I Feel You: Impact of Shared Body Sensations on Social Interactions in Virtual Reality

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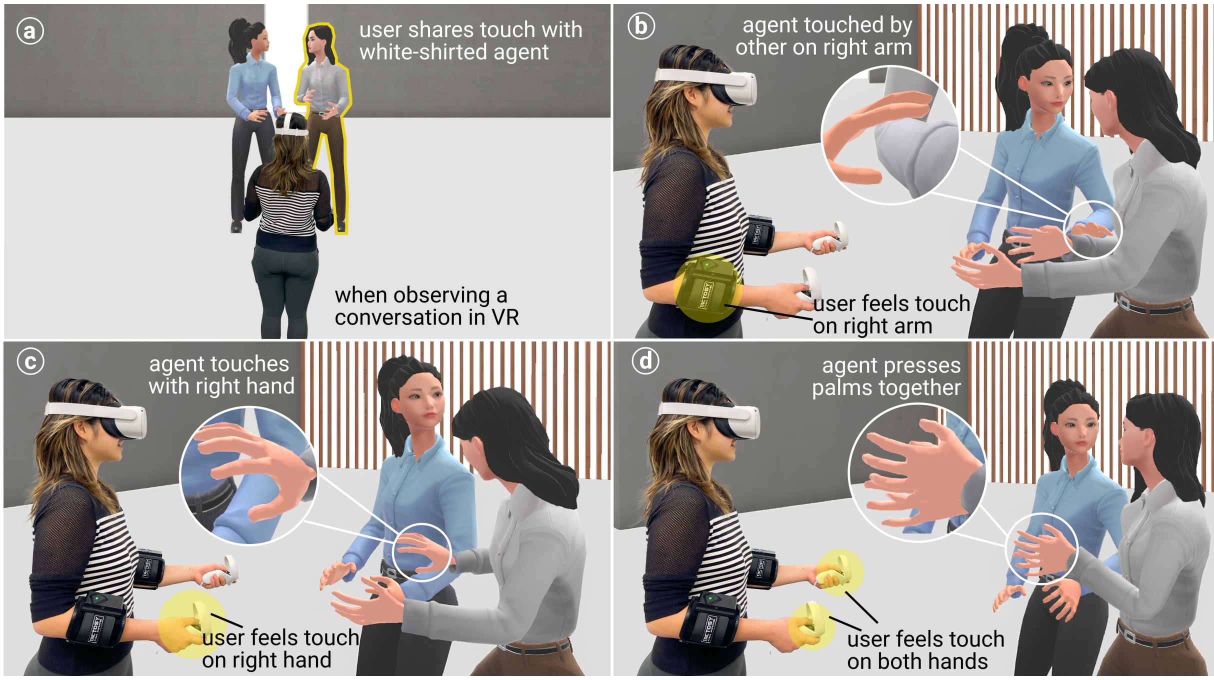

Figure 1: (a) A user observing a conversation between two embodied agents in VR. Here, the user shares body sensations with the white-shirted agent, with the sensation felt on the same body part. (b) - (d): Three types of touch interactions that happen in the conversation sessions during the study. (b) When the white-shirt agent is touched on the right arm, the participant also receives vibration feedback on the right arm through the armband. (c) When the white-shirt agent touches others using the right hand, the participant receives vibration feedback on the right palm through the controller. (d) When the white-shirt agent presses its hands together, the participant receives vibration feedback on both palms through the controllers.

Abstract

While one's facial expression and voice can be easily broadcasted from one to many via digital media, the sense of touch is limited to direct interactions. What happens if such body sensations can be shared across individuals, in which one feels a touch while watching someone else being touched? In this work, we investigated the impact of such shared body sensations on social interactions in virtual reality (VR). Building upon previous research that used psychophysics methods, our work explores the practical implications of shared body sensations in Social VR, which enables interactions beyond what's physically possible. We conducted a within-group user study (n = 32) in which participants observed conversations between two virtual agents and shared touch with one of the agents, as shown in Figure 1. Our results showed that even experiencing shared touch sensations several times during a conversation can affect social perception and behavior. Participants reported a stronger body illusion and empathy towards the virtual agent they shared touch with and stood closer to them. These results occurred both with and without a virtual mirror that made participants' self-avatars more salient. The findings from this study introduce a new technique to enhance social connectedness in VR, and we discuss its applications in various contexts, such as asynchronous communication and collaboration.

Index Terms: Social Touch, Haptics, Virtual Reality

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1 Introduction

Body sensations, such as the feeling of being touched, are private and unique to the person experiencing the touch. But to build social connections, people need to understand and share what others are feeling. Sayings like "I feel you" reflect this desire to relate to and understand other's experience both emotionally and bodily.

What happens when one can physically feel what others are experiencing on their bodies (i.e., shared body sensations)? Imagine you are listening to two people in a conversation (Figure 1). During emotional moments, one touches the other on the forearm to show support. At the same time, you feel a touch on your forearm. How do such shared body sensations impact your relationship with others? Researchers have long been interested in this inquiry and explored it in psychophysics experiments. By synchronously brushing the face of a participant as they watched a video of a stranger's face being brushed in the same ways for a few minutes, the participant

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reported an illusion of looking at another person's face but feeling the sense of looking at themselves in the mirror [69, 33, 73, 72]. Moreover, shared body sensations were also found to enhance empathy [59], facilitate emotion recognition [54, 20] and even elicit conformity toward others [59].

While past work uncovered the benefits of shared body sensations through highly controlled psychophysics methods, the practical impact of this technique on social interactions is rather unknown. Feeling brushing sensations on the face while observing others getting brushed diverges from day-to-day interactions. In this work, we aim to understand the impact of shared body sensations in a more naturalistic social setting, where the shared body sensations align with touch events commonly found in natural interactions and happen at particular narrative moments in the social interactions [71]. With this goal, we adopted social contexts in VR. VR is an emerging social media featuring platforms such as Horizon and VR Chat [56, 51]. While feeling what others experience on their bodies is not typical in physical interactions, such experience aligns well with VR in unlocking experiences that go beyond what is physically possible [12, 9]. Moreover, in VR, researchers can programmatically control factors such as appearances and motions of other virtual agents, which ensures all participants go through similar experiences, only varying the shared body sensations. Consequently, VR maintains the same level of experimental control as typical psychophysics studies while maximizing what social psychologists call mundane realism [16].

