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Embodiment in the Enfacement Illusion is mediated by self-other overlap

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ABSTRACT

The enfacement illusion is a facial version of the rubber hand illusion, in which participants experience tactile stimulation of their own face synchronously with observation of the same stimulation applied to another's face. In previous studies, participants have reported experiencing illusory embodiment of the other's face following synchronous compared to asynchronous stimulation.

In a series of three studies, we addressed three questions: a) how does similarity between the self and the other, operationalised here as being of the same or different gender to the other, impact the experience of embodiment in the enfacement illusion; b) does the experience of embodiment result from alterations to the self-concept; and c) is susceptibility to the experience of embodiment associated with interoceptive processing, i.e., perception of the internal state of the body?

Results indicate that embodiment is facilitated by similarity between the self and the other and is mediated by the incorporation of the other into the self-concept; but sensitivity to one's own internal states does not impact upon embodiment within the enfacement illusion.

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1. Introduction

Understanding how an individual's self-representation is built and maintained, such that they have a clear and stable sense of self, is a fundamental challenge. This is, in part, because individuals change across their lifespan, which necessitates a balance between malleability and coherence across different components of the self (Crocetti et al., 2015; Xiang et al., 2023). The component parts, as well as their contributions, are still debated. While cognitive psychology addresses the 'bodily self', social psychology addresses the 'conceptual self'. Both are central to an individual's sense of self (Gallagher, 2000) but the interplay between the two on self-representation remains poorly understood.

The bodily self is examined in terms of body ownership. That is, the experience of the body as one's own. It is widely agreed that this perceptual experience of body ownership is borne from multisensory integration processes which are modulated by prior expectations about the body (Apps & Tsakiris, 2014) to generate a coherent bodily self-representation (Blanke, 2012; Longo et al., 2008; Tsakiris, 2010). The processes underlying this type of self-representation have been largely elucidated by examining the ways in which one's self-representation can be temporarily disrupted, such as with embodiment illusions.

The most commonly used embodiment illusion is the Rubber Hand Illusion (RHI; Botvinick & Cohen, 1998). A participant positions their arm and hand in front of themselves, which are obscured from view. A rubber hand is then placed on the same surface such that it is visible and positioned congruently with the body. Both the rubber hand and the biological hand are then stroked simultaneously by an experimenter so that the participant can see the tactile movement on the rubber hand only. The synchronicity and congruency between the multisensory cues is sufficient for participants to perceive the rubber hand as part of their bodily self. The presence of the illusion likely represents the brain's "goodness of fit"

estimation (Tsakiris et al., 2010; Dempsey-Jones and Kritikos, 2014), such that, if the multisensory signals are sufficiently congruent, one will feel a sense of ownership. In this way, the presence of the illusion indicates that, temporarily, one's self-representation is altered by the inclusion of the 'other' – in this case the rubber hand – into the self.

Such illusions are not only possible with limbs (Botvinick & Cohen, 1998; Tsakiris et al., 2010) but also with whole-bodies (Ehrsson, 2007; Petkova & Ehrsson, 2008) and faces (Sforza et al., 2010). In the 'Enfacement' illusion, a participant has their face stroked while watching another person's face being stroked either synchronously or asynchronously. Typically, the latter serves as a control condition because it seems not to induce the illusion (Porciello et al., 2018). The synchronous, interpersonal multisensory stimulation, however, is sufficient to blur the boundaries of self and other, such that participants experience illusory embodiment of the other's face (Sforza et al., 2010). As with the RHI, this embodiment effect is evident from explicit measures, such as questionnaire responses indicating a subjective feeling of ownership over the other's face, but also by implicit measures such as the attribution of the other's facial features to the self in self-recognition and self-other discrimination tasks (Bufalari et al., 2014). For instance, Tajadura-Jiménez et al. (2012) showed participants a series of images in which the participant's face was increasingly morphed with the other's face. After the synchronous stimulation, the point at which participants accepted that a morphed image depicted themselves was altered. Participants accepted an image of a morphed face as 'self' when it contained 5% more of the other's face. These changes to self-representation induced by interpersonal multisensory stimulation lead to a partial overlap between self and other (Tsakiris, 2008; Sforza et al., 2010).

The changes to bodily self-representation that are induced by the interpersonal multisensory stimulation also affect broader cognitive processes. Previous research has shown that

embodiment illusions influence affective ratings for others, as well as an individual's perception of the other as more attractive and trustworthy (Paladino et al., 2010; Tajadura-Jiménez et al., 2012) and more similar in personality (Mazzurega et al., 2011). Moreover, it has been shown that embodiment can alter implicit attitudes and beliefs towards the other, such that previously negative attitudes – such as racial prejudice – may be reduced (Maister et al., 2013, 2015; Banakou et al., 2016, 2020; Peck et al., 2013). Finally, it has been demonstrated that when adults embody the avatar of a child via virtual reality, they subsequently deem child-like attributes to be more relevant to themselves (Banakou et al., 2013). This suggests that embodiment illusions not only alter body perceptions of the self and other but also alter one's conceptual representation of self and other (Panagiotopoulou et al., 2022).

However, this more abstract 'conceptual self' has been difficult to reconcile with the literature on the bodily self, such that they are often researched as separate fields. In social psychology literature, the conceptual self is described as a multifaceted cognitive construct, comprising one's self-knowledge and self-beliefs, and encompassing everything that constitutes "me" or "mine" (Krol et al., 2019). This includes personality attributes, attitudes, beliefs, preferences, social roles and material possessions (Mittal, 2006; Belk, 1988). Similar to bodily self-representation, the conceptual self-representation must also be malleable given that what constitutes 'self' is likely to change over time. For instance, previous research suggests that people incorporate close others (e.g., romantic partners) into their sense of self (e.g., Aron et al., 1991).

Empirical studies have previous demonstrated the malleability of the conceptual self via the use of a socio-associative perceptual matching paradigm. Specifically, participants are asked to form new associations between three social identities – one of which is the self – and three stimuli. This, originally done with three geometric shapes (Sui et al. 2012), has

been replicated with a broad range of stimuli, including stimuli that would typically be represented by the bodily self, e.g. faces (S. Payne et al., 2017) and voices (B. Payne et al., 2020). For instance, participants are asked to associate one unfamiliar face with themselves, one with a friend, and one with a stranger. In a subsequent test phase, participants are presented with mixed pairings of a face and an identity label onscreen and are required to make speeded judgements of whether or not the two stimuli were correctly matched. The results typically show that the stimulus that has been associated with the self is responded to more quickly and accurately relative to the stimuli associated with the friend or other, an effect which has become known as the self-prioritisation effect. The attribution of a perceptual processing bias to the new stimulus – here, a face – is taken as evidence that the face has been incorporated into the conceptual self. Thereafter, the conceptual self "serves to bolster the stability of its components via enhanced stimulus processing" (Golubickis et al., 2020, pg. 34), and, accordingly, the newly self-associated face is perceptually prioritised.

However, although this result shows that the conceptual self has been expanded, this does not seem to translate to an expansion of the bodily self. S. Payne et al. (2017) additionally employed a face-morphing task equivalent to that used after the Enfacement Illusion, and assessed whether perceived similarity between one's own face and the newly self-associated face had increased, but found no significant effect. Thus, while theory suggests that these two notions of self – the bodily self and the conceptual self – are related (Gallagher, 2000), the relation between the two is not yet well established.

If the bodily self and the conceptual self are related, then one might expect that the malleability of one is related to the malleability of the other. This is supported by previous studies showing that the extent of the changes to the bodily self is predictive of the changes to the conceptual self – such that stronger embodiment induces greater changes to the

conceptual self (Farmer et al., 2012; Banakou et al., 2013; Maister et al., 2013). However, it is possible that this is not a unidirectional relationship and the boundaries of the conceptual self may influence the boundaries of the bodily self.

