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Sadness is reduced by virtual hugging

Xinyan Wang[1] | **Qiuhong Liu**[1] | **Xiang Li**[1] | **Xixi Zheng**[1] | **Bernhard Hommel**[2] | **Ke Ma**[1]

[1]Key Laboratory of Personality and Cognition, Faculty of Psychological Science, Southwest University, Chongqing, China

[2]Department of Psychology, Shandong Normal University, Jinan, China

Correspondence
Ke Ma, Key Laboratory of Personality and Cognition, Faculty of Psychological Science, Southwest University, Beibei, Chongqing, China.
Email: psyke1@swu.edu.cn

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Abstract

This study investigated the possible effect of virtual interpersonal hugging on alleviating individual sad emotion. Using emotional self-assessment and skin conductance responses, we recorded subjective and objective indicators before and after sad emotion induction, and after virtual interpersonal hugging, and assessed the role of (1) the characteristics of hugging, (2) participants' familiarity with the virtual hugging target, and (3) participants' face resemblance and perspective toward the virtual me-avatar initiating the hugging. Results showed that (1) hugging a virtual target, but not the mere action of hugging, improves the regulation of sad emotion, (2) visual information dominates haptic information in the virtual hugging process, (3) facial familiarity of virtual targets of hugging and facial resemblance of the me-avatar to participants do not affect the emotion regulation effect, and (4) first-person perspective of the virtual me-avatar influences both perceived ownership of hugging action and emotion regulation. Overall, virtual interpersonal hugging contributes to the regulation of sad emotion.

KEYWORDS

emotional regulation, hugging, sad emotions, virtual reality

INTRODUCTION

Touch is a particularly important human sense, on which newborns rely already, and which continues to be important during daily life. Touch is, in a sense, the modality that allows as the most direct experience of our physical and social environment. We often do not only touch ourselves but also receive touch from family members, peers, and even strangers through handshake, hugs, or massage. Social touch (Field, 2019) has been revealed to promote our physical and mental well-being, such as to relieve stress and regulate negative emotions, to increase prosocial behavior, reduce stereotypes and prejudice, possibly through conveying of sympathy and love feelings, and build togetherness (Packheiser et al., 2024; Saarinen et al., 2021).

The importance of touch was made particularly salient through the recent COVID-19 pandemic, which significantly reduced the frequency of social touch by increasing interpersonal distance. Indeed, the sudden outbreak of the COVID-19 pandemic during late 2019 had a profound impact on global mental health. According to the World Health Organization's (WHO) World Mental Health Report released in June 2022 (World Health Organization. World Mental Health Report: Transforming Mental Health for All), the incidence of common mental disorders such as depression and anxiety increased by over 25% in the first year of the COVID-19 pandemic, indicating a rise in negative emotional experiences in individuals (Aknin et al., 2022). Negative emotions encompass a range of unpleasant subjective experiences that not only narrow consciousness and impair behavioral capabilities but also disrupt adaptive behaviors (Fredrickson & Branigan, 2005). Moreover, negative emotions can manifest anxiety and depression symptoms, impairing people's ability to pursue future intentions (Harris & Cumming, 2003).

In the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), sadness is considered to be a significant criterion for diagnosing depression, and individuals with a depression predisposition show a preference for sad emotions in specific situations (Rottenberg, 2005). Sadness, as a typical and common negative emotion, often arises from events involving loss, setbacks, pain, or misfortune, making individuals feel distressed and helpless (Bonanno, 2004), and links to dysfunctional beliefs (van Rijsbergen et al., 2015). Previous research indicates a correlation between the number of previous episodes of major depressive disorder (MDD) and heightened levels of sadness during recovery (van Rijsbergen et al., 2015). Additionally, experiences of sadness or daily stress can directly predict the recurrence of depression (Rucci et al., 2011; van Rijsbergen et al., 2012).

Emotional regulation toward the sad and other negative emotions is important in daily life (Koole, 2010). Evidence suggests that college students who use fewer emotional regulation strategies tend to exhibit more depressive symptoms (Dryman & Heimberg, 2018). Importantly, emotional touch (one of various kinds of emotional social contact), as an important emotional regulation strategy (Eckstein et al., 2020; Morrison, 2016a; Wijaya et al., 2020), was tremendously reduced during the COVID-19 pandemic. The emotional touch refers to interpersonal contact that is pleasant, comfortable, and akin to caressing, including social touch, C-tactile touch, and massage therapy (Spitoni et al., 2020). When individuals experience emotional touch, various brain regions associated with positive emotions are activated (Morrison, 2016b). Hugging another person, as one of the earliest forms of touch and emotional communication in humans, has been extensively studied for its positive effects on physical and mental health. For example, research has shown that hugging can increase testosterone levels in males (van Anders et al., 2011), buffer stress (van Raalte, & J., & Floyd, K., 2021), and convey emotional support and social support effectively (Cohen et al., 2015), and daily hugging frequency correlates with better daily mood (Packheiser et al., 2022).

However, during the pandemic, public health measures implemented to curb the spread of COVID-19, such as regional lockdowns, travel restrictions, and social contact limitations, significantly disrupted routines of daily life. Especially these measures led to a reduction in social interactions, social touch from others was unavailable and not considered to be safe (Packheiser et al., 2023), which in turn resulted in decreased social support and an increase in perceived stress, depressive symptoms, feelings of loneliness, and anxiety among the population (Buecker & Horstmann, 2021). Research indicates that the lack of social support during the pandemic led to a decrease in the release of oxytocin (Gryksa & Neumann, 2022), a hormone associated with emotional bonding and emotional social contact (Morhenn et al., 2012). Thus, during the pandemic, the frequency of hugging significantly decreased (Packheiser et al., 2023), which probably contributed to a sustained negative emotional state in many individuals.

How can science help to deal with such situations, like when social distancing and separation is unavoidable? Here, we considered the possibility to find a way replacing human-to-human hugging by means that still contribute to regulating negative emotions. Recent developments in technology have led researchers to explore the effects of hugging between humans and man-made objects, such as Hugive pillows (Keshmiri et al., 2018; Sumioka et al., 2019) and hugging robots (Block & Kuchenbecker, 2019; Hedayati et al., 2019), commonly with a positive impact on emotional regulation. Given the rather high cost of such dedicated devices, we were interested to see whether virtual reality (VR) technology, which can be used to interact with other (virtual) agents in a virtual world (Freeman et al., 2017; Mohr et al., 2013), might provide comparable advantages. While virtual worlds share some commonalities with the real-world (Girvan, 2018), VR technology is rather cheap and flexible, which makes it easier to adjust it to individuals and their specific needs. Of particular interest for our purposes, acting in virtual environments liberates the agent from the constraints of the real world, which is particularly useful under real-world conditions that are psychologically counterproductive, like the pandemic. VR technology has been successfully used to induce more relaxed emotional states and more positive emotions (Beverly et al., 2022; Riva et al., 2020), to reduce people's subjective stress (Beverly et al., 2022), and to overcome psychological burdens of the COVID-19 pandemic (Riva et al., 2020).

Importantly and directly related to our current study, in previous touch studies, social touch in VR environments has been proven to be effective in affecting emotion and behavior responses (Ahmed et al., 2020; Askari et al., 2021; Ravaja et al., 2017). In the present study, we applied this approach to the regulation of sad emotions, which we attempted to improve through virtual hugging. Given that we know relatively little about hugging in general, except for its positive effects, and virtual hugging in particular, we were not testing directed hypotheses but explored possible conditions that might moderate the efficiency of virtual hugging with respect to the regulation of sad emotions.

More specifically, we conducted four experiments to thoroughly investigate the effect of virtual interpersonal hugging on sad emotion regulation (see Figure 1). The first two experiments focused on the effect of hugging. In Experiment 1, we aimed to establish our paradigm and, if possible, demonstrate a sad emotion regulation effect of virtual hugging. We also tested the role of visual contact between the avatar that served to represent the participant (the me-avatar) and the avatar to which the hugging action was directed. Experiment 2 aimed to assess the possible role of tactile information in the virtual hugging process, Experiment 3 tested whether the facial

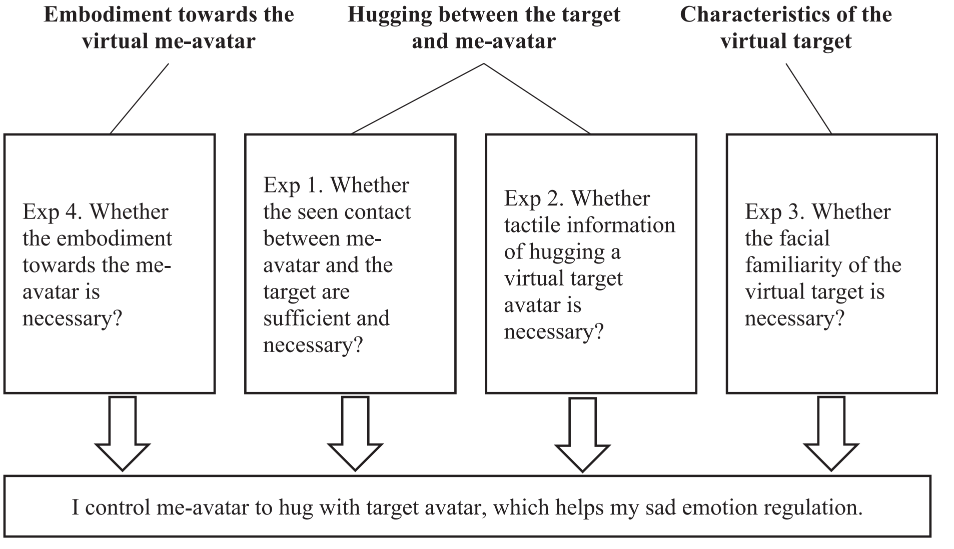

FIGURE 1 General schematic diagram of experimental content.

familiarity of the hugging target is important, and Experiment 4 finally tested the impact of the embodiment of the me-avatar. Like previous studies, participants' emotions were assessed by means of both subjective ratings and objective measures—skin conductance responses (SCRs) reflecting arousal changes in the autonomic nervous system (Bufo et al., 2022). SCR has long been used to assess physiological responses in emotion studies (Cacioppo et al., 1993). For example, participants' SCR level were found to be activated more after watching sadness-inducing films than watching neutral films (Gross & Levenson, 1997; Kreibig et al., 2007) and also after participants recognized sad as compared to neutral facial emotions (Banks et al., 2012).

The four factors of interest (roles of visual contact, tactile information, facial familiarity, and embodiment) were determined with reference to previous studies (Packheiser et al., 2024; Saarinen et al., 2021), in which the authors used meta-analysis on previous social touch studies, concluding that the intervention efficacy of social touch is likely to rely on characteristics of the toucher (the virtual target in current study), the touchee (the me-avatar participants controlled) and the touch (the motor, visual and tactile information associated with the hugging and contact).