To investigate the impact of shared body sensations in social interactions in VR, we conducted a within-group user study with 32 participants. In the study, participants joined a VR space and observed conversations between two other virtual agents. Shared body sensations happened at particular narrative moments during the conversation, when virtual agents enacted touch events, as shown in Figure 1. In each conversation, participants shared body sensations with one of the virtual agents, receiving haptic feedback when that agent felt touch. To distinguish the effect of shared body sensations versus embodying a self-avatar, we manipulated the presence of a virtual mirror between the conversations; this makes the participant's virtual body more salient.

Overall, participants reported stronger body illusion and empathy toward the agents whom they shared touch with, compared to the ones without shared touch. Behaviorally, participants stood closer to the agents they previously shared touch with as opposed to the agents without the shared touch. The benefits of shared body sensations held when participants were aware that their virtual body was separate from the virtual agent they shared touch with.

We see the findings from this work unlocking a new technique to transform social interactions in VR and discuss various applications. For example, shared body sensations can be used to enhance connectedness with characters in recordings of past interactions in VR, bridging the gap of time separations in asynchronous communication. In collaborations, the shared body sensations can also be used to create physical connections with other online users, fostering teamwork. Moreover, in anonymous sharing environments like VR support groups, users can utilize shared body sensations to strengthen empathic bonds with other members. Lastly, we compiled a set of design considerations to enable content creators to leverage shared body sensations effectively.

Our key contributions are : (1) We expanded the understanding of shared body sensations into social interactions within immersive VR, moving beyond controlled psychophysics approaches. (2) Our study (n = 32) showed that feeling what other virtual agents feel on their bodies, activated only several times during a conversation, impacts social perception and behavior. (3) The study findings unlocked a new interactive technique for enhancing social connectedness in VR. We discussed its potential applications and outlined an initial set of design considerations.

2 Related Work

2.1 Shared Multisensory Experience

One notable example of experiencing shared body sensations in a daily context is known as mirror-touch synesthesia, a neurological condition in which people feel a tactile sensation on their own body when watching another being touched [14, 34].

Similarly, our work creates a shared multisensory experience by artificially stimulating mirror touch. Such a paradigm is widely used to elicit the "enfacement illusion", looking at another person's face but feeling the sense of looking at themselves in the mirror [61]. This effect is elicited through synchronously brushing the face of a participant as they watched a video of a stranger's face being brushed in the same way [59]. Researchers found that participants felt a stranger to be closer and more similar to themselves after they observed the face of this person receiving synchronous stimulation than observing asynchronous stimulation. In addition, observing synchronous stimulation elicited more positive affective reactions and conformity toward the other [59] and more interpersonal trust [19]. Researchers further found that shared touch between faces can influence self-identity perception [69, 33, 73, 72], facilitate emotion recognition [54, 20], impact on visual remapping of touch [21] and remap peripersonal space [53]. The mapping between visual and tactile cues can also be manipulated. Mazzurega et al., for instance, investigated how non-ecological pairs of visual and tactile events (e.g., electro-tactile feedback on the cheek while seeing the white dots) impact self-other merging [55]. Beyond synchronous stimulation on the face, researchers also investigated similar effects for hands by displaying visual-tactile feedback while watching others get touched through the computer screen [35].

While prior work provides a theoretical grounding of shared body sensations in enhancing social connectedness between individuals, they are limited to using controlled psychophysics methods. In this work, we extend the investigation of shared body sensations to a more naturalistic setting using Social VR.

2.2 Enhancing Social Interactions in Virtual Reality

Virtual reality offers immersive digital environments where individuals can interact with each other through embodied means. The rise of platforms such as Horizon [3] and VR Chat [8] further make social virtual spaces accessible for everyday usage. With the advancement of haptic devices, researchers have developed experiences that simulate the sensation of social touch from virtual agents, making it feel like real-world interactions [41, 67]. Our work does not focus on directly experiencing social touch from another person. Instead, it examines the impact of feeling a sense of touch when observing others being touched or touching.

Social VR provides an ideal platform for studying the practical impact of shared body sensations as it innately embraces interactions that go beyond physical limits. While sharing body sensations across individuals transcends how we normally interact with each other, in VR, such transformations of social interactions are commonplaces. For instance, taking a user's physical movement and remapping it in the shared VR space creates more semantically coherent interactions, enhancing the effectiveness of remote collaboration [40, 84, 70]. Users can also "relive" past experiences from different individuals' perspectives [81, 80] in VR. The replay of past events has been shown to enhance teamwork in the context of collaborative design [80]. Moreover, researchers created new techniques augment non-verbal communication in Social VR, such as sharing bio-signals [26, 49, 50, 27, 25], enhancing facial expressions [58, 37, 65, 13], manipulating motion synchrony [66, 75] and changing interpersonal distance [48, 82]. Thus, studying shared body sensations can potentially unlock a new technique to transform social interactions in VR [12, 13, 78].

Another prominent benefit of using VR to study shared body sensations is the ability to programmatically control the interactions of virtual agents. When studying the shared body in a more socially complex setting, factors such as body language and voice can arise as confounding factors, also influencing social perception [29, 10]. The digital nature of VR allows researchers to record and later playback the embodied interactions to the participants [32, 82], ensuring all participants go through the same experience and only varying the variables of interests. Blascovich et al. [16] summarized these unique benefits of VR in offering both experimental control (i.e., precise control of independent variables) and mundane realism (i.e., how well the studied scenarios align with everyday context).

Overall, this work builds upon prior literature on shared multisensory experiences and social interactions in VR. Moving beyond controlled psychophysics approaches (i.e., continuously brushing participants' faces), the study investigates shared body sensations in naturalistic conversational contexts within VR. Such experience also aligns well with VR in unlocking interactions beyond what is physically possible. Thus, the study uncovers practical implications of shared body sensations and as well as introduces a new tool to enhance social connectedness in virtual reality.