This is demonstrated, in part, by Pellencin et al. (2018) who found that the representation of an individual's peripersonal space (PPS) – the space immediately surrounding the body – is affected by social perceptions of others. That is, participants' PPS was relatively more extended when participants perceived the other to be moral, relative to immoral, and when the participant was more willing to interact with that other. This suggests that the conceptual representation of others in relation to oneself can also affect the representation of the bodily self, such that that the boundaries between what is 'self' and what is 'other' are malleable, dependent on social context. However, this has not yet been tested in the context of embodiment.

There has been further recent debate about the role of cognitive factors in the changes to bodily representation that are demonstrated in embodiment. Specifically, Lush et al. (2020) posited that the RHI may be entirely driven by top-down expectancies. The authors demonstrated that when hypnotizable participants controlled their phenomenology in line with expected effects of the task (i.e., they expected to experience stronger embodiment in either the synchronous or asynchronous condition or neither), their level of phenomenological control predicted the strength of the RHI. However, upon reanalysis of Lush et al.'s data, Slater and Ehrsson (2022) found significant differences between synchronous and asynchronous conditions remained, suggesting the continued influence of multisensory cues. Moreover, Ehrsson et al. (2023) found no significant relationships between hypnotic suggestibility and the RHI.

Notwithstanding this failure to demonstrate top-down effects on the malleability of the bodily self, if an individual's peripersonal space can be modulated by higher cognitive processes (Pellencin et al., 2018), it is plausible that the representation of the bodily self also can be. However, it remains unclear whether the extent to which participants alter their boundaries of the conceptual self, plays a role in determining the level of embodiment experienced.

The influence of distinctions between the self and other on embodiment illusions may be illustrated by studies exploring the relation between interoception – the perception of the internal state of the body – and embodiment. Importantly, the distinction between self and other is thought to be stabilised by interoception, such that individuals with greater interoceptive awareness have better self-other distinction (Palmer & Tsakiris, 2018). It is interesting then, that individuals with greater interoceptive sensitivity are also less susceptible to embodiment illusions (Tsakiris et al., 2011; Tajadura-Jiménez & Tsakiris, 2014, though see Crucianelli et al., 2018; Horvath et al., 2020; Ma et al., 2022). Together, this suggests that individuals with greater interoceptive ability may have a clearer self-other distinction (i.e., their conceptual self is less prone to disruption), may experience less disruption to their representation of the bodily self, and so experience relatively weaker embodiment illusions. However, in these studies, the measure of interoceptive ability has been almost exclusively indexed by the heartbeat counting task (Schandry, 1981). This is problematic, as several studies have now highlighted methodological concerns about this task (Murphy et al., 2018), including that it largely involves non-interoceptive processes (Desmedt et al., 2018), that heartbeat counting is unrelated to heartbeat detection (Ringer & Brener, 2018), and that the results suggest indistinguishable interoceptive capacities within those who score within the top 60% (Zamariola et al., 2018). Therefore, it is important to retest the relation between interoceptive ability and susceptibility to embodiment using validated questionnaires such as the Interoceptive Accuracy Scale (Murphy et al., 2020); the Interoception Sensory Questionnaire (Fiene et al., 2018); and the Interoceptive Confusion

Questionnaire (Brewer et al., 2016). These questionnaires allow us to obtain a trait-based measure of a participant's beliefs concerning their interoceptive accuracy, based on a wider range of interoceptive signals than solely cardiac (i.e., hunger, pain, thirst, temperature) and therefore provide a more nuanced indication of interoceptive capacities.

In summary then, previous literature suggests that interpersonal multisensory stimulation can temporarily disrupt the representation of the bodily self as evidenced by embodiment illusions and this, in turn, induces changes to the conceptual self, i.e., altering perceptions, attitudes, and beliefs towards oneself and others. However, it is possible that this is not a unidirectional influence but instead bidirectional, such that the malleability of the conceptual self gates the malleability of the bodily self. This possibility has not yet been tested in the context of embodiment. Here, therefore, we report on three studies assessing the interplay between the conceptual self and the bodily self and, specifically, whether the extent to which participants include the 'other' within the self plays a role in determining the level of embodiment experienced during the enfacement illusion.

Our examination is three-fold. First, we ask whether greater initial conceptual similarity between the self and the other, operationalised as being of the same gender, impacts the experience of the enfacement illusion. To our knowledge, only two studies of the illusion used other-gender faces and, while both studies demonstrated a successful enfacement illusion for female participants observing a male face (Quintard et al., 2020) and, separately, male participants observing a female face (Zhang et al., 2021), they did not analyse whether the illusion was strengthened by observing a more similar other (i.e., same gender face) relative to a dissimilar other (other gender face). If interpersonal multisensory stimulation-induced alterations to the boundaries of the conceptual self can influence changes in the representation of the bodily self – or vice versa – then changes to one should relate to changes in the other. As such, we predict that greater initial conceptual overlap between self

and other (on the basis of being of the same vs a different gender) should result in a stronger enfacement illusion. If this is the case, following experience of the illusion with a same-gender face compared to a differently-gendered face, participants should have *both* a stronger illusionary effect, and also stronger self-other overlap scores.

Second, we ask whether the extent of the changes to the conceptual self (as measured by self-other overlap) have a mediatory effect on the interpersonal multisensory stimulation-induced changes to the representation of the bodily self (as measured by the strength of the enfacement illusion). This would be in contrast to the typically reported relationship between the bodily self and conceptual self which assumes that the relationship is unidirectional, from bodily self to conceptual self but not vice-versa.

Finally, if having greater interoceptive ability is a protective factor against self-other overlap, it follows that the extent of one's interoceptive ability should correlate inversely with the strength of the enfacement illusion. This is assessed utilising more psychometrically sensitive measures of interoceptive ability than those used in previous studies.

Experiment 1 examines all three questions, whilst Experiments 2 and 3 serve as replications of the results.

2. General Methods

The following section outlines the methods for all three studies, which utilize the same set up for the enfacement illusion. Specifics to each experiment are outlined within.

2.1 Participants

All participants (n=328) were recruited from an undergraduate psychology course at King's College London. All participants voluntarily agreed to participate in partial completion of

course requirements after providing informed consent. Each participant only participated in a single experiment such that: 71 participants took part in Experiment 1 (64 female, 7 males, mean age 19.96, age range = 18 - 28); 92 in Experiment 2 (83 female, 8 male, 1 preferred not to say, mean age 19.79, age range = 18 - 25); and 167 in Experiment 3 (146 female, 20 male, 1 preferred not to say, mean age 19.85, age range = 18 - 36).

2.2. Stimuli

The stimuli set comprised 2 videos. Each depicted a real, unfamiliar, White/Caucasian target (1 cisgender female, 1 cisgender male) receiving tactile stimulation to the face. The videos were presented in colour and included the person's hair, ears, and upper torso.

2.3 Procedure

2.3.1 Inducing the Enfacement Illusion: Visuo-tactile stimulation

The basic experimental set up to induce the Enfacement Illusion (Tsakiris, 2008; Sforza et al., 2010) was followed. Here, all participants were presented with both targets (female target and male target) such that one target was the same gender as the participant, and one was a different gender to the participant. While watching the target receive tactile stimulation to the face, the experimenter applied tactile stimulation to the participant's face, either synchronously or asynchronously to the target in the video. Thus, each participant experienced four experimental conditions: synchronous stimulation with a same-gender face, asynchronous stimulation with a same-gender face, synchronous stimulation with a different-gender face, and asynchronous stimulation with a different-gender face. The order of these conditions was randomised and counterbalanced across participants. Further, participants took it in turns to be the experimenter, such that half of the sample experienced being an experimenter before becoming the participant and vice versa. To ensure the enfacement illusion is a persistent effect (i.e., the experience of it remains unaffected by awareness or knowledge of the effect) and not subject to order effects, additional analyses

were run and reported in the supplemental material, confirming no order effects were found. In the instances where the participants' gender was not recorded as part of the demographic information (i.e., they answered 'prefer not to say') the experimenter presented stimuli according to the participants' verbal preference. This accounts for only two datasets.