EXPERIMENT 1. THE EFFECT OF VIRTUAL HUG ON SAD EMOTIONS

Method

Experiment 1 employed a within-subject design with four conditions (see Table 1 for details), the order of which was fully counterbalanced. The dependent variables were participants' emotional level, measured through emotional self-assessment scores and SCR. The main hypothesis was that, when people are in a sad emotional state, engaging in a virtual hugging action with a visible virtual other significantly reduces their sadness.

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TABLE 1 Experimental design of Experiment 1.

Condition/action	Virtual target present	Hugging	Virtual contact with target
1. Hugging target	Yes	Yes	Yes
2. Hugging empty space with target	Yes	Yes	No
3. Watching target	Yes	No	No
4. Hugging empty space without target	No	Yes	No

Participants

A total of 38 participants, all female, right-handed, and aged between 18 and 24 (Average = 20.03, STD = 1.24), took part in the virtual experiments. Only female participants were recruited in order to control for potential effects of gender, as previous evidence indicated that females tend to be more easily influenced by social hugging (Benenson, 2013). The study received approval from the local ethics committee, ethical guidelines were followed, and participants provided informed consent. Participants were compensated for their participation and debriefed of the experimental procedures after the experiment.

Apparatus and materials

We used HTC Vive Head-Mounted Display (HMD) and four wireless motion trackers. The motion trackers are bonded on the forearms and feet of participants for movements tracking and interacting within the virtual environment. VR programming was accomplished using software Vizard. Throughout the experiment, the Biopac mp160 was used to collect SCR, and the remote transmitter was tied to participants' left wrist. The virtual scene was constructed using 3ds Max software (see Figure 2).

Sad Emotion Induction Video: At first, the experimental video materials were created and screened by psychology students. Then, 15 participants who did not take part in the experiment were invited to rate the sadness and arousal of 12 videos on a 1–9 scale (sadness: 1 indicating not sad at all, 9 indicating very sad; arousal: 1 indicating very excited, 9 indicating very calm). Objective indicators (SCR) were also collected before and after participants viewed the videos. Lastly, four sad film clips with consistent subjective and objective levels were selected, among them there were no significant difference in sadness: $F(3,15) = 0.327$, $p = .806$, and arousal: $F(3,15) = 0.752$, $p = .526$. See Table 2.

Research procedure

Each condition of Experiment 1 consists of four stages: the preparation stage, emotion induction stage, virtual action stage, and resting stage. The specific experimental process is shown in Figure 3.

Preparation Stage: Upon entering the laboratory, participants first filled out a personal information form. The experimenter explained the instructions and procedures and then assisted participants to put on the HMD and the SCR remote transmitter. In the virtual environment,

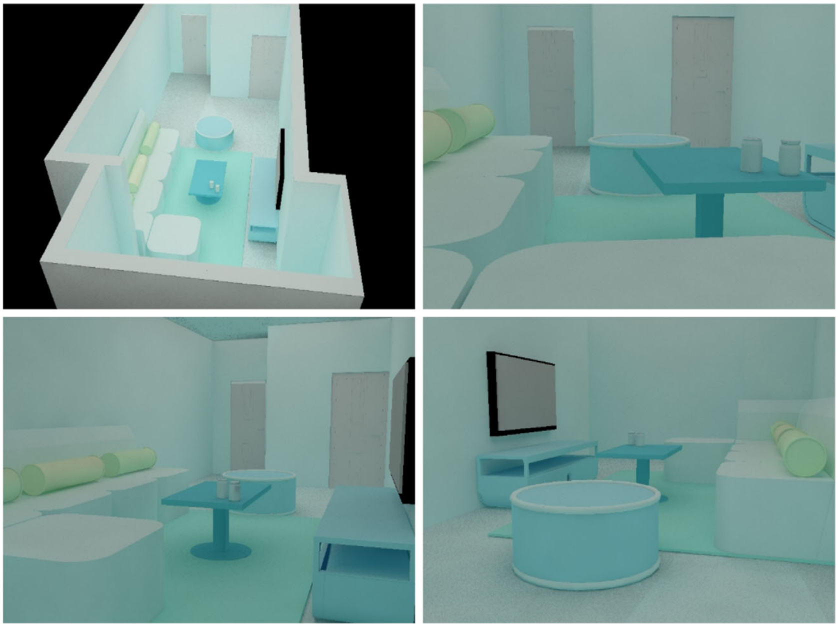

FIGURE 2 3ds Max Virtual Space.

TABLE 2 Arousal and sadness for four sad emotion induction materials (M ± *SD*).

Film source (all in Chinese)	Duration	Arousal level	Sadness level
"Ex-Files 3: The Return of the Exes"	268 s	4.86 ± 2.41	5.86 ± 1.77
"I Want Us to Be Together"	273 s	4.00 ± 2.00	6.86 ± 1.35
"Sorrow Floats Upstream"	260 s	4.53 ± 1.81	6.80 ± 1.21
"Hi, Mom"	265 s	4.47 ± 1.51	7.13 ± 0.99

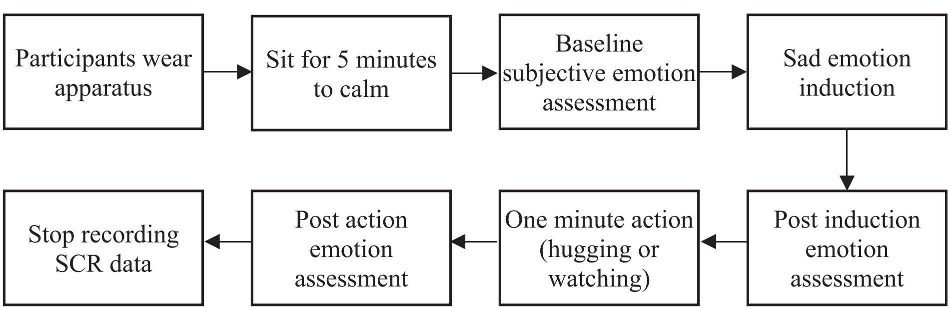

FIGURE 3 Experimental flowchart.

participants took a first-person perspective (1PP) of a virtual avatar (the me-avatar), whose virtual body coincided spatially with their own real body. With Vive trackers, participants could control the virtual avatar's limb movements, walk around, and see the avatar in a virtual mirror. After becoming familiar with virtual environment and avatar, participants sat quietly for

5 min and then completed an emotion self-assessment rating (van Rijsbergen et al., 2012, 2015) as a baseline measure, where participants rated their emotional sadness (1 indicating "not sad at all" and 9 indicating "very sad") on a 9-point Likert scale.

Emotion induction Stage: Participants watched a video clip, completed emotion ratings again (the post-induction emotion assessment).

Virtual action Stage: In Condition 1, participants saw a virtual target (the target was always female avatar, same gender with participants) approaching from a distance and sitting in the virtual sofa nearby, extending arms to hug with the participant, as shown in the left image of Figure 4. Participants were required to lean to her and hug with the virtual target for 1 min. The hugging was only visually seen, without any haptic feedback. In Condition 2, participants saw a virtual target approaching and sitting in the virtual sofa, but the target would not hug, as shown in the right image of Figure 4. Instead, participants were required to perform the hugging with the empty space for 1 min, without seeing or touching any virtual target. In Condition 3, participants saw a virtual target approaching and sitting in the virtual sofa, without extending arms for hugging, participants were required to do nothing, but just simply sit with the target for 1 min. In Condition 4, the virtual target did not appear, but participants were required to hug the empty space for 1 min. After that the virtual target stood and left, participants filled in the emotion ratings again (the post hugging emotion assessment).

Resting Stage: Participants sat quietly for another minute; the experimenter stopped collecting SCR data and assisted participants to take off the HMD and SCR apparatus.

Results

Ratings

Results were analyzed by means of a 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 4 (Condition) repeated measures analysis of variance (ANOVA). It revealed a significant effect

FIGURE 4 The participant immersed in the virtual environment, experiencing the embodiment from a 1PP. If looking downward and seen from the mirror, the participant could see the virtual me-avatar engaging in interpersonal interaction with a virtual target (left) vs. no hugging (right).

of time stage, F(2,74) = 33.950, $p < .001$, pŋ2 = 0.745, but no effect of experimental condition, $p = .201$. The significant interaction, F(6,222) = 4.360, $p < .001$, pŋ2 = 0.105, was disentangled by running one-factorial ANOVAs (Time Stage: Baseline vs. post-induction vs. post-action) separately for each condition. See Figure 5 and Table 3.

The main effect was significant for all four conditions: Cond1. F(2,74) = 39.717, $p < .001$, pŋ2 = 0.518; Cond2. F(2,74) = 48.025, $p < .001$, pŋ2 = 0.565; Cond3. F(2,74) = 59.897, $p < .001$, pŋ2 = 0.618; and Cond4. F(2,74) = 33.207, $p < .001$, pŋ2 = 0.473. LSD post hoc comparisons also showed significant increases of sadness from baseline to post-induction for all four conditions: Cond1. Mean Difference = 1.658, SE = 0.236, $p < .001$; Cond2. Mean Difference = 2.184, SE = 0.244, $p < .001$; Cond3. Mean Difference = 2.206, SE = 0.187, $p < .001$; and Cond4. Mean Difference = 1.711, SE = 0.196, $p < .001$. This suggests that the movie successfully induced sadness in the participants.

Also, sadness was reduced from post-induction to post-action for all four conditions: Cond1. Mean Difference = 2.079, SE = 0.291, $p < .001$; Cond2. Mean Difference = 1.421, SE = 0.191, $p < .001$; Cond3. Mean Difference = 1.289, SE = 0.164, $p < .001$; and Cond4. Mean Difference = 1.237, SE = 0.234, $p < .001$. However, sadness was significantly lower at post-action than at baseline in Condition 1 only, Mean Difference = 0.421, SE = 0.205, $p = .047$, but still higher at post-action than at baseline in all other conditions: Cond2. Mean Difference = 0.763, SE = 0.240, $p = .003$; Cond3. Mean Difference = 0.737, SE = 0.209, $p = .001$; and Cond4. Mean Difference = 0.474, SE = 0.219, $p = .037$. Hence, all activities (or the time they took) were successful in reducing sadness after induction, but only Condition 1 allowed emotion regulation to reduce sadness to the pre-induction level or more.