3 Method

To understand the impact of shared body sensations on social interactions in VR, we conducted a within-group user study with 32 participants. In the study, participants watched two conversations, each from a dyad of virtual agents. In each conversation, participants shared touch with one of the virtual agents. The body part where shared touch was felt (same or opposite body part) was alternated between participants as a nested variable. To distinguish the effect of shared body sensations from self-avatar embodiment, between the two conversations, we manipulated the presence of a virtual mirror, which makes participants' self-avatar more salient.

3.1 Condition Design

3.1.1 Shared touch/no shared touch

The primary independent variable is the manipulation of shared body sensations felt by the participants. In each session, participants shared body sensations with one of the virtual agent in the conversation. Particularly, the two virtual agents exerted touch interactions that are commonly found in natural conversations, including tapping other's forearm and pressing the palms together, as shown in Figure 1. When sharing body sensations with one of the virtual agents, participants received haptic feedback when they observed touch event happening to that agent. Each agent performed 5 touch events in one conversation: 3 times using one palm to touch the other's forearm and 2 times pressing their own palms together. This resulted in a total of 8 shared touch feedback received by participants per conversation, including 3 touches felt on a single palm (when the agent touch others with hand), 3 touches felt on the forearm (when the agent being touched on forearm), and 2 touches felt on both palms (when the agent presses hands together). In each session, the virtual agent with whom participants shared touch was chosen randomly and balanced across all participants. Information on the timing of touch events during the conversation session can be found in the supplemental materials.

Felt shared touch on the same/opposite body part. As VR extends digital interactions from viewing someone's face on a flat screen to engaging in a three-dimensional environment, the application of shared body sensations in VR should also account for spatial transformations of self-other perspectives [76]. As shown in Figure 2, if a virtual agent is being tapped on their right forearm, should the shared touch be felt on right (same) or left (opposite) forearm of the user? Interpreting left and right from the perspective of someone standing in front of one requires mental rotation, which is a common source for left-right confusion [79]. Thus, we don't predict a difference between the two spatial mappings of shared touch. To ensure the generalizability of the results, we incorporated both levels of spatial mapping in the study. As a nested variable, half of the participants received touch on the same body part for both conversations, while the other half received the touch mapped to the the opposite body part.

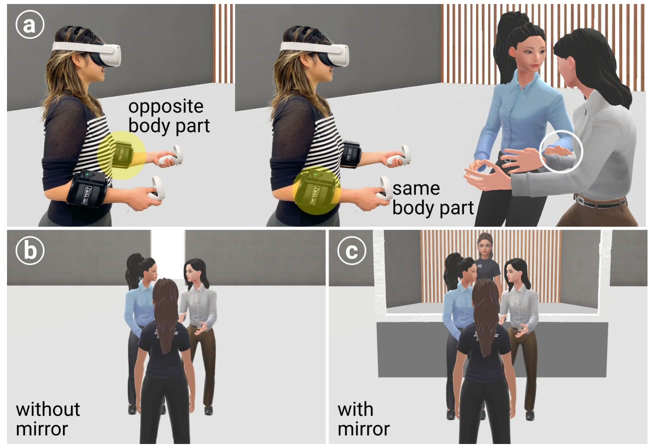

Figure 2: Here, the participant shares touch with the white-shirted virtual agent. (a) When the agent is touched on the right arm, the shared touch might be felt on the same (right) or opposite (left) arm of the participant. (b) Conversation session without the presence of a virtual mirror. (c) Conversation session with the virtual mirror that makes participants' self-avatar more salient.

3.1.2 Mirror/no mirror

Another unique feature of VR is that users embody and control their own virtual body (i.e., self-avatar), as shown in Figure 2 (b). A common technique to create the body ownership over one's self-avatar is to synchronize what users see with what they feel [45, 46], similar to the experience of shared body sensations in this paper. To distinguish the effect of shared body sensations from embodying a self-avatar, we introduced an additional independent variable: the presence of a virtual mirror [24, 83]. The mirror helps participants clearly see that their self-avatar is separate from the virtual agents they observe. Between the two conversations, we counterbalanced the order in which the participants would see a virtual mirror placed behind the talking agents or not, as shown in Figure 2 (b) and (c).

3.2 Task Design

In this study, the interactions that participants observed were prescripted to ensure all participants to go through the same social experience. Such designs control the impact of confounding variables (e.g., appearance, voice of virtual agents) on social perception. Observation of conversations is also typical in interactions on social VR platforms, where individuals observe conversations but not actively participating at the moment (i.e., "lurkers").

In order to provide structure to the conversation and to ensure similar topics across sessions, we adapted scenarios from Choice Dilemma Questionnaire (CDQ) [47]. The CDQ consists of hypothetical scenarios where characters choose between riskier options with higher rewards and safer choices offering moderate rewards. For each choice dilemma, a corresponding question is included to assess participants' opinions on risk-taking. Job search (Scenario A) and chess competition (Scenario G) were chosen for this study as they are neutral topics and fit in everyday conversational contexts [22]. In each observed conversation, one virtual agent held a pro-risk opinion and the other virtual agent held a pro-caution opinion about the choice dilemma. Thus, using this questionnaire as the conversation context also allows us to measure if risk-taking opinions of participants shift due to shared body sensations. The order of conversation topics was counterbalanced.

At the end of each conversation, the participants were asked to physically walk toward the dyad of agents as if they were going to join the conversation. This task aims to measure the comfort or intimacy participants feel toward others by assessing interpersonal distance [38, 30]. The walking task used in this study was adapted from previous research that measured non-verbal social behavior in augmented reality, requiring participants to walk to one of the seats near another virtual agent [57, 44]. Since our study takes place in VR and doesn't use physical chairs, we visually indicate two standing spots for participants to walk to, as shown in Figure 4.

3.3 Other Design Considerations

Training. As shared body sensations introduces novel sensory experience, training was found necessary from initial pilots. Therefore, before the main task sessions, participants underwent a brief training session. In VR, participants watched three motion clips of two agents in front of them enacting touch events: agent A touching agent B on forearm, agent B touching agent A on forearm, and agent A pressing palms together. Participants watched all motion clips twice, each time receiving vibrotactile feedback in relation to one of the agents. The side of the body that participants received touch during training matched with the assigned conditions.