2.3.2 Measuring the Enfacement Illusion

We collected responses on two different measures after each experimental condition.

2.3.2.1. Enfacement Questionnaire

The first measure was the Enfacement Questionnaire, comprising seven items from the longer questionnaire used by Tajadura-Jiménez et al. (2012). These items (see Supplemental material) were scored on a scale of 1-7 where a higher value response indicates stronger agreement with the item. The responses were summed to give a total enfacement score, where a higher score indicates a stronger experience of the illusion. Typically, the Enfacement Illusion is determined to be present by significantly higher scores in the synchronous condition relative to the asynchronous condition, such that a relatively greater difference between the two conditions is indicative of a stronger illusion.

2.3.2.2. Inclusion of the Other in the Self

The second measure was the "Inclusion of the Other in the Self" (Aron et al., 1992) which is a single-item measure assessing the extent to which the representation of the other person overlaps with the representation of the self. Participants were presented with seven pairs of circles that progressively overlap, and were asked to select the pair (representing the degree of overlap) that best describes their relationship with the other. This measure was included to determine whether the illusion affects the representations of others as

being part of the self-concept. This, again, is scored from 1-7 where a higher value response indicates a greater overlap.

2.3.2.3 Assessing Interoceptive Ability

Finally, we measured individual differences in self-reported ability to identify one's internal states. In Study 1, this was measured using the Interoceptive Confusion Questionnaire (Brewer et al., 2016), which is scored out of 100, with high scores indicating poorer self-reported interoceptive ability. For Study 2, this was measured using the Interoception Sensory Questionnaire (Fiene et al., 2018), which is scored out of 140, with high scores indicating worse self-reported interoceptive ability. For Study 3, this was measured using the Interoceptive Accuracy Scale (Murphy et al., 2020), which is scored out of 105, with high scores indicating better self-reported interoceptive ability.

3. ANALYSIS

In each study, we ran four main analyses, detailed below. Additionally, we assessed whether order effects (i.e., whether a participant was the experimenter first or second) influenced any of the reported results, see supplementary material.

3.1 Assessing embodiment

To determine whether participants experienced the enfacement illusion – and whether the strength of the illusion varied as a function of initial similarity (i.e., gender match or mismatch) – we carried out a repeated measures ANOVA on the enfacement questionnaire responses in each experiment. In each, the two factors were: synchrony (synchronous, asynchronous) and gender (same, different). Here, we predicted a main effect of synchrony in the responses to the enfacement questionnaire, which would indicate the successful induction and experience of the enfacement illusion. Further, we predicted a main effect of gender, hypothesizing that participants would respond differently for a face of the same

versus that of a different gender. Finally, we predicted an interaction between synchrony and gender, hypothesizing that the illusion is affected by whether it is experienced with someone of the same or different gender.

3.2 Assessing self-other overlap

To determine whether participants experienced changes to the conceptual self, i.e., self-other overlap – and whether the extent of this overlap was modulated by initial similarity (i.e., gender match or mismatch) or the synchrony of the visuo-tactile stimulation, another two-way repeated measures ANOVA was conducted. The dependent variable was the Inclusion of Other in the Self (IOS) scores and, in each experiment, the factors were synchrony (asynchronous, synchronous) and gender (same, different). We predicted a main effect of synchrony, suggesting that self-other overlap is induced by shared synchronous stimulation. Further, we predicted a main effect of gender, such that increased similarity (i.e., same-gender face relative to different-gender face) should result in greater overlap. Lastly, we predicted an interaction, hypothesizing that self-other overlap and the degree to which the other is represented as part of the self-concept would be greater in the synchronous condition – when the enfacement illusion is present – relative to when the illusion is not present (i.e., in the asynchronous condition).

3.3 Assessing whether embodiment is mediated by self-other overlap

To assess whether interpersonal multisensory stimulation directly induced the changes to the representation of the bodily self (as measured by the enfacement effect) or, rather, whether these changes are mediated by the degree of self-other overlap, we ran Bayesian within-subjects mediation analyses with the “bmlm” package (Vuorre and Bolger, 2018) in the R environment (R Core Team, 2016). For each mediation model, we ran four Markov Chain Monte Carlo (MCMC) chains with 10,000 iterations to ensure convergence and stable estimates. Synchrony was treated as a binary variable (coded 1 (sync), 0 (async)).

3.4. Analysis of Interoceptive Ability

We conducted a correlation analysis to determine whether the strength of the enfacement illusion was related to interoceptive ability. Here we focused on the same-gender faces, allowing that the possible relation between interception and enfacement is comparable to previous studies. Specifically, the strength of the illusion was derived from the size of the difference between synchronous and asynchronous conditions for the total enfacement score. We therefore calculated a difference score corresponding to synchronous minus asynchronous conditions. A higher difference score thus indicated a stronger experience of the illusion. This score was then correlated with the interoceptive questionnaire in which a higher score indicates worse self-reported interoceptive ability (Studies 1 and 2). Thus, a negative correlation would indicate that those with better interoceptive ability show a greater illusion. In Study 3, high scores indicate better self-reported interoceptive ability, thus a positive correlation would indicate that those with better interoceptive ability show a greater illusion.

4. RESULTS

The results of Experiment 1 are reported in detail, while for Experiments 2 and 3, we provide more concise summaries as the results replicate across all experiments. Mean scores from the Enfacement Illusion Questionnaire for Experiments 1, 2, and 3 are included in Table 1 and plotted in Figure 1A-C. Mean scores from the Inclusion of Other in Self Scale are included in Table 2. The relationship between synchrony, self-other overlap, and enfacement is depicted via mediation paths in Figure 2 and full mediation outputs showing the population-level parameters are included in the Supplemental Material.

[Insert Tables 1 & 2 – see end of file]

4.1 Experiment 1

4.1.1 Embodiment in the Enfacement Illusion

The two-way repeated measures ANOVA revealed a significant interaction between Synchrony and Gender ($F(1, 70) = 15.670$, $p < .001$, $\eta^2 = .012$), as well as significant main effects of both Synchrony ($F(1, 70) = 66.489$, $p < .001$, $\eta^2 = .116$) and Gender ($F(1, 70) = 35.819$, $p < .001$, $\eta^2 = .072$) on participants' responses to the enfacement illusion questions. Participants reported significantly stronger embodiment in the synchronous compared to the asynchronous condition, confirming the presence of the enfacement illusion. However, participants also experienced a stronger illusion when the target face was the same gender as their own face (simple effect of synchrony ($t(70) = 8.74$, $p < .001$, $dz = .65$)) relative to when the face was of a different gender (simple effect of synchrony ($t(70) = 4.97$, $p < .001$, $dz = .49$)). These results demonstrate that synchronous visuo-tactile stimulation gives rise to an embodiment effect and this effect is stronger when the target has the same gender as the participant compared to when the target has a different gender. These findings provide support for the hypothesis that greater initial similarity between the self and the other influences the embodiment experience.