SCR

We averaged SCR values across 30 s, for the time (a) before watching the clip, (b) at the end of emotion induction, and (c) at the end of the action, separately, corresponding to the subjective emotional assessment at three time points: baseline, post-induction, and post-action (Bufo et al., 2022). Results were analyzed as the ratings. The 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 4 (Condition) repeated measures ANOVA revealed a significant main effect of time stage, F(2,74) = 19.806, $p < .001$, pŋ2 = 0.349, but not of experimental

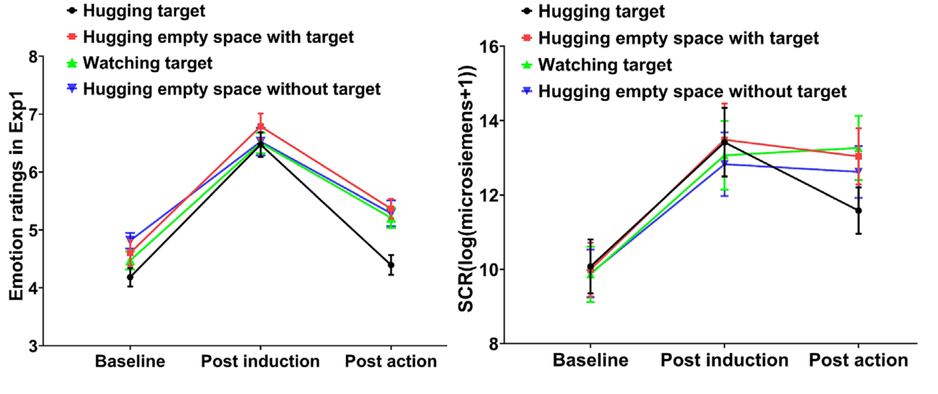

FIGURE 5 Sadness levels under different experimental conditions at different time stages in Experiment 1.

TABLE 3 Sadness levels under virtual hug and control conditions at different time stages in Experiment 1 ($n = 38$).

Stage	Measure	Action	M	SE
Baseline	Emotion ratings	1. Hugging target	4.816	0.159
		2. Hugging empty space with target	4.605	0.222
		3. Watching target	4.474	0.154
		4. Hugging empty space without target	4.816	0.135
	SCR	1. Hugging virtual target	10.075	0.726
		2. Hugging empty space with target	9.995	0.723
		3. Watching target	9.867	0.746
		4. Hugging empty space without target	9.886	0.643
Post-induction	Emotion ratings	1. Hugging virtual target	6.474	0.212
		2. Hugging empty space with target	6.789	0.220
		3. Watching target	6.500	0.176
		4. Hugging empty space without target	6.526	0.238
	SCR	1. Hugging virtual target	13.414	0.925
		2. Hugging empty space with target	13.483	0.975
		3. Watching target	13.064	0.924
		4. Hugging empty space without target	12.825	0.855
Post-action	Emotion ratings	1. Hugging virtual target	4.395	0.171
		2. Hugging empty space with target	5.368	0.170
		3. Watching target	5.211	0.173
		4. Hugging empty space without target	5.289	0.223
	SCR	1. Hugging virtual target	11.579	0.624
		2. Hugging empty space with target	13.036	0.757
		3. Watching target	13.262	0.864
		4. Hugging empty space without target	12.617	0.695

Abbreviation: SCR, skin conductance response.

condition, $p = .573$. The interaction was significant, $F(6,222) = 2.619$, $p = .018$, $p\eta 2 = 0.066$; and thus disentangled like the ratings.

The main effect was significant for all four conditions: Cond1. $F(2,74) = 12.741$, $p < .001$, $p\eta 2 = 0.256$; Cond2. $F(2,74) = 13.822$, $p < .001$, $p\eta 2 = 0.272$; Cond3. $F(2,74) = 15.107$, $p < .001$, $p\eta 2 = 0.290$; and Cond4. $F(2,74) = 15.677$, $p < .001$, $p\eta 2 = 0.298$. Comparisons showed that SCR increased from baseline to post-induction in all four conditions: Cond1. Mean Difference = 3.340, SE = 0.629, $p < .001$; Cond2. Mean Difference = 3.488, SE = 0.790, $p < .001$; Cond3. Mean Difference = 3.197, SE = 0.703, $p < .001$; and Cond4. Mean Difference = 2.940, SE = 0.524, $p < .001$, indicating that the emotion induction worked. SCR decreased significantly from post-induction to post-action in Condition 1, Mean Difference = 1.835, SE = 0.741, $p = .018$; but in the other three conditions: Cond2. Mean Difference = 0.447, SE = 0.758, $p = .559$; Cond3. Mean Difference = 0.198, SE = 0.759, $p = .795$; and Cond4. Mean Difference = 0.208, SE = 0.681, $p = .762$.

The SCR at post-action was still significantly higher than at baseline in all four conditions: Cond1. Mean Difference = 1.505, SE = 0.611, $p = .019$; Cond2. Mean Difference = 3.041, SE = 0.603, $p < .001$; Cond3. Mean Difference = 3.395, SE = 0.611, $p = .001$; and Cond4. Mean Difference = 2.732, SE = 0.541, $p < .001$. Taken altogether, results indicate that only the hugging of a virtual other was successful in reducing sadness-related emotional activation.

Discussion

Even though the result patterns differ in detail (which may imply that SCR changes more slowly than subjective ratings do), both ratings and SCR measures suggest that only Condition 1, with the actual hugging of a virtual other, was successful in supporting emotional regulation. This may suggest that the hugging action and target are both necessary, while the mere hugging action or the dealing with a virtual other as such are not sufficient. This result is consistent with previous findings (Levav & Argo, 2010), in which the authors found that participants were more likely to conduct risky decisions if they received a comforting touch on shoulder by a stranger, as compared to no touch.

EXPERIMENT 2. THE CONTRIBUTION OF VISUAL-HAPTIC STIMULATION

Of all our sensory modalities, vision usually dominates information acquisition for human perception (Ernst & Banks, 2002). Multisensory integration, the process by which the brain combines information from independent but temporally corresponding signals from multiple sensory modalities (Miller et al., 2017), can resolve perceptual ambiguities, enhance perceptual judgments, and optimize individual actions (Helbig & Ernst, 2007; Lalanne & Lorenceau, 2004; Talsma, 2015). Along the same lines, in VR studies, participants who were exposed to multimodal stimuli reported a better presence in virtual environments (Marucci et al., 2021). Researchers also found that participants' sense of identification in tasks involving bimodal and trimodal stimuli was superior to tasks involving only visual stimuli (Venkatesan et al., 2023). Especially, one study (Haynes et al., 2022) designed a haptic cushion and participants were made to believe that, if the cushion can "breathe" (similar to a breathing human), it can ease participants' anxiety. It thus is possible that multisensory stimulation enhances the effectiveness of sad emotion regulation with virtual hugging, and haptic information may play an important role therein.

Experiment 2 combined visual information about virtual hugging with real haptic sensation. Manipulations targeted the visual virtual target (hugging targeted a human or a doll), the real haptic sensation (related to a human or doll), and the modality consistency of the hugging. We hypothesized that, when visual-haptic information is modality consistent, especially when both visual and haptic information related to a human, the impact on sadness would be strongest.

Method

A two-factor within-subject design was employed, with three experimental conditions (Condition 1, hugging seen virtual human and felt real person; Condition 2, hugging seen virtual human and felt real doll; Condition 3, hugging seen virtual doll and felt real doll), and three time Stage (Baseline vs. post-induction vs. post-action). The dependent variables were again emotional self-rating scores and SCR. The sequence of the experimental conditions was fully counterbalanced. See Table 4.

Participants

Forty-two female students from Southwest University in China were recruited. After preliminary analysis, two participants with invalid data were excluded, leaving 40 participants (age range: 18–24, M = 21.00, *SD* = 1.52) for data analysis.

Research materials

Visual and haptic stimuli: The haptic stimulus was provided by real doll and a real human, who was a trained experimenter. The corresponding virtual doll was constructed using 3ds Max software (see Figure 6), and the virtual human was the same as in Experiment 1. The trained experimenter wore specific attire, to control for additional variables when conducting the hugging. Everything else was as in Experiment 1.

TABLE 4 Experimental design of Experiment 2.

Condition	See hugging with	Feel hugging with
1. Human/human	Human	Human
2. Human/doll	Human	Doll
3. Doll/doll	Doll	Doll

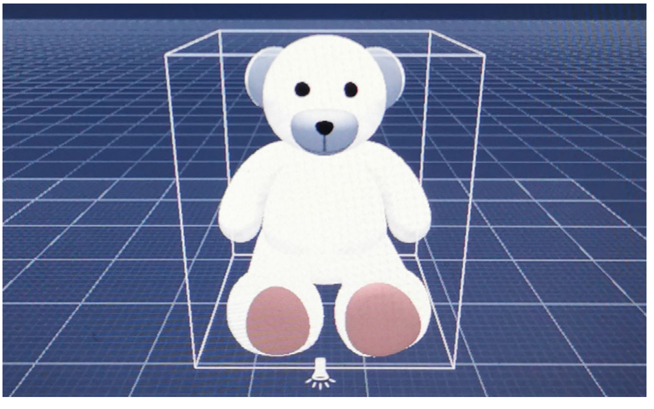

FIGURE 6 3D Virtual doll model.

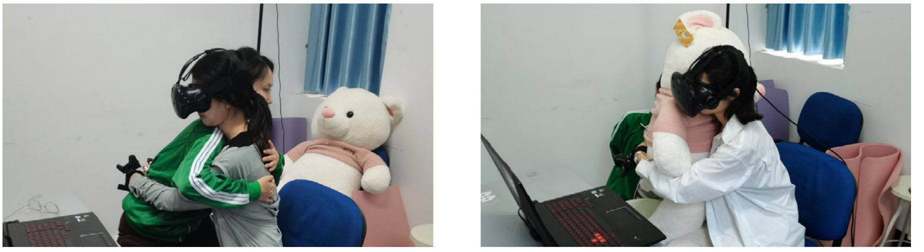

FIGURE 7 Haptic stimuli in Experiment 2; left panel: hugging human; right panel: hugging doll.

Experimental procedure

The experimental procedure was similar to Experiment 1, with the only difference relating to the hugging process. In Condition 1, participants hugged the experimenter in reality and watched this event (i.e. their me-avatar hugging a virtual human) in the virtual mirror in the VR environment. In Condition 2, participants hugged the doll in reality but watched their me-avatar hugging a human in the virtual mirror. In Condition 3, participants hugged the real doll and watched this event (i.e. their me-avatar hugging a virtual doll) in the virtual mirror (see Figure 7).

Results

Ratings

A 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 3 (Condition) repeated measures ANOVA was conducted. Again, the main effect of time stage was significant, $F(2,78) = 164.063$, $p < .001$, $p\eta 2 = 0.808$, while the effect of experimental condition was not, $p = .296$. The interaction was close to significance, $F(4,156) = 2.402$, $p = .052$, $p\eta 2 = 0.058$.

Separate one-factorial ANOVAs showed significant effects of time stage for all three conditions: Cond1. $F(2,78) = 63.907$, $p < .001$, $p\eta 2 = 0.621$; Cond2. $F(2,78) = 89.037$, $p < .001$, $p\eta 2 = 0.695$; and Cond3. $F(2,78) = 81.426$, $p < .001$, $p\eta 2 = 0.676$. LSD comparisons showed significant increases of sadness from baseline to post-induction for all three conditions: Cond1. Mean Difference = 2.400, SE = 0.240, $p < .001$; Cond2. Mean Difference = 2.425, SE = 0.189, $p < .001$; and Cond3. Mean Difference = 2.075, SE = 0.180, $p < .001$; indicating again that the induction of sadness worked.