Virtual agent customization. We also took consideration of the in-group/out-group effect introduced by demographics. Prior works showed people tend to prefer and positively evaluate individuals who belong to their own social group (in-group) over those who belong to different social groups (out-group) [39, 52]. Thus, we customized the appearance of virtual agents to align with the demographics of the participants, mitigating in-group/out-group effects. Based on the demographic information provided by the participants, experimenters selected the agent dyads that best matched the participants' reported gender and ethnic group.

3.4 Procedure

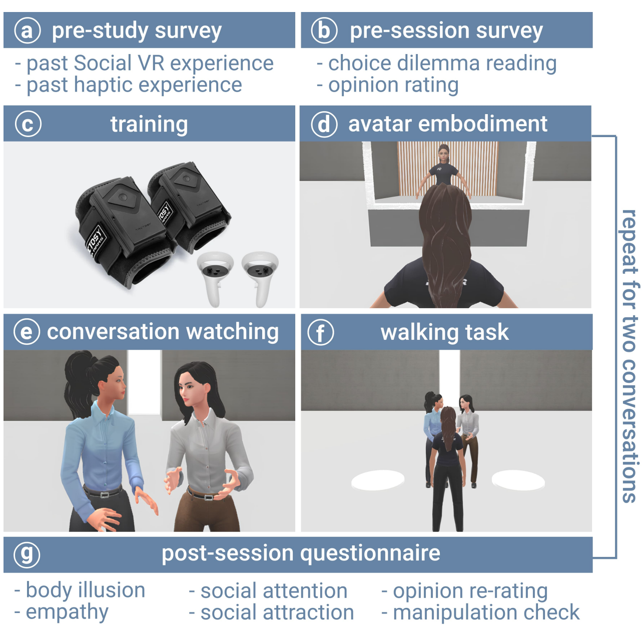

Figure 3: Overview of study procedure.

Figure 3 shows the procedure of the study. We invited participants to the lab, where they filled out the consent form (IRB # 71992) and a pre-study questionnaire. Then, participants designed their self-avatar using the ReadyPlayerMe [5].

The study started with participants reading about a choice dilemma as described in Sec. 3.2 and reporting their initial risk-taking opinion. Then, participants put on the VR headset and haptic devices. They were introduced to the concept of "touch sharing", in which the vibrotactile feedback they receive would relate to the touch of another agent. We disclosed the shared touch concept to mitigate the participants' surprise at the haptic feedback, but we didn't explicitly tell them which agent they would share touch with. A short training session followed, as described in Sec. 3.3. Participants were instructed to perform a T-pose to calibrate their self-avatar based on body height and arm length. This was followed by a 2-minute warm-up session in front of a virtual mirror to familiarize participants with their virtual body [36, 17].

The task session began when a dyad of virtual agents appeared in front of the participants and started the conversation. Touch interactions were involved in the conversation, as described in Sec. 3.1.1 and each conversation lasted for 5 minutes. At the end of the conversation, participants were asked to physically walk toward the dyad of agents as if they were going to join the conversation. After the walking task, participants completed the post-session questionnaire, which included questions regarding their perception toward each of the virtual agents in the conversation, re-rating on risk taking opinion of the choice dilemma, and the manipulation checks.

Participants repeated the process mentioned above for the second conversation session. No training was involved for the second half of the study. After both conversation sessions, participants filled out a post-study questionnaire which asked about their general experience in the study sessions.

The study took approximately 60 minutes in total, and all participants were compensated 25 USD for their time.

3.5 Apparatus

We used two types of haptic devices to render the shared touch experience: (1) *Meta Quest 2 controller* [4] for rendering touch felt on the hand; (2) *bHaptics Tactosy for Arms* [1] for rendering feedback on the forearm. The haptic feedback on hand was programmed to be 0.7s long, and the feedback on the forearm to be 1s.

We used the ENGAGE Platform [2], a social VR software, to pre-record the body motions used in the conversation sessions. Head and hand position and rotation data (6DOF) were first logged from two human actors and we post-processed the motion data using inverse kinematics pipeline [6] (RootMotion FinalIK [6]) and physics engine (RootMotion PuppetMaster [7]) in Unity 3D. We used the same set of body motion for both conversations and invited 4 dyads of voice actors to record the conversations (2 conversations x 2 genders). Each conversation is composed of 11 rounds of dialogue exchanged between the two agents. The full conversation script can be found in supplemental materials.

We used ReadyPlayerMe [5] to pre-design virtual agent appearance to align with demographics of participants. We designed virtual agents of 5 ethnicity groups (Asian, Caucasian, Black, Native, and Hispanic), 2 gender groups (female, male), and for 2 conversations, resulting in a total of 20 dyads of agents. The full set of virtual agents can be found in the supplemental materials.

The final application was developed in Unity 3D and ran on an ASUSTeK Computer through Meta Quest Link. We recorded participants' head and hand positions and rotations at approximately 30Hz during the study session using the Meta Quest 2 device.

3.6 Measures

3.6.1 Self-report measures

To evaluate change of self-other connectedness in VR, we adopted body illusion, empathy, social attention, and social attraction as the key measures. These measures are based on prior psychophysics studies on shared body sensations [59].

Synchronous visual-tactile stimulation fosters the body illusion, a key factor in inducing a sense of body ownership [45, 46]. In this study, as the touch experience was shared across individuals, we measured **the degree of body illusion participants felt over other virtual agents' bodies**. We adapted the avatar embodiment questionnaire from Peck et al. [60], which was originally designed for measuring embodiment over self-avatars [74]. In particular, we modified the assessment target from "self-avatar body" to the names of the talking agents. **Empathy** was measured using the Inclusion of Other in the Self (IOS) Scale [11], a well-established scale for measuring how close a person felt to other individuals. Interpersonal closeness was found to be strongly associated with empathy [43], leading to long-term relationship bonding [18]. Upon **social attention allocation**, we adapted Networked Minds Measures of Social Presence Scale [15, 31] to measure perceived attention. **Social attraction**, as part of interpersonal attraction, was measured with a 4-item construct with questions such as "I would get along with this person", following prior work [31].