[Insert Figures 1A-C – see end of file]

4.1.2 Self-other overlap

Similarly, the two-way repeated measures ANOVA revealed a significant interaction between Synchrony and Gender ($F(1, 70) = 21.217$, $p < .001$, $\eta^2 = .016$), as well as significant main effects of Synchrony ($F(1, 70) = 74.730$, $p < .001$, $\eta^2 = .177$), and Gender ($F(1, 70) = 41.565$, $p < .001$, $\eta^2 = .081$), on the degree of self-other overlap, as measured by the IOS scale. Self-other overlap was higher after synchronous stimulation and, moreover, when participants also observed a target face that was the same gender as their own face (simple effect of synchrony ($t(70) = 9.11$, $p < .001$, $dz = .62$)) relative to when the

face was of a different gender (simple effect of synchrony ($t(70) = 6.02$, $p < .001$, $dz = .70$)). This indicates that participants experience greater self-other overlap when the target in the enfacement illusion shares the same gender as themselves.

4.1.3 Mediation by self-other overlap

To investigate the mediation effect of Inclusion of Other in Self (IOS) scores on the relationship between synchrony and enfacement illusion scores, we conducted a Bayesian within-subjects multilevel mediation analysis.

The total effect of synchrony on enfacement illusion scores (c) is estimated to be 5.64, with a 95% credible interval ranging from 4.28 to 7.09. This suggests that, on average, participants rated enfacement illusion scores 5.64 points higher when experiencing synchronous stimulation compared to asynchronous stimulation. The mediation effect (me) is estimated to be 3.78, with a 95% credible interval ranging from 2.14 to 5.73. This indicates a strong mediation effect, as the magnitude of the mediation effect is only slightly lower than the total effect. After considering the Inclusion of Other in Self scores, the direct effect of synchrony on enfacement illusion scores (cp) is approximately 1.86, with a credibility interval of [0.28, 3.42]. This suggests that the relationship between synchrony and enfacement illusion scores is partially mediated by IOS scores. The proportion of the effect that is mediated (pme) is estimated to be 0.67, with a 95% credible interval ranging from 0.41 to 0.95. This indicates that approximately 67% of the effect of synchrony on enfacement illusion scores is mediated by IOS scores. This supports the hypothesis that changes to the boundaries of the conceptual self mediate the extent of the disruption to the representation of the bodily self.

[Insert Figure 2 – see end of file]

4.1.4 Interoceptive Ability: Interoceptive Confusion Questionnaire (Brewer et al., 2016)

The correlation analysis revealed a null effect ($r(69) = .108$, $p = .368$), indicating that, at least when considering this particular questionnaire, self-reported interoceptive ability does not influence the magnitude of the enfacement illusion.

4.2 Study 2

4.2.1 Embodiment in the Enfacement Illusion

The two-way repeated measures ANOVA revealed a significant interaction between Synchrony and Gender ($F(1, 91) = 17.176$, $p < .001$, $\eta^2 = .009$), as well as significant main effects of both Synchrony ($F(1, 91) = 58.616$, $p < .001$, $\eta^2 = .080$) and Gender ($F(1, 91) = 45.011$, $p < .001$, $\eta^2 = .061$) on embodiment. Participants again reported significantly stronger embodiment in the synchronous compared to the asynchronous condition, and also when the target face was the same gender as their own face (simple effect of synchrony ($t(91) = 7.71$, $p <.001$, $dz = .22$)) relative to when the face was of a different gender (simple effect of synchrony ($t(91) = 5.19$, $p <.001$, $dz = .11$)).

4.2.2. Self-other overlap

The two-way repeated measures ANOVA revealed a significant interaction between Synchrony and Gender ($F(1, 91) = 9.494$, $p = .003$, $\eta^2 = .009$), as well as significant main effects of Synchrony ($F(1, 91) = 66.420$, $p < .001$, $\eta^2 = .132$) and Gender ($F(1, 91) = 32.825$, $p < .001$, $\eta^2 = .062$), on the degree of self-other overlap. Replicating from Study 1, self-other overlap was greater after synchronous stimulation and also when the self and other were of the same gender (simple effect of synchrony ($t(91) = 7.44$, $p <.001$, $dz = .36$)) relative to different gender (simple effect of synchrony ($t(91) = 6.15$, $p <.001$, $dz = .37$)).

4.1.3 Mediation by self-other overlap

The relationship between synchrony and enfacement illusion scores was partially mediated by IOS scores. The proportion of the effect that was mediated (pme) was estimated to be 0.76, with a 95% credible interval ranging from 0.54 to 0.98, indicating that approximately 76% of the effect of synchrony on enfacement illusion scores is mediated by IOS scores.

4.2.4. Interoceptive Ability: Interoception Sensory Questionnaire (Fiene et al., 2018)

ISQ scores for one participant were not recorded. The correlation between ISQ scores and the enfacement illusion for the remaining 91 participants revealed a null effect, $r(89) = 0.045$, $p = 0.669$.

4.3 Study 3

4.3.1 Embodiment in the Enfacement Illusion

The two-way repeated measures ANOVA revealed a significant interaction between Synchrony and Gender ($F(1, 166) = 11.032$, $p < .001$, $\eta^2 = .003$) as well as significant main effects of both Synchrony ($F(1, 166) = 90.874$, $p < .001$, $\eta^2 = .069$) and Gender ($F(1, 166) = 53.809$, $p < .001$, $\eta^2 = .057$) on participants' responses to the enfacement illusion questions. As before, participants reported significantly stronger embodiment in the synchronous compared to the asynchronous condition, confirming the presence of the enfacement illusion. Additionally, there was stronger embodiment when the target face was the same gender as their own face (simple effect of synchrony ($t(166) = 10.13$, $p <.001$, $dz = .28$)) relative to when the face was of a different gender (simple effect of synchrony ($t(166) = 6.54$, $p <.001$, $dz = .12$)).

4.3.2. Self-other overlap

The two-way repeated measures ANOVA revealed a significant interaction between Synchrony and Gender ($F(1, 166) = 20.839$, $p < .001$, $\eta^2 = .008$), as well as significant main effects of Synchrony ($F(1, 166) = 99.017$, $p < .001$, $\eta^2 = .079$) and Gender ($F(1, 166) =$

31.902, $p < 0.001$, $\eta^2 = 0.035$). Replicating from Studies 1 and 2, self-other overlap was greater after synchronous stimulation and also when the self and other were of the same gender (simple effect of synchrony ($t(166) = 10.14$, $p < .001$, $dz = .41$)) relative to different gender (simple effect of synchrony ($t(166) = 6.28$, $p < .001$, $dz = .10$)).

4.3.3. Mediation by self-other overlap

The relationship between synchrony and enfacement illusion scores was again partially mediated by IOS scores. The proportion of the effect that was mediated (pme) was estimated to be 0.72, with a 95% credible interval ranging from 0.55 to 0.98. This indicates that approximately 72% of the effect of synchrony on enfacement illusion scores was mediated by IOS scores.

4.3.4. Interoceptive Ability: Interoceptive Accuracy Scale (Murphy et al., 2020)

Finally, we assessed whether self-reported differences in interoceptive ability were correlated with the experience of the illusion. Again, this correlation was non-significant, $r(165) = -.009$, $p = .904$, suggesting that the size of the enfacement illusion is not affected by self-reported interoceptive ability.

5. DISCUSSION

This study aimed to further our understanding of the relationship between the conceptual self and the bodily self by investigating the interplay between the two during the enfacement illusion. Specifically, we first asked whether greater initial similarity between the conceptual self and another other, here operationalised as being of the same gender, affects embodiment. Second, we asked whether the extent of the change to the conceptual self (i.e., the degree of self-other overlap) mediates the degree to which interpersonal multisensory stimulation can disrupt the representation of the bodily self. Finally, we asked whether susceptibility to the effect is associated with interoceptive processing, as

measured by self-report scales of interoceptive ability. Overall, the results indicated that embodiment is facilitated by similarity between the self and the other and is mediated by the incorporation of the other into the self-concept. However, perception of one's own internal states (interoception) did not impact upon embodiment. All these results replicated across studies 1-3. By addressing these objectives, this study demonstrates and quantifies the strong modulation by the cognitive construct of 'self' of the representation of the bodily self.