Sadness decreased significantly from post-induction to post-action in all three conditions: Cond1. Mean Difference = 2.750, SE = 0.320, $p < .001$; Cond2. Mean Difference = 2.100, SE = 0.208, $p < .001$; and Cond3. Mean Difference = 2.125, SE = 0.197, $p < .001$; indicating that all actions were accompanied by a reduction of sadness. This reduction reached the original baseline, as implied by the nonsignificance of differences between baseline and post-action in all three conditions: Cond1. Mean Difference = 0.350, SE = 0.225, $p = .128$; Cond2. Mean Difference = 0.325, SE = 0.194, $p = .102$; and Cond3. Mean Difference = 0.050, SE = 0.193, $p = .797$. See Figure 8 and Table 5.

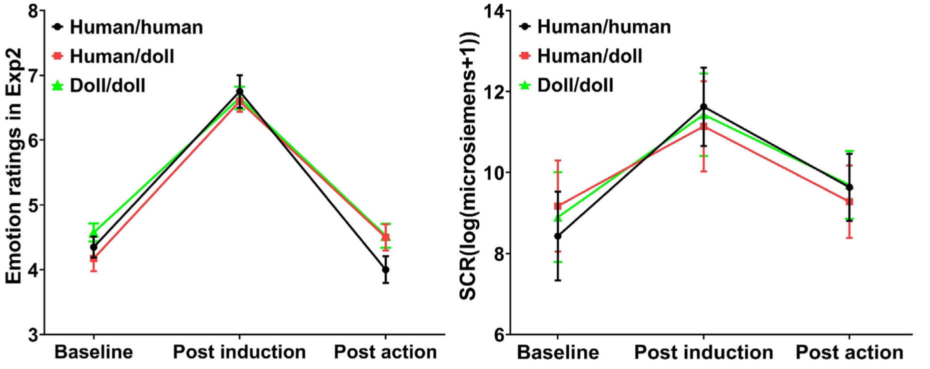

FIGURE 8 Sadness levels under different experimental conditions at different time stages in Experiment 2.

TABLE 5 Sadness levels under different visual-haptic stimulation conditions at different time stages in Experiment 2 ($n = 40$).

Stage	Measure	Condition (see/touch)	M	SE
Baseline	Emotion ratings	1. Human/human	4.350	0.162
		2. Human/doll	4.175	0.199
		3. Doll/doll	4.575	0.138
	SCR	1. Human/human	8.434	1.097
		2. Human/doll	9.174	1.124
		3. Doll/doll	8.899	1.107
Post-induction	Emotion ratings	1. Human/human	6.750	0.250
		2. Human/doll	6.600	0.163
		3. Doll/doll	6.650	0.174
	SCR	1. Human/human	11.626	0.970
		2. Human/doll	11.143	1.117
		3. Doll/doll	11.430	1.019
Post-action	Emotion ratings	1. Human/human	4.000	0.206
		2. Human/doll	4.500	0.203
		3. Doll/doll	4.525	0.183
	SCR	1. Human/human	9.636	0.829
		2. Human/doll	9.281	0.895
		3. Doll/doll	9.694	0.835

Abbreviation: SCR, skin conductance response.

SCR

A 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 3 (Condition) repeated measures ANOVA yielded a significant main effect of time stage, $F(2,78) = 13.073$, $p < .001$, $p\eta 2 = 0.251$, but neither an effect of experimental condition, $p = .931$, or an interaction, $p = .337$. Similarly to ratings, LSD post hoc comparisons showed a significant increase of SCR from baseline to post-induction, Mean Difference = 2.564, SE = 0.586, $p < .001$, a significant decrease from post-induction to post-action, Mean Difference = 1.862, SE = 0.358, $p < .001$, and no difference between baseline and post-action, Mean Difference = 0.701, SE = 0.579, $p = .233$, suggesting that the movie successfully induced participants' subjective sad emotions and that all the manipulations did support the reduction of sadness.

Discussion

Despite some numerical differences pointing to a particularly strong effect of Condition 1, the three conditions are statistically equivalent with respect to their impact on emotion regulation. Our finding is consistent with previous study that manipulated visuo-tactile congruency and found that the incongruence only influences participants' perceptual bias but not their sensitivity to visuo-tactile stimulation (Lanfranco et al., 2024). Our results were also consistent with previous predictions that, people engaging in touch with other human or even object both benefits, while the human–human touch benefits larger on physical and mental health. This is possible because of the contribution of skin-to-skin contact in human–human interaction (Packheiser et al., 2024).

EXPERIMENT 3: THE EFFECT OF FACIAL FAMILIARITY OF THE VIRTUAL TARGET

Experiment 3 investigated the effect of virtual target identity on sad emotions regulation with virtual hugging. Specifically, we examined whether the participants' perceived familiarity of the virtual target can influence the regulation effect. We manipulated this factor by creating familiar virtual faces (that the virtual other was equipped with) based on photos of participants' friends, an unfamiliar virtual face, and a virtual doll with a corresponding doll face. We assumed that the social relationships implied by the degree of familiarity would strengthen the impact of virtual hugging on sadness regulation, because in previous studies, females tended to avoid social touch in a non-intimate interpersonal situation involving strangers more than males did (Sorokowska et al., 2021); also touch from a partner or familiar person was shown to be experienced as more pleasant than touch from a stranger (Saarinen et al., 2021), and participants reported lower levels of pain (Goldstein et al., 2016).

Method

Participants

Forty-two students from Southwest University in China were recruited. The participants' ages ranged from 18 to 24 years (M = 20.22, *SD* = 1.5).

Research design

A two-factor within-subject design was employed, with three experimental conditions. In Condition 1, the virtual target's face looked like a friend of the participant; in Condition 2, the

TABLE 6 Experimental design of Experiment 3.

Condition
1. Human/friend's face
2. Human/unfamiliar-avatar face
3. Doll

virtual target's face was unfamiliar to the participant, like in Experiments 1 and 2, and in Condition 3, the virtual target's face was of a doll, as shown in Figure 6. The other independent and dependent variables were as in the previous experiments. See Table 6.

To measure familiarity, we used the Inclusion of Other in the Self Scale (IOS) and asked participants to rate the closeness degree between themselves and the virtual other on a scale ranging from 1 to 7—with increasing overlap of two circles from nonoverlapping to overlapping. The scale was thought to reflect the psychological distance (perceived otherness) between oneself and others, where low overlap indicates more and high overlap indicates less psychological distance (Aron et al., 1992).

Research procedure

The experimental procedure was similar to Experiments 1 and 2, with the only exception relating to the hugging process. For Condition 1, we built new virtual target with the face of a friend of the participants; in Condition 2, we just used the same virtual target as in Experiments 1 and 2, and in Condition 3, we used the same humanoid doll as in Experiment 2.

Results

Manipulation check

IOS results were assessed by means of an ANOVA with conditions as factor. The main effect was significant, $F(2,72) = 17.313$, $p < .001$, $p\eta 2 = 0.325$, and LSD comparisons showed that IOS ratings were significantly higher in Condition 1 (mean = 4.351, SE = 0.202) than in Condition 2 (mean = 2.862, SE = 0.244), with Mean Difference = 1.459, SE = 0.311, $p < .001$, and higher than in Condition 3 (mean = 2.784, SE = 0.230), with Mean Difference = 1.568, SE = 0.286, $p < .001$, while Condition 2 did not differ from Condition 3, with Mean Difference = 0.108, SE = 0.295, $p = .715$. This confirms our assumption that face familiarity was higher in Condition 1 than in the other two conditions.

Ratings

A 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 3 (Condition) repeated measures ANOVA yielded a significant main effect of time stage, $F(2,72) = 148.105$, $p < .001$, $p\eta 2 = 0.804$, but no effect of experimental condition, $p = .591$, or the interaction, $p = .326$. LSD comparisons showed a significant increase of sadness from baseline to post-induction, Mean

Difference = 2.640, SE = 0.187, $p < .001$, a significant decrease from post-induction to post-action, Mean Difference = 2.514, SE = 0.165, $p < .001$, and no difference between baseline and post-action, Mean Difference = 0.126, SE = 0.166, $p = .453$. Like in Experiment 2, this suggests that the sadness induction worked, and that all three conditions had a comparable impact of sadness reduction down to baseline levels. See Figure 9 and Table 7.

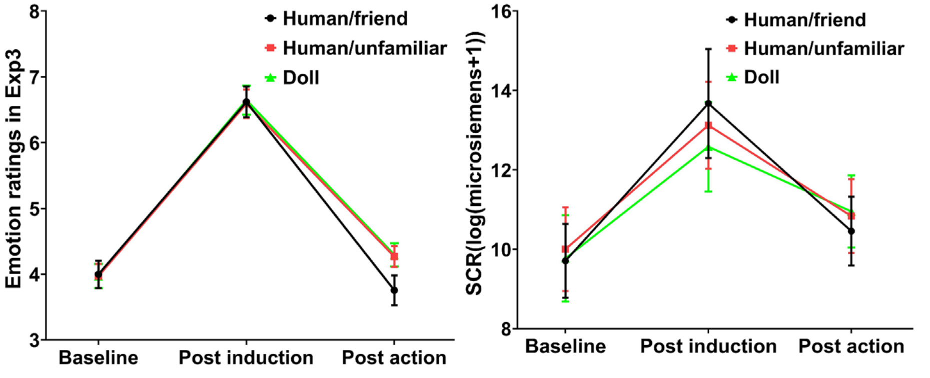

FIGURE 9 Sadness levels under different experimental conditions at different time stages in Experiment 3.

TABLE 7 Sadness when the virtual target showing different facial familiarity and at different time stages in Experiment 3 ($n = 42$).

Stage	Measure	Condition	M	SE
Baseline	Emotion ratings	1. Human/friend	4.000	0.209
		2. Human/unfamiliar	3.973	0.184
		3. Doll	3.973	0.184
	SCR	1. Human/friend	9.710	0.932
		2. Human/unfamiliar	10.002	1.054
		3. Doll	9.771	1.086
Post-induction	Emotion ratings	1. Human/friend	6.622	0.234
		2. Human/unfamiliar	6.595	0.217
		3. Doll	6.649	0.220
	SCR	1. Human/friend	13.672	1.373
		2. Human/unfamiliar	13.124	1.096
		3. Doll	12.582	1.124
Post- action	Emotion ratings	1. Human/friend	3.757	0.227
		2. Human/unfamiliar	4.270	0.158
		3. Doll	4.297	0.177
	SCR	1. Human/friend	10.456	0.866
		2. Human/unfamiliar	10.837	0.926
		3. Doll	10.952	0.908

Abbreviation: SCR, skin conductance response.

SCR

A 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 3 (Condition) repeated measures ANOVA yielded a significant main effect of time stage, $F(2,72) = 30.355$, $p < .001$, $p\eta 2 = 0.457$; but no main, $p = .871$, or interaction effect, $p = .289$. LSD comparisons showed that SCR increased from baseline to post-induction, Mean Difference = 3.298, SE = 0.481, $p < .001$, decreased from post-induction to post-action, Mean Difference = 2.377, SE = 0.439, $p < .001$, but that the post-action SCR was still significantly higher than at baseline, Mean Difference = 0.921, SE = 0.385, $p = .022$. While this pattern again suggests the sadness induction worked and that SCR may change more slowly than ratings do, it does not provide evidence that the three different conditions would support sadness reduction in different ways.