3.6.2 Behavioral measures

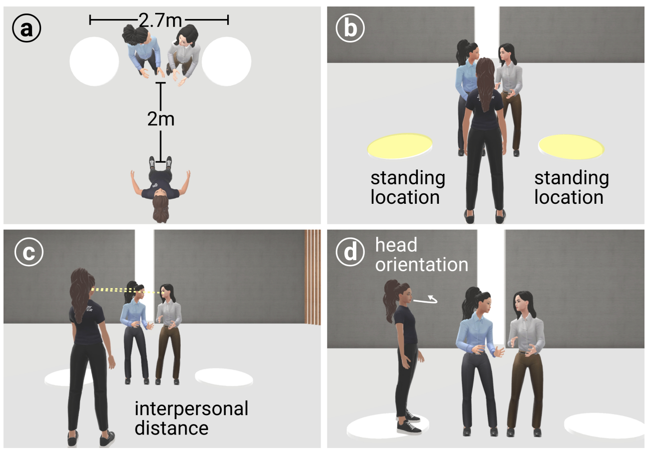

Figure 4: Illustration of walking task. (a) Distance between participants and agents and the distance between two standing locations. (b) A participant physically walks toward one of the standing locations as if they were going to join the conversation. (c) During the walking task, the distance between the participant and each of the virtual agents is recorded. (d) Post walking task, the head rotation of participants was also recorded to approximate where they looked at.

Beyond self-report measures, VR offers valuable insights into social behavior elicited by shared body sensations, which were not possible in traditional psychophysics studies. In the walking task, we recorded the final standing location of participants. The choice of one **standing location** versus another (with one near each virtual agent) indicates the social closeness participants feel toward each virtual agent. Moreover, we measured the **minimum interpersonal distance** between the participant and each virtual agent (Figure 4(b)) during the walking process, using the euclidean distance between head positions (x, z axis). Furthermore, we calculated **head orientation** after participants arrived at selected standing locations, shown in Figure 4(c). We categorized the head orientation based on whether they turned their face toward the two virtual agents or not. A turn is defined as the action of rotating the head on the yaw axis from the default position (i.e., participants facing forward and not looking at any agents). This measure indicates whether the participants would like to involve themselves in the conversations and maintain eye contact with others.

3.7 Hypotheses

We formulated the hypotheses based on prior work [59] and pre-registered hypotheses through the Open Science Framework [1]. Key hypotheses are as follows and details are in the pre-registration.

H1: Body Illusion toward others. We hypothesized that body illusion should be stronger toward the agent that the participant shared touch with than the agent without shared touch **(H1a)**. As the appearance of a digital mirror reminds users about the existence of their own virtual body, we also hypothesized that body illusion should be lower toward both agents when there is a mirror display than without **(H1b)**. Moreover, there should be a significant interaction effect between touch sharing and mirror display on body illusion, indicating that the impact of touch sharing on body illusion differs depending on the use of mirror display **(H1c)**.

H2: Empathy. Similarly, we hypothesized that empathy should be stronger toward the agent that the participant shared touch with than the agent without shared touch **(H2a)**. Empathy toward both speaking agents should not be significantly different between with a mirror display and without a mirror display **(H2b)**.

H3: Attention. We hypothesized participants should report greater attention toward the agent that they shared touch with than the agent without shared touch **(H3a)**. As the appearance of self-avatar through the mirror might distract participants, we hypothesized the reported attention should be lower toward both agents when there is a mirror display than without a mirror display **(H3b)**.

H4: Social preference. We hypothesized that social preference should be stronger toward the agent that the participant shared touch with than the agent without shared touch **(H4a)**. Social preference toward both agents should not be significantly different between with a mirror display and without a mirror display **(H4b)**.

3.8 Participants

Following pre-registration, we recruited 33 participants between the ages of 18 to 65 years old. One participant was excluded from the following analysis as they had the same name as one of the virtual agents' names. Thus, the final sample size is 32 participants: 16 self-identified as females, 14 self-identified as males, 1 self-identified as gender non-conforming, and 1 self-identified as female/non-binary. The average age of participants was 21.7 years old (SD=2.1). Participants in this study had relatively limited experience with the Social VR platform. 16 out of 32 participants had never used a Social VR platform before, with 14 participants having used one before but only a few times. Most participants had not used standalone haptic devices for VR before (n=26).

4 Results

We first conducted manipulation checks for general attention and the awareness of self-avatar presence through the virtual mirror in the study. All participants correctly identified the opinion that each virtual agent held (pro-risk or pro-caution) in both conversations, indicating overall attention to the conversations. Using a Welch's t-test, we confirmed participants are more aware of their self-avatar presence in the sessions with virtual mirrors (M=6.56, SD=0.9) than in the no mirror sessions (M=1.59, SD=1.56), p=0.

We also conducted a Two-Sample t-Test on the pre and post conversation risk-taking opinion ratings for each choice dilemma and found no significance, either when participants shared touch with the pro-risk agent (p=0.77) or when they shared touch with the anti-risk agent (p=0.77). This indicates that participants held their opinions, regardless of the opinion of the agent they shared touch with. Overall, participants chose to take moderate risks when evaluating the choice dilemma. On the scale of 1 (pro-risk) to 6 (pro-caution), participants tended to choose a balanced stance for both chess conversation (M_{pre}=3.19, SD_{pre}=1.18, M_{post}=3.06, SD_{post}=1.43) and job conversation (M_{pre}=3.75, SD_{pre}=0.9, M_{post}=4.06, SD_{post}=1.14).

We analyzed the subjective measures with linear mixed effects models using the condition groups (shared touch condition, mirror condition, and touch mapping body side within the shared touch condition) and participant-specific predictors (gender, prior social

[1] https://osf.io/pr6mz

VR experience, and prior haptic experience) as fixed effect factors. We modeled participant identifier, conversation topic, and session order as random effect factors to account for individual differences and variability influenced by conversation topic and order.