First, we showed that initial conceptual similarity between the self and the other does affect embodiment in the enfacement illusion. Specifically, participants experienced a significantly stronger embodiment effect when the target was the same gender as them, compared to when they were a different gender. While previous studies have demonstrated successful embodiment of individuals of a different gender in the enfacement effect, this is the first to show that the strength of the effect is increased when the other is of the same gender as the self.

Importantly, it is unlikely that greater perceived *physical* similarity between the self and the other is the driving factor here. In our study, the extent of differences in facial feature between participants and the targets they saw will have varied for each pair but there was a consistent effect of a same-gender face. Previous research suggests that physical similarity between self and other has little effect on the strength of the embodiment illusion. For instance, racial dissimilarity between the fake and biological hand does not preclude the RHI (Farmer et al., 2012), such that participants still experienced embodiment over hands of a different skin colour to their own. As such, while temporal, spatial, and anatomical congruency between the fake hand and the biological hand are essential, physical similarity is not (Tsakiris & Haggard, 2005; Tsakiris et al., 2010; Lloyd, 2007; Costantini & Haggard, 2007). Thus, it is more plausible that greater initial *conceptual*

similarity, specifically sharing the same gender identity or belonging to the same gender-based in-group, underlies the increased embodiment.

This is supported by our second finding, which indicates that participants felt significantly greater self-other overlap after synchronous visuo-tactile stimulation when the target was of the same gender. We measured self-other overlap via the Inclusion of Other in Self scale (Aron et al., 1992), a measure which correlates highly with perceived social closeness (Aron et al., 1992). Here, a more similar other – someone of the same gender – was incorporated into the self to a greater extent than a less similar other. This may be because a more similar other is more congruent with what already defines 'self' such that the conceptual self can be more easily extended to encompass the other without conflict.

Our third finding then reveals, for the first time, the strong mediating role of self-other overlap in the relationship between synchronous multisensory stimulation and embodiment. Specifically, we show that the extent to which participants alter their boundaries of the conceptual self plays a crucial role in determining the level of embodiment experienced; the greater the self-other overlap, the stronger the embodiment. This indicates that the temporary disruption to the representation of the bodily self, as indexed by the strength of the embodiment illusion, is not solely determined by the synchrony of the stimulation itself. Instead, the extent of its effect on the bodily self is mediated by higher-order cognitive processes underlying the overlap between the conceptual self and an other. This is striking because temporal synchrony has traditionally been considered the most critical factor in embodiment research. Although the current finding supports the notion that higher-order cognition could assert a stronger influence on multisensory integration processes than previously thought, it does not support the notion that top-down processes are fully responsible for the effect. Rather, in the current studies, we verify that interpersonal multisensory stimulation induces the enfacement effect;

however, for the first time, we demonstrate that the extent of its effect on the bodily self is extensively mediated by its impact on the conceptual self.

Finally, we assessed whether susceptibility to the embodiment effect is associated with interoceptive processing, as measured by self-report scales of interoceptive ability. Specifically, we explored whether people with higher interoceptive abilities – and thus better self-other distinction – would be less susceptible to manipulations blurring the boundary of self and other. Here we measured interoceptive ability using three different validated scales across the three experiments. However, we found no evidence of an association between participants' interoceptive ability and the degree to which they experienced the embodiment of another. This contrasts with studies by Tsakiris et al. (2011) and Tajadura-Jimeñez and Tsakiris (2014) but adds to the literature which has been unable to detect a relationship between interoception and embodiment illusions (Crucianelli et al., 2018; Horvath et al., 2020; Ma et al., 2022). To our knowledge, this remains the only investigation of embodiment to use a measure of interoception that is not reliant on cardiac signals, so further assessment is needed to validate these results.

Overall, this study provides empirical evidence that initial similarity between the self and other facilitates the incorporation of that other into the self. Importantly, we show for the first time that the effect of interpersonal synchronous stimulation on the enfacement illusion is mediated by the degree of conceptual self-other overlap, with greater overlap determining greater enfacement. Notably, this suggests that that the extent of the effect of interpersonal synchronous stimulation is gated by conceptual processing, shedding new light on the interplay between the conceptual self and the bodily self. Our findings also indicate that interoceptive ability does not significantly impact the extent to which another person can be embodied when measured by self-report beliefs concerning participants' general interoceptive ability. This contrasts with previous studies that have exclusively

used the detection of cardiac signals to index interoception. By continuing to investigate the interactions between representation of the bodily self, the conceptual self, and how they are each affected by multisensory integration as seen in embodiment illusions, valuable insights can be gained into the processes underlying the construction and maintenance of the sense of self.

References

Apps MA, Tsakiris M (2014). The free-energy self: a predictive coding account of self-recognition. Neurosci Biobehav Rev. doi: 10.1016/j.neubiorev.2013.01.029. Epub 2013 Feb 15. PMID: 23416066; PMCID: PMC3848896.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology, 63*(4): 596-612

Banakou, D., Groten, R., & Slater, M. (2013). Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proceedings of the National Academy of Sciences*, *110*(31), 12846–12851. https://doi.org/10.1073/pnas.1306779110

Banakou, D., Hanumanthu, P. D., & Slater, M. (2016). Virtual embodiment of white people in a black virtual body leads to a sustained reduction in their implicit racial bias. *Frontiers in Human Neuroscience*, *10*. https://doi.org/10.3389/fnhum.2016.00601

Banakou, D., Beacco, A., Neyret, S., Blasco-Oliver, M., Seinfeld, S., & Slater, M. (2020). Virtual body ownership and its consequences for implicit racial bias are dependent on social context. *Royal Society Open Science*, *7*(12), 201848. https://doi.org/10.1098/rsos.201848

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using Eigen and S4. *Journal of Statistical Software*, **67**, 1– 23. https://doi.org/10.18637/jss.v067.i01

Belk, R. (1988). Possessions and the Extended Self. *Journal Of Consumer Research*, *15*(2), 139. doi: 10.1086/209154

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. *Nat Rev Neurosci* 13, 556–571https://doi.org/10.1038/nrn3292

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature*, *391*(6669), 756-756. doi: 10.1038/35784

Brewer, R., Cook, R., & Bird, G. (2016). Alexithymia: a general deficit of interoception. *Royal Society Open Science, 3*(10):150664.

Bufalari, I., Lenggenhager, B., Porciello, G., Serra Holmes, B., & Aglioti, S. M. (2014). Enfacing others but only if they are nice to you. *Frontiers in Behavioral Neuroscience*, *8*. https://doi.org/10.3389/fnbeh.2014.00102

Costantini, M., & Haggard, P. (2007). The rubber hand illusion: Sensitivity and reference frame for body ownership. *Consciousness and Cognition*, *16*(2), 229–240. https://doi.org/10.1016/j.concog.2007.01.001

Crocetti, E., Rubini, M., Branje, S., Koot, H. M., & Meeus, W. (2015). Self-concept clarity in adolescents and parents: A six-wave longitudinal and multi-informant study on development and intergenerational transmission. *Journal of Personality*, *84*(5), 580–593. https://doi.org/10.1111/jopy.12181

Crucianelli, L., Krahé, C., Jenkinson, P. M., & Fotopoulou, A. (Katerina). (2018). Interoceptive ingredients of body ownership: Affective touch and cardiac awareness in the rubber hand illusion. *Cortex*, *104*, 180–192. https://doi.org/10.1016/j.cortex.2017.04.018

Desmedt, O., Luminet, O., & Corneille, O. (2018). The heartbeat counting task largely involves non-interoceptive processes: Evidence from both the original and an adapted counting task. *Biological Psychology*, *138*, 185188.https://doi.org/10.1016/j.biopsycho.2018.09.004

Ehrsson, H. Henrik. (2007). The experimental induction of out-of-body experiences. *Science*, *317*(5841), 1048–1048. https://doi.org/10.1126/science.1142175

Ehrsson, H. H. (2020). Multisensory processes in body ownership. *Multisensory Perception*, 179–200. https://doi.org/10.1016/b978-0-12-812492-5.00008-5

Ehrsson, H. H., Fotopoulou, A., Radziun, D., Longo, M. R., & Tsakiris, M. (2023). No specific relationship between hypnotic suggestibility and the rubber hand illusion. *Nature Communications*, *13*(1). https://doi.org/10.1038/s41467-022-28177-z

Farmer, H., Tajadura-Jiménez, A., & Tsakiris, M. (2012). Beyond the colour of my skin: How skin colour affects the sense of body-ownership. *Consciousness and Cognition*, *21*(3), 1242–1256. https://doi.org/10.1016/j.concog.2012.04.011

Fiene, L., Ireland, M. J., & Brownlow, C. (2018). The Interoception Sensory Questionnaire (ISQ): A Scale to Measure Interoceptive Challenges in Adults. *Journal of Autism and Developmental Disorders*, *48*: 3354–66.