Discussion

No significant difference among the three conditions was found, which suggests that participants do not care so much whether a hard avatar looks familiar or humanlike—as long as some actual target is actually hugged. We note that this outcome does not quite fit with the mentioned previous study, which found touch avoidance of females in non-intimate relationships (Sorokowska et al., 2021). However, a closer look reveals rather complicated data patterns obtained in related studies. Sorokowska et al. (2021) asked participants to report their willingness to hug a stranger and the felt comfort with touch and found that females scored higher than males on both measures (Fromme et al., 1989). Another study found that females value social touch as more positive, whereas men consider touch toward strangers as more comfortable (Trotter et al., 2018), and in yet another study, females were more likely to report touch comfort with a less familiar other female (Schirmer et al., 2022). Hence, the available findings suggest a complicated picture. Moreover, our participants were certainly aware that they were in a VR environment, which means that it was clear to them that they would not actually interact with a stranger but with an avatar, like in other games, they may be familiar with. In other words, hugging an avatar may not be comparable to real interactions with unfamiliar others. Nevertheless, Experiment 3 suggests that the positive impact of virtual hugging is not hampered by a lack of familiarity with the hugged virtual other. This result pattern is consistent with previous touch studies, in which familiarity of the toucher did not matter too much for at least adult participants (Packheiser et al., 2024). Also another reason may be possible: as our samples are university students, the familiar target avatar was designed according to their friends rather than partners. Previous findings suggest that touch from romantic partners may be more effective than friend and strangers, while touch effectiveness from the latter two may be similar (Floyd et al., 2018; Saarinen et al., 2021).

EXPERIMENT 4. THE EFFECT OF EMBODIMENT TOWARD THE VIRTUAL AVATAR

In Experiment 4, we investigated the effect of embodiment (Maselli & Slater, 2013) toward the virtual me-avatar. The embodiment of physical bodies is generally assumed to influence how individuals perceive the world (Cosmelli & Thompson, 2011). Embodiment has at least three main properties: (1) a highly spatially specific representation of self in the body (i.e. people locate themselves inside the skin of their body); (2) the self-attribution of this spatial representation; and (3) the assumption that the body acts out one's own will (Ma et al., 2023). In the words of Kilteni et al. (2012), the sense of embodiment (i.e. the degree to which participants feel a virtual body is their own) relies on self-location (me located in the virtual body), agency (me controlling the virtual body's movements), and ownership (the appearance of the virtual body is consistent to my memory). Given that Experiments 1–3 have already shown the importance of agency, as participants freely controlled the me-avatar to hug the target avatar and watched this event in the virtual mirror, Experiment 4 focused on the influence of the two remaining factors: self-location and ownership.

We manipulated ownership by varying the facial resemblance between participants' own face and the face of their me-avatar, which participants could watch through the virtual mirror. We hypothesized that, if embodiment plays a role, this resemblance should increase the impact of virtual hugging on sadness reduction, as implied by a previous study (Senel et al., 2023). We manipulated location by varying perspectives: first vs. third-person perspective (1PP/3PP). Studies have found that the embodiment sense in 3PP is not as strong as in 1PP (Slater et al., 2010), and compared to 3PP, the activation of the motor cortex during motion observation or imagination is stronger in 1PP (Ge et al., 2018; Lorey et al., 2009). We thus inferred that 1PP may improve sadness reduction as compared to 3PP.

Method

A 2 (Perspective) × 2 (Resemblance) within-subject design was employed. The resemblance degree was manipulated by building the virtual avatar face with participants' own facial photo or using a pre-built avatar, which was the same as the avatar in Experiments 1 and 2. The dependent variables were the same as before. See Table 8.

Participants

Forty female undergraduate students from Southwest University participated in the experiment. After preliminary analysis of the data from 40 participants and post-experiment interviews, three participants with inadequate data were excluded, resulting in a total of 37 valid datasets. The participants' ages ranged from 18 to 24 years ($M = 20.90$, $SD = 1.39$).

Research materials

We used a body embodiment questionnaire (Kokkinara et al., 2015; Ma et al., 2023), assessing the sense of agency, self-location, and the sense of ownership. The questionnaire included

TABLE 8 Experimental design of Experiment 4.

Condition	Me-avatar face	Perspective
1. Own/1 pp	Own face	1 pp
2. Unfamiliar/1 pp	Unfamiliar/avatar face	1 pp
3. Own/3 pp	Own face	3 pp

Likert scales ranging from 1 to 7, where 1 represented strongly disagree, 4 represented undecided, and 7 represented strongly agree. The average score across all questions was taken as the subjective sense of body ownership.

Q1. During the game I felt as if I was located where I saw the virtual avatar to be.
Q2. During the game I felt that the virtual avatar was me.
Q3. The movements of the virtual avatar were caused by my movements.
Q4. It seemed that I can control the virtual avatar.

Research procedure

The experimental procedure was similar to the other experiments, with the only differences in the virtual hugging stage (see Figure 10). 1PP: Participants were located in the body of the

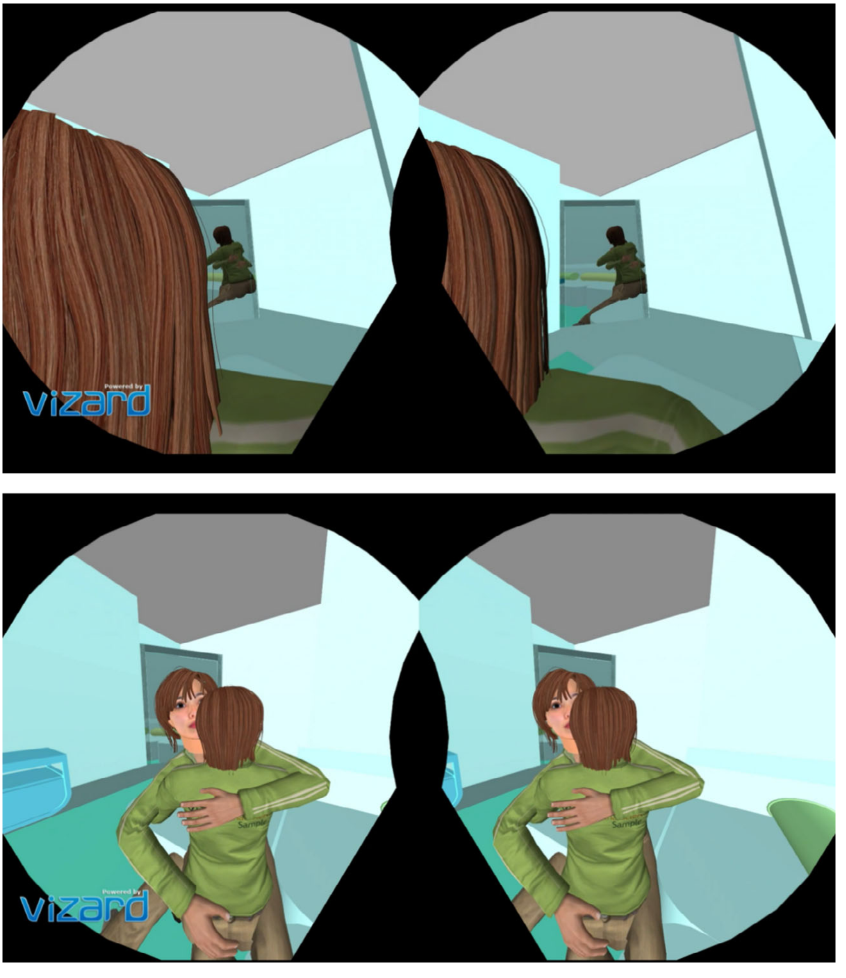

FIGURE 10 (upper panel) First-person perspective (1PP), (lower panel) third-person perspective (3PP) in Experiment 4.

virtual me-avatar and controlled it at will; they could see their virtual "me" avatar through the virtual mirror, as in Experiment 1. 3PP: Participants were located out of and behind the virtual avatars; they could control and see the virtual me-avatar and the hugging from 3PP or through the virtual mirror.

Results

Manipulation checks

Ownership results were tested by means of a repeated measures analysis ANOVA with condition as factor. The analysis revealed a significant main, $F(2,70) = 7.937$, $p = .001$, $p\eta 2 = 0.185$. LSD post hoc comparisons showed that ownership ratings were significantly higher in Condition 1 (mean = 9.333, SE = 0.326) than in Condition 2 (mean = 7.833, SE = 0.502), with Mean Difference = 1.500, SE = 0.628, $p < .022$, or Condition 3 (mean = 7.139, SE = 0.515), with Mean Difference = 2.194, SE = 0.632, $p = .001$, while Condition 2 did not differ from Condition 3, with Mean Difference = 0.694, SE = 0.396, $p = .88$. Hence, visual resemblance between participant and me-avatar boost perceived ownership, when combined with 1 pp.

Ratings

A 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 3 (Condition) repeated measures ANOVA yielded a significant main effect of time stage, $F(2,70) = 249.391$, $p < .001$, $p\eta 2 = 0.877$, but no effect of experimental condition, $p = .294$. The interaction was significant, $F(4,140) = 2.610$, $p = .038$, $p\eta 2 = 0.069$. Separate one-factorial ANOVAs showed significant effects of time stage for all three Conditions: 1. $F(2,70) = 137.060$, $p < .001$, $p\eta 2 = 0.797$; 2. $F(2,70) = 111.779$, $p < .001$, $p\eta 2 = 0.762$; and 3. $F(2,70) = 82.898$, $p < .001$, $p\eta 2 = 0.703$. See Figure 11 and Table 9.

LSD comparisons showed significant increases of sadness from baseline to post-induction for all three conditions: Cond1. Mean Difference = 2.222, SE = 0.165, $p < .001$; Cond2. Mean Difference = 2.389, SE = 0.208, $p < .001$; and Cond3. Mean Difference = 2.250, SE = 0.212, $p < .001$, indicating again that the induction of sadness worked. Sadness decreased significantly

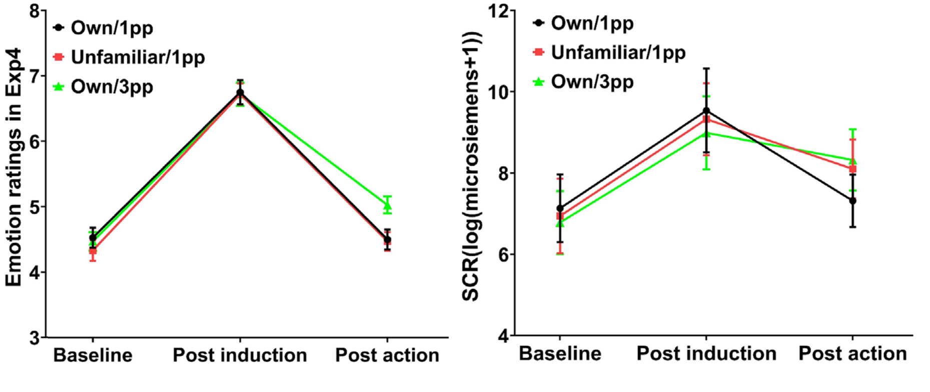

FIGURE 11 Sadness levels under different experimental conditions at different time stages in Experiment 4.

