Is Seeing Believing? The Effect of Morphological Congruent Visual Feedback on Mediated Touch Experience

Sima Ipakchian Askari
Human-Technology Interaction group,
Eindhoven University of Technology
s.ipakchian.askari@tue.nl

Antal Haans
Human-Technology Interaction group,
Eindhoven University of Technology
a.haans@tue.nl

Wijnand A. IJsselsteijn
Human-Technology Interaction group,
Eindhoven University of Technology
w.a.ijsselsteijn@tue.nl

ABSTRACT

Mediated social touch (MST) provides physical contact over a distance for geographically separated individuals. Despite advances in actuator technologies, it remains difficult to recreate the feel and sensation of natural human touch. Combining touch with morphologically congruent visual feedback may overcome limitations related to the low fidelity of current-day tactile displays. Being able to both feel and see the touch act being initiated on an input device could enhance the perceived realism of the touches. In two studies, we test the effects of such visual feedback on self-reported naturalness of touch, social presence, and emotional experiences.

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KEYWORDS

Mediated social touch; computer mediated communication; haptic feedback; visual feedback, morphological congruency; media transparency; social presence

Figure 1: The morphological congruent visual feedback shown to participants.

Figure 2: The Morphological incongruent visual feedback shown to participants.

INTRODUCTION

Social touch is important for human development, interpersonal communication, social attachment and well-being [5]. For geographically separated individuals, so-called mediated social touch (MST) devices are being developed that allow for physical contact over a distance by means of tactile or haptic displays (for an overview see [5]). Despite technological advances in actuator technology, it remains difficult to reproduce the actual feel and sensation of naturalistic human touch.

Improving the experience of MST devices, however, may not necessarily require high fidelity tactile displays that mimic more closely real touch. Low fidelity head-mounted displays can create convincing experiences of being "there" in a computer simulated virtual environment (called presence [7]), and one can experience a rubber hand as being a part of one's own body, despite it being obviously fake [2]. Both phenomena are examples of so-called illusions of non-mediation, and rely on the capacity of the central nervous system (CNS) to incorporate technological tools and artifacts into our embodiment [4]. The illusion of non-mediation depends primarily on the extent to which the CNS can extract lawful correlations between various sensory modalities and motor actions (i.e., sensorimotor contingencies). Moving one's head while wearing a head-mounted display and seeing the image of the simulated environment being updated in a coherent manner is sufficient for the user to "forget" about the display, and to perceive and interact with the virtual content as if the mediating technology were not there—thus reaching a similar state of transparency as one experiences with one's own biological perceptual system. Similarly, seeing a fake hand being touched by a brush, while feeling one's own concealed hand being stimulated in a similar manner, can produce feelings of bodily ownership over the fake hand. The strength of this rubber hand illusion (RHI) depends on temporal and spatial synchrony of seen and felt touch (i.e., the mapping between seen and felt touch), and is constrained, top-down, by visual dissimilarities in form between the external object and a real human hand (i.e., an effect of morphological congruence; [8]).

Research investigating whether correlated multimodal stimulation can render existing MST displays more transparent—and thus the mediated touches more realistic—remains rare. In Haans and IJsselsteijn [3], participants received vibrotactile stimulation to several body parts while simultaneously seeing the touch act being performed through either a button press on a touch screen (incongruent visual feedback) or by moving a finger over a sensor-equipped mannequin (congruent feedback in terms of both mapping and form). As expected, participants perceived the MST as more natural and also reported higher social presence (i.e., the feeling of being touched directly by the toucher) in the congruent visual feedback condition. However, this study involved a small sample of participants, preventing, for example, proper psychometric analysis of the self-report items used.

In the two present studies, we will extend the research by Haans and IJsselsteijn [3]. Using a more appropriate sample size, we first investigate the validity and reliability of the self-report items used

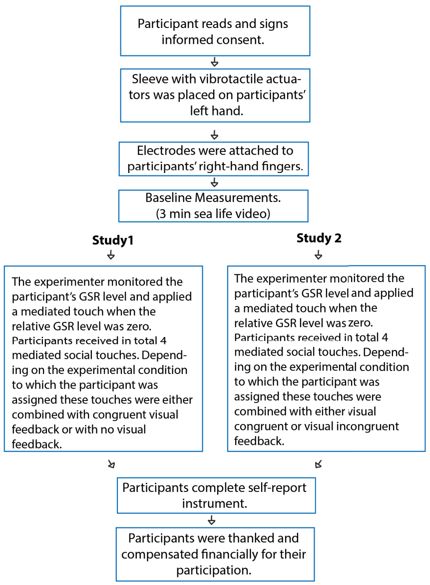

Figure 3: Experimental procedure of Studies 1 and 2

to assess perceived naturalness of the mediated touch, social presence, and emotional experience (i.e., valence and arousal). Using these self-reports, we compared MST experiences in conditions with and without visual feedback (congruent in mapping and form) in Study 1. In Study 2, we compare two conditions with visual feedback: one incongruent (button press on touch screen) and the other congruent in mapping and form (touch initiated by a finger touching a rubber hand).