4.1 Body illusion over others' bodies

As shown in Figure 5, we found a main effect for touch sharing condition on overall body illusion toward other agents ($p<0.001$). Participants reported a stronger body illusion toward the virtual agent that they shared touch with ($M=3.02$, $SD=1.15$) compared to the agent they did not share touch with ($M=1.6$, $SD=0.54$). The results confirmed H1a.

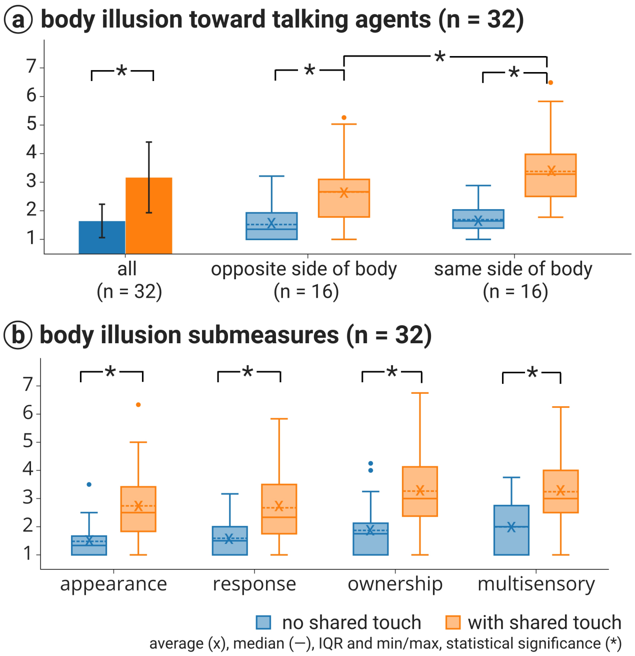

Figure 5: Self-report measures of body illusion over talking agents and its submeasures.

A main effect was also found for the nested variable, the side of the body that participants shared touch with ($p=0.008$). A post-hoc analysis was thus conducted with Bonferroni correction. A significant difference ($p=0.018$) was found in body illusion toward other agents between receiving shared touch on opposite and same sides of the body. Participants reported higher body illusion toward the agent that they shared touch with when the touch was mapped to the same side ($M=3.38$, $SD=1.12$), than the opposite side of the body ($M=2.66$, $SD=1.05$). No significant difference was found in body illusion over the agent with no shared touch between two touch mapping conditions ($p=1$). Under both the same ($p<0.001$) and opposite ($p<0.001$) side of touch mapping, participants reported a stronger body illusion toward the agent that they shared touch with.

There was also a main effect of past Social VR experience ($p=0.04$) on body illusion. Specifically, participants who "rarely" used Social VR prior to the study reported a stronger body illusion than those who "sometimes" used Social VR platforms.

No main effect was found on the presence of a virtual mirror ($p=0.43$), not confirming H1b. This means that the awareness of self-avatar presence through the mirror didn't impact the body illusion participants felt toward either the agent they shared touch with or the agent they did not share touch. No interaction effect was found between the two independent variables, not confirming H1c. There were also no main effects found on gender ($p=0.16$), or prior haptic experience ($p=0.88$).

Looking into the sub-scales of the body illusion ratings, we observed a similar trend as described for the overall body illusion. Significant differences were found on all submeasures, appearance ($p<0.001$), ownership ($p<0.001$), response ($p<0.001$), and multi-sensory ($p<0.001$), between shared touch and no shared touch. Experiencing shared touch on the same side of the body elicited stronger control ($p=0.007$), response to physical stimuli ($p=0.02$), and multi-sensory experience ($p=0.04$) compared to experiencing shared touch on the opposite side of the body. Detailed self-report results can be found in Figure 5 and supplementary materials.

4.2 Empathy

A main effect was found for the touch condition on the IOS rating ($p<0.001$), confirming H2a. It was shown that participants held a stronger level of empathy toward the avatar that they shared touch ($M=4.33$, $SD=1.9$) than the avatar that did not share touch with ($M=2.83$, $SD=1.63$). No main effect was found for virtual mirror presence ($p=0.53$), mapping of the touch ($p=0.8$), or any of the participant-specific predictors. The result confirms H2b.

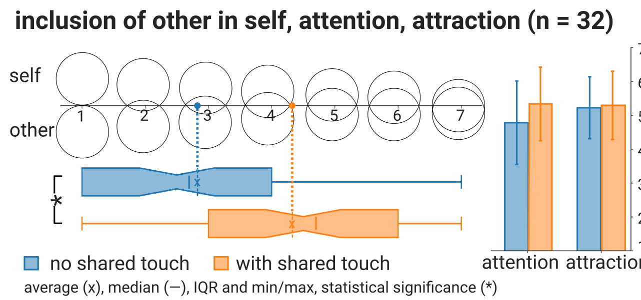

Figure 6: Self-report measures of Inclusion of other in the self (IOS), attention and social attraction.

4.3 Social Attention and Attraction

Social attention and attraction measures were also analyzed using the linear mixed effects model described above. Participants reported slightly higher social attention toward the agent that they shared touch with ($M=5.34$, $SD=1.09$) compared to the one without shared touch ($M=4.78$, $SD=1.23$); however, the difference is not statistically significant ($p=0.09$). This suggests that the introduction of shared touch experience did not significantly impact the level of social attention. No main effect was found for virtual mirror presence ($p=0.9$) or any of the participant-specific predictors. The results don't confirm H3a or H3b.

As for social attractions, participants exhibited the same level of social attraction toward both the agent with whom they shared touch ($M=5.29$, $SD=1.01$) and the agent with whom there was no share touch ($M=5.22$, $SD=0.91$). No main effects were observed for either of the independent variables. This indicates that subjective interpersonal attraction is independent of shared touch ($p=0.4$) and awareness of self-avatar through a virtual mirror ($p=0.55$). The results confirm H4b but not H4a.