TABLE 9 Sadness levels at different embodiment degree and time stages, in Experiment 4 ($n = 40$).

Stage	Measure	Condition	M	SE
Baseline	Emotion ratings	1. Own/1 pp	4.528	0.152
		2. Unfamiliar/1 pp	4.333	0.159
		3. Own/3 pp	4.472	0.141
	SCR	1. Own/1 pp	7.131	0.835
		2. Unfamiliar/1 pp	6.942	0.917
		3. Own/3 pp	6.781	0.773
Post-induction	Emotion ratings	1. Own/1 pp	6.750	0.184
		2. Unfamiliar/1 pp	6.722	0.162
		3. Own/3 pp	6.722	0.176
	SCR	1. Own/1 pp	9.535	1.031
		2. Unfamiliar/1 pp	9.323	0.884
		3. Own/3 pp	8.989	0.899
Post-action	Emotion ratings	1. Own/1 pp	4.500	0.152
		2. Unfamiliar/1 pp	4.472	0.141
		3. Own/3 pp	5.028	0.129
	SCR	1. Own/1 pp	7.314	0.647
		2. Unfamiliar/1 pp	8.099	0.728
		3. Own/3 pp	8.321	0.754

Abbreviation: SCR, skin conductance response.

from post-induction to post-action in all three conditions: Cond1. Mean Difference = 2.250, SE = 0.156, $p < .001$; Cond2. Mean Difference = 2.250, SE = 0.140, $p < .001$; and Cond3. Mean Difference = 1.694, SE = 0.182, $p < .001$, indicating that all actions were accompanied by a reduction of sadness. This reduction reached the original baseline for the 1 pp conditions, as implied by the nonsignificance of differences between baseline and post-action in Cond1, Mean Difference = 0.028, SE = 0.146, $p = .851$, and Cond2, Mean Difference = 0.139, SE = 0.183, $p = .454$, while in Cond3, sadness was still significantly higher at post-action as compared to baseline, Mean Difference = 0.56, SE = 0.146, $p = .001$.

SCR

A 3 (Time Stage: Baseline vs. post-induction vs. post-action) * 3 (Condition) repeated measures ANOVA revealed a significant main effect of time stage, $F(2,70) = 26.316$, $p < .001$, pŋ2 = 0.429, but no significant effect of conditions, $p = .925$, or an interaction, $p = .257$. LSD comparisons showed that SCR increased from baseline to post-induction, Mean Difference = 2.331, SE = 0.319, $p < .001$, decreased from post-induction to post-action, Mean Difference = 1.371, SE = 0.308, $p < .001$, but the post-action SCR was still significantly higher than at baseline, Mean Difference = 0.960, SE = 0.341, $p = .008$. As before, this pattern suggests that the sadness induction worked, and that SCR may change more slowly than ratings do. It does not suggest differences between the three conditions, however.

Discussion

The ratings suggest that participants did not care whether the me-avatar was or was not similar to themselves, as long as hugging occurred under 1 pp conditions. Hence, it is the perspective that matters (Petkova & Ehrsson, 2008). This time, the SCR data did not only differ with respect to the degree to which the baseline level was reached after action but they also failed to show any difference between 1 and 3 pp. This may to some extent be consistent with previous studies showing that vicarious touch has a stronger impact on SCR than on subjective feelings. For example, research has shown that individuals can accurately recognize different emotional states when observing others engaging in touch communication, suggesting that vicarious touch may elicit similar emotional responses as personal touch (Walker et al., 2017). Moreover, when individuals observe others being touched, similar brain regions are activated as when they themselves are touched (Rigato et al., 2019). It thus may be possible that subjective feelings were mediated by cognitive processes including considerations about embodiment, in a top-down fashion; in contrast, the SCR might have been triggered more in a bottom-up fashion, thereby reduce the impact of embodiment (Ma & Hommel, 2013).

COMPARISON ACROSS EXPERIMENTS

Given that four conditions of our four experiments had very similar designs (viz., Condition 1 of Experiment 1, Condition 1 of Experiment 2, Condition 2 of Experiment 3, and Condition 2 of Experiment 4), we compared these four conditions in a cross-experimental ANOVA of ratings and SCRs with experiment as factor. Nothing significant was found, however, in the emotion ratings, $p = .296$, or SCRs, $p = .571$. The results again verified that the effectiveness and robustness of virtual hugging on emotion regulation across different samples. In view of the remaining differences between these conditions, this can be taken to suggest that haptic information is not as important as visual information if it comes to the impact of virtual hugging on emotion regulation. Indeed, considering that in all these conditions participants could freely control the movement of the me-avatar in 1PP, the visuomotor correlation can be taken to be sufficient to induce embodiment (Ma & Hommel, 2015) and thus contribute to emotion regulation, whereas haptic information and visuo-haptic modality congruency may not add much.

GENERAL DISCUSSION

The current study aimed to test whether, and to what degree, virtual hugging might serve to reduce personal sadness. We explored several factors that the existing literature deems as potentially important, including the target of the hugging action, the characteristics of the me-avatar, and the avatar representing the hugged other, multisensory visuo-haptic-motor integration, familiarity, and embodiment.

Experiment 1 established the effectiveness of virtual hugging in the regulation of sadness, and the other experiments demonstrate that this effect is replicable. Previous studies have indicated that hugging behavior itself, or the so-called self-touch, may already be sufficient to reduce stress and cortisol responses (Dreisoerner et al., 2021). This raised the possibility that mere hugging may already improve sadness, even in the absence of any target. However, Experiment 1 indicated that mere hugging is not sufficient, but that some virtual target is needed. Previous studies that might be taken to suggest that hugging might work by itself (e.g. Fromme et al., 1989) might actually reflect the impact of the readiness or intention to interpret touch as positive, rather than any effect of the hug actually given. Participants may acquire beliefs that self-soothing touch may be a good means to regulate stress through experience or communication, and it may be these beliefs that are at play in studies demonstrating an impact of self (Dreisoerner et al., 2021). However, moving such scenarios to VR might reduce the impact of experience from real life, which may explain that we did not find any evidence for the impact of hugging actions as such. In other words, it is not impossible that moving our designs back to real life shows a stronger effect of the hugging action on its own.

In Experiment 2, we tested the possible impact of haptic information and visuo-haptic correspondence on the virtual hugging effect, because previous research with hugging robots has emphasized the importance of multimodal information and integration (Eckstein et al., 2020; Geva et al., 2022). While all we found were a few numerical hints without any statistical significance. Accordingly, our findings indicated that the visual experience of a hugging agent and a receiving other, together with the motor experience of hugging action, are sufficient to support people's regulation of sadness.

In addition, previous research also suggested that the characteristics of the receiving other, the hugging target might matter. It was reported that social support from familiar audiences reduces self-reported anxiety, even without showing stress-buffering effects on cortisol levels (Debrot et al., 2024; Mascret et al., 2019). Though checks confirmed that our manipulation of familiarity of the target in Experiment 3 worked as intended, we did not find any evidence for a role of familiarity. For one, this may have to do with the fact that previous studies, like that of Mascret et al. (2019), signaled social support by providing facial and bodily information, which may have attracted the attention of participants significantly. In contrast, our research design in VR environment might have attracted attention more to the hugging process, so that facial features may have been more neglected. For another, previous studies (e.g. Debrot et al., 2024) have manipulated the familiarity degree with romantic partners and opposite-gender strangers, while we used same-gender virtual avatars with different faces—which may also have induced other forms of attentional salience. Nevertheless, our observation, that familiarity does not seem to play a central role for the impact of hugging, is consistent with findings showing that social robots (which are clearly unfamiliar to us and dissimilar to our acquaintance) can help with pain and stress relief through interactive touch (Geva et al., 2022).

Also consistent with previous observations (e.g. Petkova & Ehrsson, 2008) is our finding in Experiment 4 that a 1PP renders virtual hugging more effective. As our embodiment sense to our real body naturally implies the self-location, which is that "I" locate in my own body and interact with outside world from a 1PP. If so, with the 1PP, as compared to the third-person perspective, the participant more likely feels it is me who is hugging, but not just observing and imitating. While, the resemblance between participant and the me-avatar is not so important, as indicated in previous studies, with matched multisensory stimuli, people are easily to obtain embodiment sense toward avatars of different face and body features (Maister et al., 2015).

CONCLUSIONS

In this study, we verified the effectiveness of virtual hugging on sadness regulation and identified the contribution of several factors from hugging interaction, virtual target characteristics, and me-avatar embodiment. Considering the development of VR technological and practical demands of human society, VR hugging may be of great promise for not only sad emotion regulation but also human well-being promotion.

LIMITATIONS

Some limitations in both our experimental design and technical aspects may be considered in guiding future investigations. Firstly, we tested females only, which begs the question whether males may equally benefit from virtual hugging. As pointed out, sexes seem to differ in emotion response and regulation (Domes et al., 2010; Gardener et al., 2013; Kinner et al., 2014), and females tend to be more easily influenced by social hugging (Benenson, 2013), which may result in different findings in male participants. Another question is whether familiarity and similarity effects, which were lacking in our experiments, are stronger if the avatar modeling is improved and/or if the attention of participants to particular details is under tighter experimental control. Finally, it might be interesting to study if the strength of hugging effects varies with individual traits, and whether they are similar to other negative emotions, such as stress, fear, and anxiety.

ACKNOWLEDGMENTS
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CONFLICT OF INTEREST STATEMENT
The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article. All procedures performed in this study were in accordance with the ethical standards of the ethics committee of Southwest University and with the 1964 Helsinki declaration and its later amendments. Informed consents were obtained from all participants included in this study.

DATA AVAILABILITY STATEMENT
Raw data of the study are available on the Open Science Framework (https://osf.io/2cd5f/); the Experiment was not preregistered.

ETHICS STATEMENT
Ethical approval was obtained from the Southwest University in China prior to data collection (H24021).

ORCID
Ke Ma https://orcid.org/0000-0001-8240-4786

REFERENCES
Ahmed, I., Harjunen, V. J., Jacucci, G., Ravaja, N., Ruotsalo, T., & Spapé, M. M. (2020). Touching virtual humans: Haptic responses reveal the emotional impact of affective agents. *IEEE Transactions on Affective Computing*, *14*(1), 331–342. https://doi.org/10.1109/TAFFC.2020.3038137

Aknin, L. B., De Neve, J. E., Dunn, E. W., Fancourt, D. E., Goldberg, E., Helliwell, J. F., Jones, S. P., Karam, E., Layard, R., Lyubomirsky, S., Rzepa, A., Saxena, S., Thornton, E. M., VanderWeele, T. J., Whillans, A. V., Zaki, J., Karadag, O., & Ben Amor, Y. (2022). Mental health during the first year of the COVID-19 pandemic:

A review and recommendations for moving forward. *Perspectives on Psychological Science*, *17*(4), 915–936. https://doi.org/10.1177/17456916211029964

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. https://doi.org/10.1037/0022-3514.63.4.596

Askari, S. I., Harjunen, V. J., Spapé, M. M., Haans, A., Ravaja, N., & Ijsselsteijn, W. A. (2021). Receiving a mediated touch from your partner vs. a male stranger: How visual feedback of touch and its sender influence touch experience. *IEEE Transactions on Affective Computing*, *14*(2), 1044–1055.