METHOD

Participants

Seventy-one persons (26 males, 45 females) participated in Study 1. Mean age was 27 years (SD = 10.5; range 19 to 68). Eighty-four persons (38 males, 46 females) participated in Study 2. Mean age was 29 years (SD = 12.6; range 19 to 65). All participants were Dutch speaking.

Design and Apparatus

Both experiments involved a 2 condition (Study 1: congruent visual feedback vs. no visual feedback; Study 2: congruent vs. incongruent visual feedback) between-subject design in which participants received four mechanical touches to the forearm. In the feedback conditions participants simultaneously felt and saw the mediated touches being initiated through a television screen. In the congruent visual feedback condition of Study 1 and the congruent visual feedback condition of Study 2, participants saw the experimenter stroking a rubber hand to initiate the touches (Figure 1). In the morphological incongruent feedback condition the experimenter tapped on a touchscreen button labeled "forearm" (Figure 2). Mediated touched were delivered by a tactile display consisting of four 10 mm vibrotactile actuators type 0834 in a sleeve. The motors were activated by moving a magnet, attached to the experimenter's index finger, over four reed switches — each controlling one motor—placed inside the rubber hand. In the incongruent visual feedback condition, the rubber hand with reed-switches was placed outside the participant's view, and was touched by the experimenter right after pressing the "forearm" button on the touch screen. This way, the activation of the vibration motors was the same across experimental conditions. See Figure 3 for details on the procedure.

Measurements

Mediated touch experience was measured with a self-report instrument that included items tapping into the naturalness of touch (6 items), unpleasantness or valence of the touch (3 items), arousal (3 items), and social presence (6 items; see Table 1). Items were based on Haans and IJsselsteijn [3], and used a 5 point response format. Similar to Haans and IJsselsteijn [3], we obtained skin conductance response (SCR) measurements, but these will not be discussed in the present abstract.

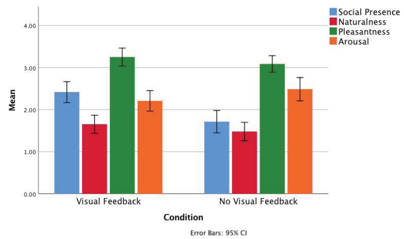

Figure 4: Means and 95% CI of Study 1. All measurements were found not to be normally distributed.

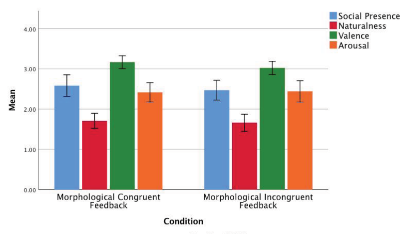

Figure 5: Means and 95% CI of Study 2. All measurements, except Social Presence were found not to be normally distributed.

RESULTS

Factor Analysis

A factor analysis was performed on the polychoric correlation matrix on the self-report data from Studies 1 and 2 combined. Four factors were extracted using principal (axis) factoring and we used oblique oblimin as rotation method. The initial factor solution is reported in Table 1. Based on the final solution Table 2, factor scores were calculated using the summated scale method. The Cronbach's alpha values for the naturalness measures were α = .83 and α = .82 for respectively Study 1 and 2. For arousal, we found respectively α = .63 and α = .75; for pleasantness of touch, α = .86 and α = .77, and for social presence, α = .76 and α = .59.

Study 1: Effect of congruent visual feedback

We used the non-parametric Wilcoxon signed-rank test for investigating the effect of congruent visual feedback on perceived naturalness, pleasantness of touch, arousal and social presence. As expected social presence was higher in the condition with as compared to without visual feedback, with $Z = 3.75$ and $p < .001$. No statistically significant differences were found on naturalness ($Z = 1.67$, $p = .096$) pleasantness ($Z= 1.20$, $p = .231$), and arousal ($Z = 1.73$, $p = .084$).

Study 2: Effect of morphological congruency of visual feedback

Using the non-parametric Wilcoxon signed-rank test, no statistically significant effect of morphological congruency was found on perceived naturalness ($Z = 0.57$, $p = .566$), pleasantness ($Z = 1.47$, $p = .14$), and arousal ($Z = 0.22$, $p = 0.825$). Using the t-test, no statistically significant effect of morphological congruency was found on social presence, with $t(82) = 0.63$, $p = 0.53$, and $d = 0.14$.