Filippetti, M. L., & Tsakiris, M. (2017). Heartfelt embodiment: Changes in body-ownership and self-identification produce distinct changes in interoceptive accuracy. *Cognition*, *159*, 1–10. https://doi.org/10.1016/j.cognition.2016.11.002

Gallagher, S. (2000). Philosophical conceptions of the self: implications for cognitive science. *Trends In Cognitive Sciences*, *4*(1), 14-21. doi: 10.1016/s1364-6613(99)01417-5

Golubickis, M., Falbén, J., Ho, N., Sui, J., Cunningham, W., & Neil Macrae, C. (2020). Parts of me: Identity-relevance moderates self-prioritization. *Consciousness And Cognition*, *77*, 102848. doi: 10.1016/j.concog.2019.102848

Horváth, Á., Ferentzi, E., Bogdány, T., Szolcsányi, T., Witthöft, M., & Köteles, F. (2020). Proprioception but not cardiac interoception is related to the rubber hand illusion. *Cortex*, *132*, 361–373. https://doi.org/10.1016/j.cortex.2020.08.026

Krol, S. A., Thériault, R., Olson, J. A., Raz, A., & Bartz, J. A. (2020). Self-Concept Clarity and the Bodily Self: Malleability Across Modalities. *Personality and Social Psychology Bulletin*, *46*(5), 808-820.

Lloyd, D. M. (2007). Spatial limits on referred touch to an alien limb may reflect boundaries of visuo-tactile peripersonal space surrounding the hand. *Brain and Cognition*, *64*(1), 104–109. https://doi.org/10.1016/j.bandc.2006.09.013

Longo, M. R., Schüür, F., Kammers, M. P., Tsakiris, M., and Haggard, P. (2008). What is embodiment? A psychometric approach. *Cognition* 107, 978–998. doi: 10. 1016/j.cognition.2007.12.004

Lush, P., Botan, V., Scott, R. B., Seth, A. K., Ward, J., & Dienes, Z. (2020). Trait phenomenological control predicts experience of mirror synaesthesia and the Rubber Hand Illusion. *Nature Communications*, *11*(1). https://doi.org/10.1038/s41467-020-18591-6

Ma, K., Yang, L., & Hommel, B. (2022). The impact of interoceptive accuracy and stimulation type on the out-of-body experience. *Quarterly Journal of Experimental Psychology*, *76*(8), 1940–1952. https://doi.org/10.1177/17470218221128285

Maister, L., Sebanz, N., Knoblich, G., & Tsakiris, M. (2013). Experiencing ownership over a dark-skinned body reduces implicit racial bias. Cognition, 128(2), 170–178. http://doi.org/10.1016/j.cognition.2013.04.002

Maister, L., Slater, M., Sanchez-Vives, M. V., & Tsakiris, M. (2015). Changing bodies changes minds: owning another body affects social cognition. Trends in Cognitive Sciences, 19(1), 6–12. http://doi.org/10.1016/j.tics.2014.11.001

Mazzurega, M., Pavani, F., Paladino, M. P., & Schubert, T. W. (2011). Self-other bodily merging in the context of synchronous but arbitrary-related multisensory inputs. Experimental Brain Research, 213, 213e221. https://doi.org/ 10.1007/s00221-011-2744-6.

Mittal, B. (2006). I, me, and mine—how products become consumers' extended selves. *Journal Of Consumer Behaviour*, *5*(6), 550-562. doi: 10.1002/cb.202

Murphy, J., Brewer, R., Hobson, H., Catmur, C., & Bird, G. (2018). Is alexithymia characterised by impaired interoception? Further evidence, the importance of control variables, and the problems with the heartbeat counting task. *Biological Psychology*, *136*, 189–197. https://doi.org/10.1016/j.biopsycho.2018.05.010

Murphy, J., Brewer, R., Plans, D., Khalsa, S. S., Catmur, C., & Bird, G. (2020). *Testing the Independence of Self-Reported Interoceptive Accuracy and Attention*. https://doi.org/10.31234/osf.io/fqgu4

Monti, A., Porciello, G., Panasiti, M. S., & Aglioti, S. M. (2021). The inside of me: Interoceptive constraints on the concept of self in neuroscience and clinical psychology. *Psychological Research*, *86*(8), 2468–2477. https://doi.org/10.1007/s00426-021-01477-7

Paladino, M., Mazzurega, M., Pavani, F., & Schubert, T. (2010). Synchronous Multisensory Stimulation Blurs Self-Other Boundaries. *Psychological Science*, *21*(9), 1202-1207. doi: 10.1177/0956797610379234

Palmer, C. E., & Tsakiris, M. (2018). Going at the heart of Social Cognition: Is there a role for interoception in self-other distinction? *Current Opinion in Psychology*, *24*, 21–26. https://doi.org/10.1016/j.copsyc.2018.04.008

Panagiotopoulou, E., Crucianelli, L., Lemma, A., & Fotopoulou, A. (2022). Identifying with the beautiful: Facial attractiveness effects on unisensory and multisensory self–other distinction. *Quarterly Journal of Experimental Psychology*, *75*(7), 1314-1329. https://doi.org/10.1177/17470218211050318

Payne, S., Tsakiris, M., & Maister, L. (2016). Can the self become another? Investigating the effects of self-association with a new facial identity. The Quarterly Journal of Experimental Psychology, 218(February), 1e29. https://doi.org/10.1080/17470218.2015.1137329.

Payne, B., Lavan, N., Knight, S., & McGettigan, C. (2020). Perceptual prioritization of self-associated voices. *British Journal Of Psychology*, *112*(3), 585-610. doi: 10.1111/bjop.12479

Peck, T. C., Seinfeld, S., Aglioti, S. M., & Slater, M. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition*, *22*(3), 779–787. https://doi.org/10.1016/j.concog.2013.04.016

Peng, Z., Wang, Y., Meng, L., Liu, H., & Hu, Z. (2019). One's own and similar voices are more attractive than other voices. *Australian Journal Of Psychology*, *71*(3), 212-222. doi: 10.1111/ajpy.12235

Pellencin, E., Paladino, M. P., Herbelin, B., & Serino, A. (2018). Social perception of others shapes one's own multisensory peripersonal space. *Cortex*, *104*, 163–179. https://doi.org/10.1016/j.cortex.2017.08.033

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PLoS ONE*, *3*(12). https://doi.org/10.1371/journal.pone.0003832

Porciello, G., Bufalari, I., Minio-Paluello, I., Di Pace, E., & Aglioti, S. M. (2018). The 'enfacement' illusion: A window on the plasticity of the self. *Cortex*, *104*, 261–275. https://doi.org/10.1016/j.cortex.2018.01.007

Quintard, V., Jouffe, S., Hommel, B., & Bouquet, C. A. (2020). Embodied self-other overlap in Romantic love: A review and integrative perspective. *Psychological Research*, *85*(3), 899–914. https://doi.org/10.1007/s00426-02001301-8

R Core Team (2013). A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org/.