Banks, S. J., Bellerose, J., Douglas, D., & Jones-Gotman, M. (2012). Bilateral skin conductance responses to emotional faces. *Applied Psychophysiology and Biofeedback*, *37*(3), 145–152. https://doi.org/10.1007/s10484-011-9177-7

Benenson, J. (2013). The development of human female competition: Allies and adversaries. *Philosophical Transactions of the Royal Society B*, *368*, 20130079. https://doi.org/10.1098/rstb.2013.0079

Beverly, E., Hommema, L., Coates, K., Duncan, G., Gable, B., Gutman, T., Love, M., Love, C., Pershing, M., & Stevens, N. (2022). A tranquil virtual reality experience to reduce subjective stress among COVID-19 frontline healthcare workers. *PLoS ONE*, *17*(2), e0262703. https://doi.org/10.1371/journal.pone.0262703

Block, A. E., & Kuchenbecker, K. J. (2019). Softness, warmth, and responsiveness improve robot hugs. *International Journal of Social Robotics*, *11*(1), 49–64. https://doi.org/10.1007/s12369-018-0495-2

Bonanno, G. A. (2004). Loss, trauma, and human resilience: Have we underestimated the human capacity to thrive after extremely aversive events? *The American Psychologist*, *59*(1), 20–28. https://doi.org/10.1037/0003-066X.59.1.20

Buecker, S., & Horstmann, K. T. (2021). Loneliness and social isolation during the COVID-19 pandemic: A systematic review enriched with empirical evidence from a large-scale diary study. *European Psychologist*, *26*(4), 272–284. https://doi.org/10.1027/1016-9040/a000453

Bufo, M. R., Guidotti, M., Mofid, Y., Malvy, J., Bonnet-Brilhault, F., Aguillon-Hernandez, N., & Wardak, C. (2022). Atypical response to affective touch in children with autism: Multi-parametric exploration of the autonomic system. *Journal of Clinical Medicine*, *11*(23), 7146. https://doi.org/10.3390/jcm11237146

Cacioppo, J. T., Klein, D. J., Bemtson, G. G., & Hatfield, E. (1993). The psychophysiology of emotion. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 109–142). Guilford Press.

Cohen, S., Janicki-Deverts, D., Turner, R. B., & Doyle, W. J. (2015). Does hugging provide stress-buffering social support? A study of susceptibility to upper respiratory infection and illness. *Psychological Science*, *26*(2), 135–147. https://doi.org/10.1177/0956797614559284

Cosmelli, D., & Thompson, E. (2011). Embodiment or envatment? Reflections on the bodily basis of consciousness. In J. Stewart, O. Gapenne, & E. di Paolo (Eds.), *Enaction: Towards a new paradigm for cognitive science* (pp. 361–386). MIT Press.

Debrot, A., Stellar, J. E., Dan-Glauser, E., & Klumb, P. L. (2024). Touch as a stress buffer? Gender differences in subjective and physiological responses to partner and stranger touch. *Journal of Nonverbal Behavior*, *48*, 1–20. https://doi.org/10.1007/s10919-024-00455-y

Domes, G., Schulze, L., Böttger, M., Grossmann, A., Hauenstein, K., Wirtz, P. H., Heinrichs, M., & Herpertz, S. C. (2010). The neural correlates of sex differences in emotional reactivity and emotion regulation. *Human Brain Mapping*, *31*(5), 758–769. https://doi.org/10.1002/hbm.20903

Dreisoerner, A., Junker, N. M., Schlotz, W., Heimrich, J., Bloemeke, S., Ditzen, B., & van Dick, R. (2021). Self-soothing touch and being hugged reduce cortisol responses to stress: A randomized controlled trial on stress, physical touch, and social identity. *Comprehensive Psychoneuroendocrinology*, *8*, 100091. https://doi.org/10.1016/j.cpnec.2021.100091

Dryman, M. T., & Heimberg, R. G. (2018). Emotion regulation in social anxiety and depression: A systematic review of expressive suppression and cognitive reappraisal. *Clinical Psychology Review*, *65*, 17–42. https://doi.org/10.1016/j.cpr.2018.07.004

Eckstein, M., Mamaev, I., Ditzen, B., & Sailer, U. (2020). Calming effects of touch in human, animal, and robotic interaction—Scientific state-of-the-art and technical advances. *Frontiers in Psychiatry*, *11*, 555058. https://doi.org/10.3389/fpsyt.2020.555058

Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, *415*(6870), 429–433. https://doi.org/10.1038/415429a

Field, T. (2019). Social touch, CT touch and massage therapy: A narrative review. *Developmental Review*, *51*, 123–145. https://doi.org/10.1016/j.dr.2019.01.002

Floyd, K., Ray, C. D., van Raalte, L. J., Stein, L. J., & Generous, M. J. (2018). Interpersonal touch buffers pain sensitivity in romantic relationships but heightens sensitivity between strangers and friends. *Research in Psychology and Behavioral Sciences*, *6*(1), 27–34. https://doi.org/10.12691/rpbs-6-1-4

Fredrickson, B. L., & Branigan, C. (2005). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition & Emotion*, *19*(3), 313–332. https://doi.org/10.1080/02699930441000238

Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B., & Slater, M. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological Medicine*, *47*(14), 2393–2400. https://doi.org/10.1017/S003329171700040X

Fromme, D. K., Jaynes, W. E., Taylor, D. K., Hanold, E. G., Daniell, J., Rountree, J. R., & Fromme, M. L. (1989). Nonverbal behavior and attitudes toward touch. *Journal of Nonverbal Behavior*, *13*(1), 3–14. https://doi.org/10.1007/BF01006469

Gardener, E. K., Carr, A. R., MacGregor, A., & Felmingham, K. L. (2013). Sex differences and emotion regulation: An event-related potential study. *PLoS ONE*, *8*(10), e73475. https://doi.org/10.1371/journal.pone.0073475

Ge, S., Liu, H., Lin, P., Gao, J., Xiao, C., & Li, Z. (2018). Neural basis of action observation and understanding from first-and third-person perspectives: An fMRI study. *Frontiers in Behavioral Neuroscience*, *12*, 283. https://doi.org/10.3389/fnbeh.2018.00283

Geva, N., Hermoni, N., & Levy-Tzedek, S. (2022). Interaction matters: The effect of touching the social robot PARO on pain and stress is stronger when turned ON vs OFF. *Frontiers in Robotics and AI*, *9*, 926185. https://doi.org/10.3389/frobt.2022.926185

Girvan, C. (2018). What is a virtual world? Definition and classification. *Educational Technology Research and Development*, *66*(5), 1087–1100. https://doi.org/10.1007/s11423-018-9577-y

Goldstein, P., Shamay-Tsoory, S. G., Yellinek, S., & Weissman-Fogel, I. (2016). Empathy predicts an experimental pain reduction during touch. *The Journal of Pain*, *17*(10), 1049–1057. https://doi.org/10.1016/j.jpain.2016.06.007

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: The acute effects of inhibiting negative and positive emotion. *Journal of Abnormal Psychology*, *106*(1), 95–103. https://doi.org/10.1037/0021-843X.106.1.95

Gryksa, K., & Neumann, I. D. (2022). Consequences of pandemic-associated social restrictions: Role of social support and the oxytocin system. *Psychoneuroendocrinology*, *135*, 105601. https://doi.org/10.1016/j.psyneuen.2021.105601

Harris, L. M., & Cumming, S. R. (2003). An examination of the relation ship between anxiety and performance on prospective and retrospective memory tasks. *Australian Journal of Psychology*, *55*, 51–55. https://doi.org/10.1080/00049530412331312874

Haynes, A. C., Lywood, A., Crowe, E. M., Fielding, J. L., Rossiter, J. M., & Kent, C. (2022). A calming hug: Design and validation of a tactile aid to ease anxiety. *PLoS ONE*, *17*(3), e0259838. https://doi.org/10.1371/journal.pone.0259838

Hedayati, H., Bhaduri, S., Sumner, T., Szafir, D., & Gross, M. D. (2019). HugBot: A soft robot designed to give human-like hugs. In *Proceedings of the 18th ACM international conference on interaction design and children* (pp. 556–561).

Helbig, H. B., & Ernst, M. O. (2007). Optimal integration of shape information from vision and touch. *Experimental Brain Research*, *179*(4), 595–606. https://doi.org/10.1007/s00221-006-0814-y

Keshmiri, S., Sumioka, H., Nakanishi, J., & Ishiguro, H. (2018). Bodily-contact communication medium induces relaxed mode of brain activity while increasing its dynamical complexity: A pilot study. *Frontiers in Psychology*, *9*, 1192. https://doi.org/10.3389/fpsyg.2018.01192

Kilteni, K., Groten, R., & Slater, M. (2012). The sense of embodiment in virtual reality. *Presence Teleoperators and Virtual Environments*, *21*(4), 373–387. https://doi.org/10.1162/PRES_a_00124

Kinner, V. L., Het, S., & Wolf, O. T. (2014). Emotion regulation: Exploring the impact of stress and sex. *Frontiers in Behavioral Neuroscience*, *8*, 397. https://doi.org/10.3389/fnbeh.2014.00397

Kokkinara, E., Slater, M., & López-Moliner, J. (2015). The effects of Visuomotor calibration to the perceived space and body, through embodiment in immersive virtual reality. *ACM Transactions on Applied Perception*, *13*, 1–22. https://doi.org/10.1145/2818998

Koole, S. L. (2010). The psychology of emotion regulation: An integrative review. *Cognition and Emotion*, *23*(1), 138–177.