4.4 Behavioral Measure: Walking Task

4.4.1 Standing location selection

We measured the behavior outcome using a walking task, in which participants were asked to walk toward the talking agents as if they were to join the conversation. The Chi-square test was applied to assess the distribution of participants' choices between two standing locations, under the assumption that, in a scenario of random chance, half of the participants would choose each location. Overall, participants were more likely to choose to stand close to the agent that they shared with ($p=0.046$) as opposed to the agent without shared touch. In 40 out of 64 sessions, participants chose the standing location near the agents that they shared touch with.

This trend holds regardless of shared touch mapping body side or virtual mirror presence. Participants who received shared touch on the same side of the body chose to stand near the agent they previously shared touch with in 21 out of 32 trials. Similarly, participants who received shared touch on the opposite side of the body chose to stand near the agent they previously shared touch with in 19 out of 32 trials. Upon the mirror condition, when there is a virtual mirror, participants chose to stand next to the shared-touch agent in 21 out of 32 trials. Similarly, in 19 out of 32 trials without mirror presence, participants decided to walk toward the agent that they previously shared touch with. In Figure 7, we plotted all participant's motion paths (approximated by head position) during the selection process in each of the two conversation sessions.

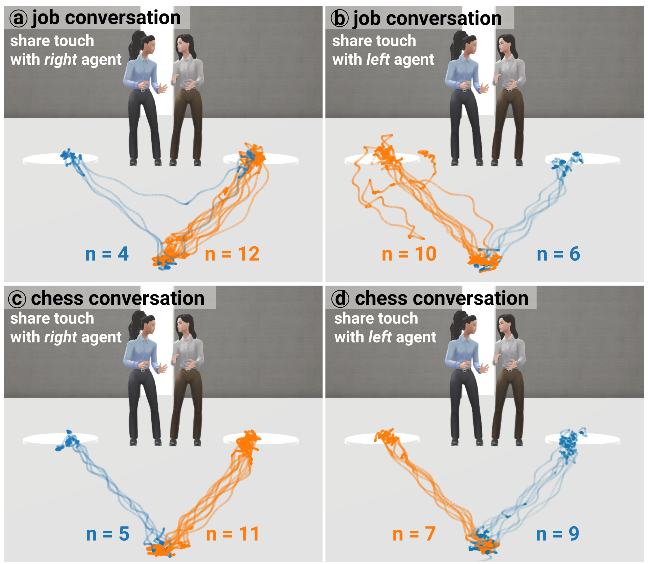

Figure 7: Motion paths during the walking task. Orange lines indicate that participants chose to stand next to the virtual agent with whom they previously shared touch. We visualize the motion by conversation topic and the virtual agent that participants shared touch with.

4.4.2 Minimum interpersonal distance

Moreover, we recorded the minimum interpersonal distance between the participant and each virtual agent during the walking task. This is computed by the Euclidean distance between head positions (x-axis and z-axis). We analyzed the data with a Two-Sample t-Test and found a significant difference in interpersonal distance between participants and the agent they shared touch with and the distance with the no shared touch agent (p=0.005). We visualized the distance data with Figure 8, a kernel density plot that shows the distribution of interpersonal distance with both agents.

While the mean distances to the agent with shared touch (M=1.05, SD=0.27) and the agent without shared touch (M=1.19, SD=0.27) are relatively close, the kernel plots' peaks, indicating the highest density of data points (mode), differ from these mean values. The mode value of the minimum distance to the agent with shared touch is 0.87 meters, while the mode value for the minimum distance to the agent without shared touch is 1.41 meters. Those values indicate that the participants tend to stay closer to the agent they shared touch with than the agent with no shared touch.

4.4.3 Head orientation

After participants walked to one of the standing locations, we measured head orientation by calculating head rotation on the yaw axis. We found that participants tended to rotate toward the virtual agents, regardless of whether they chose to stand close to the agent that they shared touch with or not. In 39 out of the 40 sessions

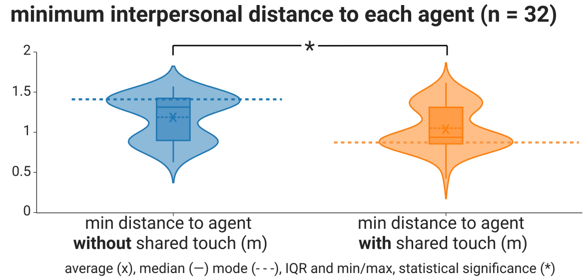

Figure 8: Kernel density and boxplot visualizing minimum interpersonal distance between participants and each of the talking agents during the walking task. The kernel density plot shows the peaks of interpersonal distance, where more participants tend to stay closer to the agent that they shared touch with.

in which participants chose to stand close to the shared touch agent, they also turned their heads toward the direction of virtual agents. Similarly, this head turn was found in 23 out of 24 sessions in which participants chose to stand close to the no shared touch agent. These findings show that participants generally paid attention to the conversation and intended to engage in social interactions.

5 Discussion

In this section, we first discuss the insights derived from the study results. Then, we lay out the applications of shared body sensations in VR and its design considerations of shared body sensations. Lastly, we discuss the limitations and directions for future work.

5.1 Shared Body Sensations and Social Perception

Body sensations, innately close-ranged and private [23, 64], provide physical grounding of self-perception [68]. When body sensations are shared across individuals, it blurs self-other boundaries [69, 33, 61]. In this study, we examined the impact of shared body sensations in a conversational Social VR setting. The results showed that receiving haptic feedback when another agent gets touched, activated only several times during a conversation session, can already enhance social connectedness with other agents. Specifically, participants reported stronger body illusion and empathy over the virtual agents with whom they shared touch compared to the agents without shared touch. Behaviorally, participants tended to stand close to the virtual agent they shared touch with. These results align with prior work that studied shared multisensory stimulation using psychophysics methods in non-VR settings [69, 33, 73]. More importantly, it demonstrates the applicability of shared body sensations in more natural social interactions.

While past works also showed that shared body sensations can enhance attraction of others [62, 42], participants in this study reported a similar level of social attraction toward both shared touch and no shared touch agents. A potential explanation lies in the actuation location, in which these past works were designed as observing the face of another person and receiving stimulation on the cheek [61]; the facial features are usually associated with social impression and physical attraction [77]. In this study, participants observed other agents with a full-body view and shared touch on the upper limb (hand and forearm) instead. We also didn't detect a significant difference between perceived attention toward shared touch and no shared touch agent.