Ring, C., & Brener, J. (2018). Heartbeat counting is unrelated to heartbeat detection: A comparison of methods to quantify interoception. *Psychophysiology*, *55*(9). https://doi.org/10.1111/psyp.13084

Schandry, R. (1981). Heartbeat perception and emotional experience. Psychophysiology, 18(4), 483e488. https://doi.org/ 10.1111/j.1469-8986.1981.tb02486.

Sforza, A., Bufalari, I., Haggard, P., & Aglioti, S. (2010). My face in yours: Visuo-tactile facial stimulation influences sense of identity. *Social Neuroscience*, *5*(2), 148-162. doi: 10.1080/17470910903205503

Slater, M., & Ehrsson, H. H. (2022). Multisensory integration dominates hypnotisability and expectations in the rubber hand illusion. *Frontiers in Human Neuroscience*, *16*. https://doi.org/10.3389/fnhum.2022.834492

Sui, J., He, X., & Humphreys, G. (2012). Perceptual effects of social salience: Evidence from self-prioritization effects on perceptual matching. *Journal Of Experimental Psychology: Human Perception And Performance*, *38*(5), 1105-1117. doi: 10.1037/a0029792

Tajadura-Jiménez, A., Grehl, S., & Tsakiris, M. (2012). The Other in Me: Interpersonal Multisensory Stimulation Changes the Mental Representation of the Self. *Plos ONE*, *7*(7), e40682. doi: 10.1371/journal.pone.0040682

Tajadura-Jiménez, A., & Tsakiris, M. (2014). Balancing the “inner” and the “outer” self: Interoceptive sensitivity modulates self–other boundaries. *Journal of Experimental Psychology: General, 143*(2), 736–744. https://doi.org/10.1037/a0033171

Tsakiris, M. (2008). Looking for Myself: Current Multisensory Input Alters Self-Face Recognition. *Plos ONE*, *3*(12), e4040. doi: 10.1371/journal.pone.0004040

Tsakiris, M., Carpenter, L., James, D., & Fotopoulou, A. (2010). Hands only illusion: Multisensory integration elicits sense of ownership for body parts but not for non-corporeal objects. *Experimental Brain Research*, *204*(3), 343–352. https://doi.org/10.1007/s00221-009-2039-3

Tsakiris, M., & Haggard, P. (2005). The Rubber Hand Illusion Revisited: Visuotactile integration and self-attribution. *Journal of Experimental Psychology: Human Perception and Performance*, *31*(1), 80–91. https://doi.org/10.1037/0096-1523.31.1.80

Tsakiris, M., Carpenter, L., James, D., & Fotopoulou, A. (2010). Hands only illusion: Multisensory integration elicits sense of ownership for body parts but not for non-corporeal objects. *Experimental Brain Research*, *204*(3), 343–352.https://doi.org/10.1007/s00221-009-2039-3

Tsakiris, M., Tajadura-Jimeñez, A., & Costantini, M. (2011). Just a heartbeat away from one's body: Interoceptive sensitivity predicts malleability of body-representations. Proceedings. Biological Sciences/The Royal Society, 278(1717), 2470e2476. https://doi.org/10.1098/rspb.2010.2547.

Vuorre, M., & Bolger, N. (2017). Within-subject mediation analysis for experimental data in cognitive psychology and Neuroscience. *Behavior Research Methods*, *50*(5), 2125–2143. https://doi.org/10.3758/s13428-017-0980-9

Xiang, G., Teng, Z., Li, Q., & Chen, H. (2023). Self-concept clarity and subjective well-being: Disentangling within- and between-person associations. *Journal of Happiness Studies*, *24*(4), 1439–1461. https://doi.org/10.1007/s10902-023-00646-2

Zamariola, G., Maurage, P., Luminet, O., & Corneille, O. (2018). Interoceptive accuracy scores from the heartbeat counting task are problematic: Evidence from simple bivariate correlations. *Biological Psychology*, *137*, 12–17. https://doi.org/10.1016/j.biopsycho.2018.06.006

Zhang, X., Hommel, B., & Ma, K. (2021). Enfacing a female reduces the gender–science stereotype in males. *Attention, Perception, & Psychophysics*, *83*(4), 1729–1736. https://doi.org/10.3758/s13414-021-02241-0

Tables and Figures

Table 1. Mean (SD) responses to Enfacement Illusion Questionnaire

SYNCHRONY	GENDER	Exp 1	Exp 2	Exp 3
Synchronous	Same	20.7 (7.8)	21.8 (9.0)	19.8 (8.1)
	Different	16.1 (6.9)	16.4 (8.1)	15.9 (6.5)
Asynchronous	Same	15.1 (4.7)	15.8 (6.9)	15.6 (5.9)
	Different	13.1 (3.7)	13.4 (6.6)	13.1 (5.1)

Table 2. Mean (SD) responses to Inclusion of Other in Self Scale

SYNCHRONY	GENDER	Exp 1	Exp 2	Exp 3
Synchronous	Same	2.63 (1.27)	2.83 (1.4)	2.56 (1.48)
	Different	1.84 (1.02)	2.05 (1.2)	1.93 (1.14)
Asynchronous	Same	1.54 (0.77)	1.76 (0.92)	1.70 (0.94)
	Different	1.23 (0.48)	1.41 (0.73)	1.46 (0.93)

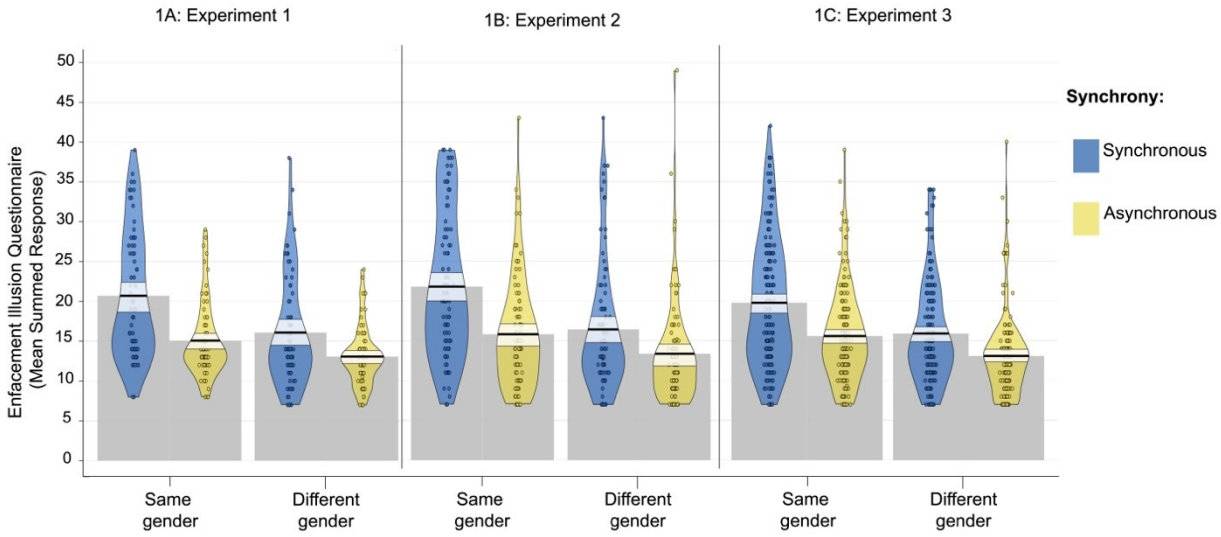

Figure 1A, 1B, and 1C. Mean summed response to the Enfacement Illusion questionnaire, in which higher scores indicate a stronger illusion. Coloured segments show smoothed density curves for the full data distribution, while individual dots indicate mean response per participant.