Kreibig, S. D., Wilhelm, F. H., Roth, W. T., & Gross, J. J. (2007). Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing films. *Psychophysiology*, *44*, 787–806. https://doi.org/10.1111/j.1469-8986.2007.00550.x

Lalanne, C., & Lorenceau, J. (2004). Crossmodal integration for perception and action. *Journal of Physiology—Paris*, *98*(1–3), 265–279. https://doi.org/10.1016/j.jphysparis.2004.06.001

Lanfranco, R. C., Chancel, M., & Ehrsson, H. H. (2024). Texture congruence modulates perceptual bias but not sensitivity to visuotactile stimulation during the rubber hand illusion. *Cognitive, Affective, & Behavioral Neuroscience*, *24*(1), 100–110. https://doi.org/10.3758/s13415-024-01155-2

Levav, J., & Argo, J. J. (2010). Physical contact and financial risk taking. *Psychological Science*, *21*(6), 804–810. https://doi.org/10.1177/0956797610369493

Lorey, B., Bischoff, M., Pilgramm, S., Stark, R., Munzert, J., & Zentgraf, K. (2009). The embodied nature of motor imagery: The influence of posture and perspective. *Experimental Brain Research*, *194*, 233–243. https://doi.org/10.1007/s00221-008-1693-1

Ma, K., & Hommel, B. (2013). The virtual-hand illusion: Effects of impact and threat on perceived ownership and affective resonance. *Frontiers in Psychology*, *4*, 604. https://doi.org/10.3389/fpsyg.2013.00604

Ma, K., & Hommel, B. (2015). The role of agency for perceived ownership in the virtual hand illusion. *Consciousness and Cognition*, *36*, 277–288. https://doi.org/10.1016/j.concog.2015.07.008

Ma, K., Yang, L., & Hommel, B. (2023). 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., Slater, M., Sanchezvives, M. V., & Tsakiris, M. (2015). Changing bodies changes minds: Owning another body affects social cognition. *Trends in Cognitive Sciences*, *19*(1), 6–12.

Marucci, M., Di Flumeri, G., Borghini, G., Sciaraffa, N., Scandola, M., Pavone, E. F., Babiloni, F., Betti, V., & Aricò, P. (2021). The impact of multisensory integration and perceptual load in virtual reality settings on performance, workload and presence. *Scientific Reports*, *11*(1), 4831. https://doi.org/10.1038/s41598-021-84196-8

Mascret, N., Vors, O., Marqueste, T., Casanova, R., & Cury, F. (2019). Social support from evaluative familiar persons–a buffer against stress? Preliminary evidence of neuroendocrine and psychological responses. *Anxiety, Stress, and Coping*, *32*(5), 534–544. https://doi.org/10.1080/10615806.2019.1638680

Maselli, A., & Slater, M. (2013). The building blocks of the full body ownership illusion. *Frontiers in Human Neuroscience*, *7*, 83. https://doi.org/10.3389/fnhum.2013.00083

Miller, L. E., Longo, M. R., & Saygin, A. P. (2017). Visual illusion of tool use recalibrates tactile perception. *Cognition*, *162*, 32–40. https://doi.org/10.1016/j.cognition.2017.01.022

Mohr, D. C., Burns, M. N., Schueller, S. M., Clarke, G., & Klinkman, M. (2013). Behavioral intervention technologies: Evidence review and recommendations for future research in mental health. *General Hospital Psychiatry*, *35*(4), 332–338. https://doi.org/10.1016/j.genhosppsych.2013.03.008

Morhenn, V., Beavin, L. E., & Zak, P. J. (2012). Massage increases oxytocin and reduces adrenocorticotropin hormone in humans. *Alternative Therapies in Health and Medicine*, *18*(6), 11–18.

Morrison, I. (2016a). Keep calm and cuddle on: Social touch as a stress buffer. *Adaptive Human Behavior and Physiology*, *2*, 344–362. https://doi.org/10.1007/s40750-016-0052-x

Morrison, I. (2016b). ALE meta-analysis reveals dissociable networks for affective and discriminative aspects of touch. *Human Brain Mapping*, *37*(4), 1308–1320. https://doi.org/10.1002/hbm.23103

Packheiser, J., Hartmann, H., Fredriksen, K., Gazzola, V., Keysers, C., & Frédéric, M. (2024). A systematic review and multivariate meta-analysis of the physical and mental health benefits of touch interventions. *Nature Human Behaviour*, *8*(6), 1088–1107. https://doi.org/10.1038/s41562-024-01841-8

Packheiser, J., Malek, I. M., Reichart, J. S., Katona, L., Luhmann, M., & Ocklenburg, S. (2022). The Association of Embracing with daily mood and general life satisfaction: An ecological momentary assessment study. *Journal of Nonverbal Behavior*, *46*(4), 519–536. https://doi.org/10.1007/s10919-022-00411-8

Packheiser, J., Sommer, L., Wüllner, M., Malek, I. M., Reichart, J. S., Katona, L., Luhmann, M., & Ocklenburg, S. (2023). A Comparison of hugging frequency and its association with momentary mood before and during

COVID-19 using ecological momentary assessment. *Health Communication*, *39*(5), 951–959. https://doi.org/10.1080/10410236.2023.2198058

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PLoS ONE*, *3*, e3832. https://doi.org/10.1371/journal.pone.0003832

Ravaja, N., Harjunen, V., Ahmed, I., Jacucci, G., & Spapé, M. M. (2017). Feeling touched: Emotional modulation of somatosensory potentials to interpersonal touch. *Scientific Reports*, *7*, 40504. https://doi.org/10.1038/srep40504

Rigato, S., Bremner, A. J., Gillmeister, H., & Banissy, M. J. (2019). Interpersonal representations of touch in somatosensory cortex are modulated by perspective. *Biological Psychology*, *146*, 107719. https://doi.org/10.1016/j.biopsycho.2019.107719

Riva, G., Bernardelli, L., Browning, M. H. E. M., Castelnuovo, G., Cavedoni, S., Chirico, A., Cipresso, P., de Paula, D. M. B., Di Lernia, D., Fernández-Álvarez, J., Figueras-Puigderrajols, N., Fuji, K., Gaggioli, A., Gutiérrez-Maldonado, J., Hong, U., Mancuso, V., Mazzeo, M., Molinari, E., Moretti, L. F., … Wiederhold, B. K. (2020). COVID feel good—An easy self-help virtual reality protocol to overcome the psychological burden of coronavirus. *Frontiers in Psychiatry*, *11*, 563319. https://doi.org/10.3389/fpsyt.2020.563319

Rottenberg, J. (2005). Mood and emotion in major depression. *Current Directions in Psychological Science*, *14*(3), 167–170. https://doi.org/10.1111/j.0963-7214.2005.00354.x

Rucci, P., Frank, E., Calugi, S., Miniati, M., Benvenuti, A., Wallace, M., Fagiolini, A., Maggi, L., Kupfer, D. J., & Cassano, G. B. (2011). Incidence and predictors of relapse during continuation treatment of major depression with SSRI, interpersonal psychotherapy, or their combination. *Depression and Anxiety*, *28*(11), 955–962. https://doi.org/10.1002/da.20894

Saarinen, A., Harjunen, V. J., Jasinskaja-Lahti, I., Jskelinen, I. P., & Ravaja, N. (2021). Social touch experience in different contexts: A review. *Neuroscience & Biobehavioral Reviews*, *131*(3), 360–372. https://doi.org/10.1016/j.neubiorev.2021.09.027

Schirmer, A., Cham, C., Zhao, Z., Lai, O., Lo, C., & Croy, I. (2022). Understanding sex differences in affective touch: Sensory pleasantness, social comfort, and precursive experiences. *Physiology & Behavior*, *250*, 113797. https://doi.org/10.1016/j.physbeh.2022.113797

Senel, G., Macia-Varela, F., Gallego, J., Jensen, H. P., Hornbæk, K., & Slater, M. (2023). Imperceptible body transformation in virtual reality: Saliency of self representation. *Iscience*, *26*(10), 107938. https://doi.org/10.1016/j.isci.2023.107938

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLoS ONE*, *5*(5), e10564. https://doi.org/10.1371/journal.pone.0010564

Sorokowska, A., Stefańczyk, M. M., Płachetka, J., Dudojć, O., Ziembik, K., Chabin, D., & Croy, I. (2021). Touch-avoidance and touch-seeking in non-intimate relationships: The null effects of sightedness. *Journal of Visual Impairment & Blindness*, *115*(5), 459–468. https://doi.org/10.1177/0145482X211047625

Spitoni, G. F., Pietro, Z., Guido, G., Gabriella, A., Gaspare, G., Vittorio, L., Gianluca, C., Giulia, T., & Maddalena, B. (2020). Disorganized attachment pattern affects the perception of affective touch. *Scientific Reports*, *10*(1), 9658. https://doi.org/10.1038/s41598-020-66606-5

Sumioka, H., Keshmiri, S., & Ishiguro, H. (2019). Information-theoretic investigation of impact of huggable communication medium on prefrontal brain activation. *Advanced Robotics*, *33*(20), 1019–1029. https://doi.org/10.1080/01691864.2019.1652114

Talsma, D. (2015). Predictive coding and multisensory integration: An attentional account of the multisensory mind. *Frontiers in Integrative Neuroscience*, *9*, 19. https://doi.org/10.3389/fnint.2015.00019

Trotter, P. D., McGlone, F., Reniers, R. L. E. P., & Deakin, J. F. W. (2018). Construction and validation of the touch experiences and attitudes questionnaire (TEAQ): A self-report measure to determine attitudes toward and experiences of positive touch. *Journal of Nonverbal Behavior*, *42*(4), 379–416. https://doi.org/10.1007/s10919-018-0281-8

van Anders, S. M., Goldey, K. L., & Kuo, P. X. (2011). The steroid/peptide theory of social bonds: Integrating testosterone and peptide responses for classifying social behavioral contexts. *Psychoneuroendocrinology*, *36*(9), 1265–1275. https://doi.org/10.1016/j.psyneuen.2011.06.001

van Raalte, L., & J., & Floyd, K. (2021). Daily hugging predicts lower levels of two Proinflammatory cytokines. *Western Journal of Communication*, *85*(4), 487–506. https://doi.org/10.1080/10570314.2020.1850851 van Rijsbergen, G. D., Bockting, C. L., Berking, M., Koeter, M. W., & Schene, A. H. (2012). Can a one-item mood scale do the trick? Predicting relapse over 5.5-years in recurrent depression. *PLoS ONE*, *7*(10), e46796. https://doi.org/10.1371/journal.pone.0046796

van Rijsbergen, G. D., Hollon, S. D., Elgersma, H. J., Kok, G. D., Dekker, J., Schene, A. H., & Bockting, C. L. (2015). Understanding emotion and emotional scarring in recurrent depression. *Comprehensive Psychiatry*, *59*, 54–61. https://doi.org/10.1016/j.comppsych.2015.02.010

Venkatesan, R. K., Banakou, D., Slater, M., & Manivannan, M. (2023). Haptic feedback in a virtual crowd scenario improves the emotional response. *Frontiers in Virtual Reality*, *4*, 1242587. https://doi.org/10.3389/frvir.2023.1242587

Walker, S. C., Trotter, P. D., Woods, A., & McGlone, F. (2017). Vicarious ratings of social touch reflect the anatomical distribution & velocity tuning of C-tactile afferents: A hedonic homunculus? *Behavioural Brain Research*, *320*, 91–96. https://doi.org/10.1016/j.bbr.2016.11.046

Wijaya, M., Lau, D., Horrocks, S., McGlone, F., Ling, H., & Schirmer, A. (2020). The human "feel" of touch contributes to its perceived pleasantness. *Journal of Experimental Psychology: Human Perception and Performance*, *46*(2), 155–171. https://doi.org/10.1037/xhp0000705

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