale: 'no pain' to 'most pain imaginable') in response to observing intense pain. Another study (Vandenbroucke et al., 2013), featuring less intense pain stimuli of hands being pricked, reported higher scores (average intensity 4.4, on a 0-10 scale: 'not intense' to 'intense', average unpleasantness of -1.6 on a -5 to +5 scale). The stimuli in the latter study are akin to ours but purposely convey low pain intensity. As such, current and previous findings imply that observing painful *touch* to hands prompts more likely and intense vicarious responses than witnessing pain alone, with overall findings reflecting a consistent mirroring across all hedonic qualities.

4.6. Observed touch type influences vicarious touch phenomenology, including tingling

Our findings displayed varied sensation distributions across the four hedonic video categories, corresponding with the observed touch quality. For example, neutral videos, typically featuring a singular, moderate-pressure touch (see Smit & Rich, 2023), mainly induced sensations of 'touch' and 'pressure', whereas pleasant videos, showing gentle strokes with soft objects or

hands, primarily elicited 'ticklish' and 'tingling' sensations. Thermal properties were also mirrored, with metal touch items evoking 'cold' sensations' and soft items, or another hand, resulting in 'warm' sensations. In line with previous studies (Banissy et al., 2009; Osborn and Derbyshire, 2010; Ward et al., 2018), we found that tingling was the most commonly reported sensation overall. Pleasant videos resulted in 'tingling' 1.7 times more often than painful videos, despite higher threat and arousal ratings for the latter. This suggests that reports of tingling likely reflect the actual 'feel' of the observed touch, in addition to any potential influence from cognitive processes such as attention, arousal, or focus on one's own corresponding body part (Tihanyi et al., 2018; Tihanyi and Köteles, 2017). Overall, these results highlight the influential role of observed touch types on the phenomenology of the vicarious touch experience.

4.7. Touch to objects

A lower proportion of participants reported experiencing sensations while watching the five videos depicting touch involving an object or its vicinity, as opposed to videos depicting touch to a hand. While it is conceivable that the sensations reported during these trials could be influenced by a response bias, the average reporting rate for such trials showing touch to an object or its vicinity was relatively low, at 12% and 7%, respectively. Therefore, it is likely that these minimal reporting rates have only a minor impact on the main results. Barring any response bias, our data indicate that while observations of human touch more readily elicit vicarious sensations, the nature of these sensations remains consistent, irrespective of the target being human or not. Whenever a finger applied touch to a hand, compared to an object, there were more reports of 'warm' sensations, hinting at mirrored heat transfer. Additionally, sensations were more often reported in the finger when observed touch to the object was finger-applied (see also Ward et al., 2018). In line with de Vignemont's (2017), we could distinguish between two aspects of touch: *touchant* (active toucher) and *touché* (passive

receiver). In some cases, vicarious touch may be evoked by seeing or inferring that another person is experiencing touch, whereas other times it may be induced by mirroring the tactile consequences of the touch itself (see also Keysers et al., 2010). The type of touch influenced response likelihood: a soft brush stroke on an object triggered sensations in thrice as many participants as a simple finger touch on an object, highlighting that touches deemed pleasant or arousing may induce stronger vicarious sensations, irrespective of the recipient being human or object. Consistent with prior research (Banissy and Ward, 2007; Baron-Cohen et al., 2016; Holle et al., 2011; Li et al., 2022; Ward et al., 2018), our findings affirm that observed touch to either humans or objects can prompt vicarious sensations and that this is more likely to occur in the former. In addition, we show that the nature of these sensations remains consistent regardless of whether the target is human or not.

4.8. Mirror-touch and mirror-pain synaesthesia

We investigated the prevalence of potential mirror-touch synaesthesia within our sample based on previously established criteria (Li et al., 2022; Ward et al., 2018; Ward and Li, 2022). Our data revealed that 18% of participants perceived some sensation in at least half of the trials. We observed a 6% prevalence for mirror-touch synaesthesia, considering only those reporting more than 20 exteroceptive sensations, a rate surpassing the often-cited ~2% (Banissy et al., 2009; Ward et al., 2018; but see Ward & Li, 2022 for similar results). The elevated prevalence in our study might stem from our diverse array of visual touch stimuli, including various hedonic qualities, potentially increasing vicarious touch responses due to heightened arousal. While our touch stimuli were likely less distressing than those in studies emphasising explicit pain (Giummarra et al., 2015; Grice-Jackson et al., 2017; Li et al., 2022; Osborn and Derbyshire, 2010; Ward et al., 2018; Ward and Li, 2022), 20% of our participants still reported a pain sensation in a minimum of 5 out of 10 painful video trials, hinting at a possibly elevated occurrence of mirror-pain synaesthesia, given the analogous threshold. Out

of participants classified as mirror-touch synesthetes, 5% also reached the criterion for potential mirror-pain synaesthesia, suggesting overlap in characterising these groups.