DISCUSSION

The aim of the present studies was to further explore whether combining tactile stimulation with congruent visual feedback of the touch act would increase the realism of MST. With respect to the measurement instrument that we used to measure these four dependent variables, our factor analyses revealed that it remains difficult to separate perceived naturalness from social presence with the current set of items. This may be explained by overlap in the formulation of these items, with both making reference to unmediated touch (i.e., touch that feels as if done directly on the skin; see Table 1). Also, factor loadings indicate that social presence items need improvement.

Research on phenomena as presence in virtual environments and illusions as the RHI demonstrate that allowing the CNS to extract correlations between various sensory modalities typically has profound effects on people's experiences. Yet our experiments did not reveal similar strong effects when MST is combined with congruent visual feedback. Although we found, in Study 1, that social presence

Table 2: Final factor solution of the perceived naturalness (NA), emotional experiences (EM) and social presence (SP) items

Item	Natural-ness	Social Presence	Pleasant-ness	Arousal
NA1	.78			
NA2	.87			
NA3	.93			
NA5	.57			
EM1				.75
EM2			.76	
EM3			.89	
EM4			.70	
EM6				.74
SP2		.77		
SP3		.54		
SP4		.57		
SP5		.68		

Note 1. Following an iterative process—in which items with low inter-item correlations, low KMO values, low factor loadings, or high cross-loadings were removed one by one—we obtained the final factor solution reported in this table.

Note 2. All items were recoded so that higher scores reflected higher naturalness and pleasantness, more social presence, and higher arousal. Factor loadings smaller than .30 are left blank. For full description of the items, see Table 1.

Table 1: Initial factor loadings of the perceived naturalness (NA), emotional experiences (EM) and social presence (SP) items

Item	Natural-ness	Social Presence	Pleasant-ness	Arousal
NA1: How natural, or artificial, was the feeling of the mediated touches on the skin?	.72			
NA2: How human, or not human, did the mediated touches feel?	.81			
NA3: How natural, or unnatural, did the mediated touches feel compared to touches by a human?	.87			
NA4: To what extent did the mediated touches match, or not match with touches performed by a human?	.35	.44		
NA5: To what extent did the mediated touches have resemblance, or no resemblance, with touched performed by a human being?	.52	.32		
NA6: To what extent did the mediated touched feel as if performed by a machine or by a human being?	.47			
EM1: How nervous, or relaxed, did you feel with the mediated touches?				.73
EM2: How comfortable, or uncomfortable, was the experience of the mediated touch?			.82	
EM3: How pleasant, or unpleasant, was the experience of the mediated touch?			.88	
EM4: How annoying, or enjoyable, was the experience of the mediated touch?			.71	
EM5: How calm, or excited, did you feel with the mediated touch?				.53
EM6: How tense, or relaxed, did you feel with the mediated touch?				.73
SP1: To what extent did it feel as if the person touched you directly on the skin or through technology?	.68			
SP2: To what extent did you, or did not, feel that it was the experiment leader who touched you?		.66		
SP3: To what extent did you, or did not, feel that the touches you felt were really being done by the other person?		.53		
SP4: To what extent did you, or did not, feel that the person was close to you?		.68		
SP5: To what extent did you feel as I you were, or were not, interacting directly with the other person?		.70		
SP6: To what extent did it occur that you at many moments forgot that you were touched by technology?				

Note 1. All items were recoded so that higher scores reflected higher naturalness and pleasantness, more social presence, and higher arousal. Factor loadings based on principal (axis) factoring and oblique oblimin rotation. Factor loadings smaller than .3

increased when providing congruent visual feedback of the touch act, no statistically significant effects were found on perceived naturalness and emotional experience of the touch. Also, contrasting to Haans and IJsselsteijn [3], no statistically significant differences were observed between morphological congruent and incongruent visual feedback on any of the four dependent variables in Study 2.

Given that we expected the effects of visual feedback, especially when congruent in mapping and morphological form, to be quite substantial, what can explain this lack of clear observed effects? One explanation is that our experimental setup did not allow the CNS to extract sufficient correlations between vision and touch. In our congruent visual feedback condition participants saw the finger of the experimenter moving slowly over the fake hand in one continuous motion. This type of tactile stimulation, as seen by our participants, amongst others, activate the CT afferents present in skin [1]. However, the CT afferents are not sensitive to vibration as provided by our tactile display. There thus may have been a mismatch between anticipated and felt quality of the touch, which has been demonstrated to inhibit the induction of the RHI [9]. At the same time, the orientation of the rubber hand may have further decreased the ability of the CNS to extract a sufficient correlation between seen and felt touch. Although the input device itself was morphologically congruent in terms of visual shape, the placement of the rubber hand in a straight-up fashion neither corresponded to that of participant's own arm nor was in a morphologically plausible orientation (see Figure 1). Research on the RHI has extensively demonstrated that these two discrepancies may weaken or disrupt the illusion [6, 8]. Future research thus should take these limitations of the present studies into account.

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