Moreover, we manipulated the side of the body that received the shared touch, considering the spatial nature of VR. Past work on enfacement illusion rendered the brushing sensation on the opposite side of the body [61, 73], as if they were looking at a mirror image of themselves. In this study, participants reported increased social connectedness with both spatial mappings of shared touch (i.e., touch felt on the same or opposite body part), indicating the generalizability of the effect. However, participants reported a stronger body illusion toward other agents when the shared touch was felt on the same body part compared to the opposite while other measures do not differ. This finding suggests that a potential mental rotation involved when interpreting the shared body sensations [76].

Another finding from the study involves the manipulation of virtual mirror presence. While previous works have shown that a virtual mirror can enhance self-avatar embodiment in VR [24, 83], this study found that the presence of a mirror did not affect the impact of shared body sensations, including the body illusion over others' bodies. These findings suggest that the enhanced social connectedness induced by shared touch experiences is separate from embodying a self-avatar and the benefits held regardless of participants are aware of their own virtual body or not. This demonstrates the generalizability of shared body sensations in enhancing social connectedness in different contexts in VR.

5.2 Applications of Shared Body Sensations in VR

As the findings from this study open up a new technique for enhancing social interactions in VR, we see various immediate applications of shared body sensations in Social VR.

Asynchronous communication. One direct application is asynchronous communication in VR. Asynchronous interaction uses recordings of past VR interactions to allow users who couldn't be present in real-time to experience what happened [32, 82]. Those recordings can be about a meeting the person missed, or a playback of the concert by users' favorite artists in VR. When watching those recordings, however, users can feel isolated as they are not part of the interactions. By sharing the body sensations with characters in the recording, users can develop a deeper social connectedness with the characters they observe. Such shared multisensory experience can potentially bridge the gap between live and recorded interactions, making users feel more immersed and engaged.

Collaboration in VR. The shared body sensations could also be applied in multi-user collaborative contexts. In Social VR applications, such as Rec Room and Cook-Out, online users pair up in teams and work on collaborative tasks together. Many of those games require individuals to be aware of the states of their partners and adjust strategies corporately. By incorporating shared body sensations between teammates, users can establish a physical connection even if they have never met in person. These shared sensations could be used to speed up the familiarization process, helping teammates to feel more comfortable and connected with each other.

VR support groups. Last but not least, we also see applications in the VR support group. VR provides a safe and immersive environment for users to interact and share their experiences without the need to travel, making support more accessible [28]. The customizable self-avatars in VR allow anonymous interactions and encourage more open and honest communication. As individuals share their personal stories in VR, adding shared body sensations could be a powerful tool to create a physical connection with others. This enhanced sense of body sensations can heighten social connectedness and empathy among group members, making the support experience even more impactful.

5.3 Design Considerations

We synthesize an initial set of design considerations to support content creators and researchers looking to apply shared body sensations in Social VR.

Designing for learning and adaptation. As shared body sensations exposed users to novel sensory experiences, training was found to be necessary for the participants to learn about new sensory mappings. We observed from the pilot studies that lack of training could cause confusion and surprise factors. We also found that participants were generally able to adapt to shared touch experiences with just a few trials. The final training in the study was thus designed to be brief and to be completed within 5 minutes. We encourage designers and researchers exploring shared body sensations in Social VR to consider training essential to the user experience.

Mitigating sensory over-stimulation. In this paper, to examine the effects of shared body sensations within a Social VR setting, every participant was subjected to the same amount of shared touch feedback (i.e., several times in a 5-minute session). Most participants described the experience as "fun" and "interesting." However, 2 out of 32 participants mentioned the feedback could be distracting (see supplementary materials). Therefore, when integrating shared body sensations into applications, designers should be mindful of the amount of stimulation delivered to users. Designers should avoid over-stimulation by considering individual differences in touch sensitivity and social contexts.

Preserving user agency. With increasing concerns about harassment and privacy in VR due to the introduction of realistic touch feedback [63], we urge designers to preemptively mitigate the potential harm that might arise from the misuse of shared body sensations. For instance, we recommend against allowing shared body sensations to occur in sensitive areas or on unwanted body parts. Thus, when integrating shared body sensations into real-world applications, designers should ensure that users have complete control over the sensory feedback they receive. The users should be able to initiate or terminate the felt shared body sensations and control the location and pattern of the stimulations based on their preferences.

5.4 Limitations and Future Work

In this study, we pre-recorded the agent conversations and their body motions to play back to the participants. While this decision mitigated confounding factors, participants stayed as observers in the conversations. Future work should expand the investigations of shared body sensations to live social contexts, where the interactions are spontaneous and real-time.

Moreover, in this work, we adopted vibrotactile feedback to simulate the experience of shared touch. The choice of using commercial devices enables our findings to be relevant to real-world applications. However, we also acknowledge that the vibrotactile feedback doesn't fully approximate the tactile experience of human touch. Future work should look into how different haptic rendering techniques and fidelity have an impact on downstream social cognition and behavior.

Last but not least, the long-term impact of shared body sensations is still unknown. This paper only investigated brief social interactions in VR (i.e., 5-minute). Expanding the temporal window of the exposure (e.g., multiple sessions or longer periods of time) could help understand how users adapt to the shared body sensations and their potential aftereffects. This also requires future work to incorporate a broader scope of experimental measures (e.g., interviews), and diversify the study sample.

6 Conclusion

In this work, we studied the impact of shared body sensations, experiencing the sense of touch while seeing that touch directed to another person, on social interactions in VR. Moving beyond controlled psychophysics methods, this work extends the investigation of shared body sensations into more socially complex settings. The results showed that receiving shared touch with another agent only several times during the interactions can already induce a stronger body illusion and empathy toward that agent. Behaviorally, we observed that participants were more likely to stand close to the agents that they shared touch with. We concluded with insights derived from the study and applications for shared body sensations in Social VR. We see future work to further extend the exploration of shared body sensations to more diverse social settings.

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