Strong responders and possible mirror-touch synaesthetes reported more intense sensations compared to the 'non-synaesthetes', and the former group reported mostly touch whereas for the later this was 'tingling'. These results corroborate previous findings (Li et al., 2022; Ward et al., 2018; Ward and Li, 2022), showing that individuals who endorse vicarious sensation on a large number of trials tend to report predominantly exteroceptive sensations compared to those with fewer reports who describe more interoceptive sensations

While Ward et al., (2018) advocate for viewing mirror-touch synaesthesia as a separate category, citing enhanced social cognitive abilities, a predominant use of body-specific (somatotopic) representations for mapping states between self and others, and stronger responses when observing touch to humans versus objects, alternative viewpoints suggest considering vicarious touch as a continuum (see for example Fitzgibbon et al., 2012; Rothen & Meier, 2013; Ward, 2019). Our findings indicate frequent vicarious sensory experiences in the general population, often with a clear somatotopic mapping between the observed and felt touch. Our empathy score comparison between the mirror-touch synaesthete and the non-synaesthete groups yielded anecdotal (i.e., inconclusive) evidence for no difference, potentially due to the low number of participants (N = 24) in the mirror-touch synaesthesia group. Interestingly, contrary to previous studies (Holle et al., 2011; Ward et al., 2018), our findings revealed that individuals from the mirror touch synaesthesia group were more likely to report vicarious sensations when observing touch to objects compared to the non-synaesthete group, and they endorsed a greater number of such trials. This may either indicate a response bias or a tendency to mirror the touch itself, as discussed above. In a previous study we used the neutral touch videos from the VTD to establish vicarious touch tendencies in our sample (Smit et al., 2023). Several participants had vicarious touch scores > 5/10; however, follow-ups revealed all of these participants were unaware of vicarious touch

experiences prior to participating, and in daily life, conflicting with 'canonical' synaesthesia characteristics (see also Vandenbroucke et al., 2013 for lower incidences of vicarious pain in daily life). This implies that for many of these 'high-scoring' individuals, vicarious touch may still be confined to experimental contexts. These results raise questions about how we can reliably differentiate mirror-touch synaesthesia from more 'typical' vicarious touch.

4.9. Limitations

In this study, we adopted a conservative approach in our analyses. While safeguarding against overestimation, our approach may underestimate true effects in the data. However, using BFs allows us to distinguish between true null effects and those stemming from insufficient power. Our study benefits from the use of validated touch videos that have been standardised for visual elements like hand appearance, hand placement, and perspective. Additionally, we included videos featuring an isolated hand to control for factors such as the person receiving the touch and their reactions. However, it is worth noting that the perceived connection to the person being touched might enhance vicarious sensations (Serino et al., 2009, 2008). In our study, some participants may have had a limited empathetic connection to the tactile experience due to the absence of a response from the person being touched. Nevertheless, we still obtained high rates of endorsements for vicarious sensations. As we are relying on self-report measures it is important to acknowledge the possibility of a response bias in our findings, where participants may provide answers they believe are expected of them. This raises the possibility that our reported rates of vicarious touch could be inflated. Although we did observe specificity in the ratings, for instance with higher endorsements for painful touch compared to unpleasant touch, making this less likely.

5. Conclusion

In conclusion, we found that under controlled experimental settings, the majority of individuals report localised vicarious sensations like touch or pain while observing videos of various forms of touch to a hand. Through a systematic examination of vicarious responses to previously validated touch videos that differed in aspects such as arousal, threat, types of touch and touching objects, we identified distinct patterns of sensations corresponding to different aspects of observed touch. By including touch videos with different hedonic qualities, including pleasant touch, we provide a comprehensive overview of vicarious touch effects. Using previously suggested criteria, our study explored the possibility of mirror-touch and mirror-pain synaesthesia within our participant sample, uncovering a higher prevalence than that commonly observed. Our results align with earlier studies, indicating that individuals with strong and weak vicarious touch tendencies tend to report different types of sensations. Further research is needed to determine whether mirror-touch synaesthesia exists as a categorical phenomenon distinct from common vicarious touch experiences or represents the extreme of a continuum. Overall, our exploratory study provides nuanced insights into the complex nature of reported vicarious sensations in a general population sample.

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