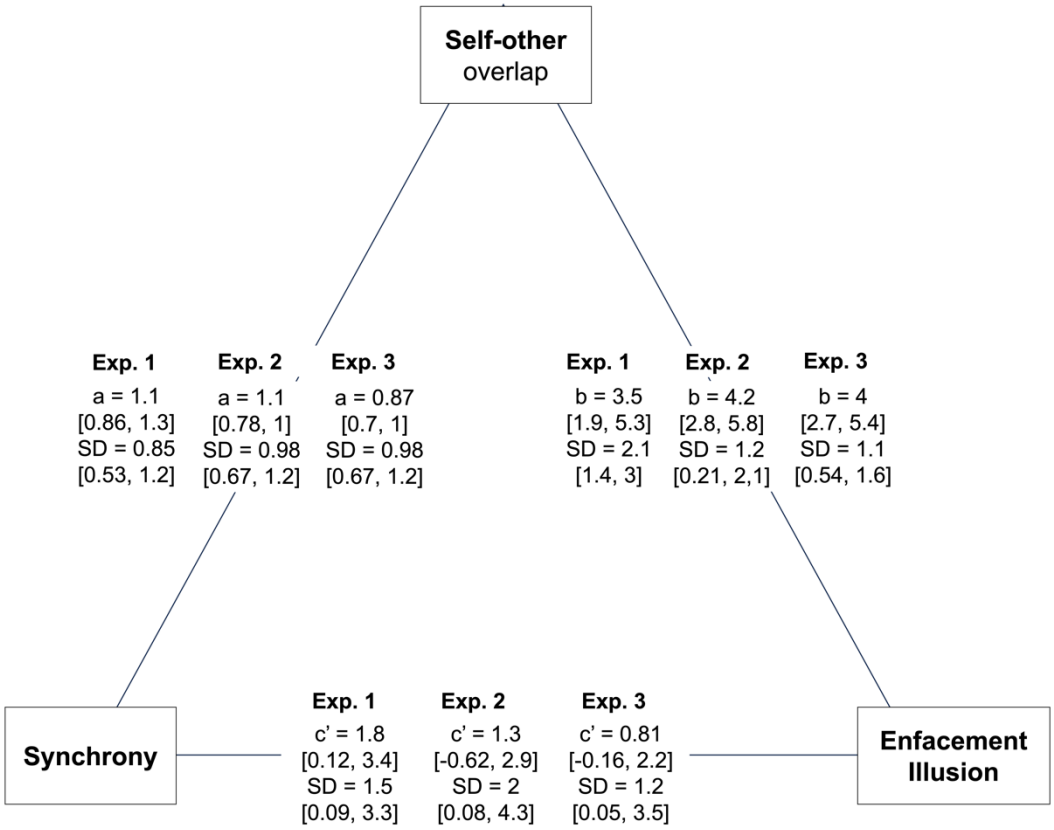

Figure 2. Path diagram representing of the relationships between synchrony, self-other overlap (IOS), and the enfacement illusion in the three Experiments. Figure includes point estimates (posterior means) of the parameters and associated 95 percent Credible Intervals (in square brackets below the point estimates). Under each estimated average effect, "SD" shows the associated effect's standard deviation, which indicates the degree to which that effect varies between people (in standard deviation units) (Vuorre & Bolger, 2016).

Embodiment in the Enfacement Illusion is mediated by self-other overlap

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Supplemental Material

1. The Enfacement Questionnaire, used across Experiments 1-3.

Seven items were used, a subset from the longer questionnaire used by Tajadura-Jiménez et al. (2012). Each was scored on a scale of 1-7, where a higher value response indicates stronger agreement with the item.

1. "I felt like the other's face was my face"
2. "It seemed like the other's face belonged to me"
3. "It seemed like I was looking at my own mirror reflection"
4. "It seemed like the other's face began to resemble my own face"
5. "It seemed like the face of the person in the video was similar to mine"
6. "It seemed like the person in the video was attractive"
7. "It seemed like the person in the video was trustworthy"

2. Order Effects Analysis

To ensure the enfacement illusion is a persistent effect and not subject to order effects, additional analyses were run. Specifically, we ran mixed effect models using lme4 (Bates, Maechler, Bolker, & Walker, 2014) to determine whether the factor of 'Order': 1 (participant first) vs 2 (experimenter first) significantly modulated experience of the enfacement illusion. The full model included predictors of *Synchrony* and *Gender* (i.e., the factors included in the main analysis) and, additionally, the predictor of *Order*, modelling a three-way interaction. We included the random intercept of *Participant*. Statistical significance was established via likelihood ratio tests by dropping the interaction or fixed effect of interest from a second null model and comparing the two models. This was done iteratively such that each two-way interaction including *Order* and the single fixed effect of *Order* was analysed. We ran this analysis three times, to assess potential order effects in Experiment 1, 2, and 3.

```
lmer(Response ~ Order*Synchrony*Gender +  (1|Participant_Number),
                                REML = FALSE)
```

Notably, we found no significant interaction effects containing *Order* (3-way or 2-way) and no significant main effect of Order (all ps > .05).

3. Full mediation outputs showing the population-level parameters.

3.1 Experiment 1

Table 3. Population-level parameters of the multilevel model in Experiment 1

Parameter	Mean	SE	Median	2.5%	97.5%	n_eff	Rhat
a	0.83	0.13	0.83	0.57	1.09	2560	1
b	4.59	0.76	4.55	3.21	6.32	171	1.02
cp	1.23	0.7	1.24	-0.23	2.58	198	1.01
me	3.36	0.84	3.3	1.83	5.08	311	1.01
c	4.58	0.74	4.59	3.17	6.03	1550	1
pme	0.73	0.15	0.73	0.46	1.05	186	1.01

c = the total effect of Synchrony on Enfacement
cp = the direct effect of Synchrony on Enfacement after IOS scores are taken into account
me = the magnitude of the mediation effect
pme = the proportion of the effect that is mediated

3.2 Experiment 2

Table 4. Population-level parameters of the multilevel model in Experiment 2

Parameter	Mean	SE	Median	2.5%	97.5%	n_eff	Rhat
a	1.06	0.15	1.06	0.78	1.36	8563	1
b	4.06	0.63	4.07	2.74	5.27	558	1.01
cp	1.45	0.73	1.45	0.04	2.95	702	1.01
me	4.51	0.86	4.48	2.89	6.32	1397	1
c	5.97	0.80	5.96	4.45	7.57	10607	1
pme	0.76	0.12	0.76	0.53	0.99	699	1.01

c = the total effect of Synchrony on Enfacement
cp = the direct effect of Synchrony on Enfacement after IOS scores are taken into account
me = the magnitude of the mediation effect
pme = the proportion of the effect that is mediated

3.3 Experiment 3

Table 5. Population-level parameters of the multilevel model in Experiment 3

Parameter	Mean	SE	Median	2.5%	97.5%	n_eff	Rhat
a	0.87	0.08	0.87	0.70	1.04	9658	1
b	3.93	0.52	3.88	3.03	5.08	99	1.01
cp	1.16	0.59	1.12	0.02	2.24	10	1.01
me	3.11	0.53	3.05	2.21	4.30	62	1
c	4.28	0.47	4.26	3.36	5.04	24	1
pme	0.73	0.12	0.73	0.53	1.00	14	1.01

c = the total effect of Synchrony on Enfacement
cp = the direct effect of Synchrony on Enfacement after IOS scores are taken into account
me = the magnitude of the mediation effect
pme = the proportion of the effect that is mediated