Simulated Social Touch in a Collaborative Game

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Abstract. In this paper we present a study in which participants played a collaborative augmented reality game together with two virtual agents, visible in the same augmented reality space. During interaction one of the virtual agents touches the user on the arm, by means of a vibrotactile display. We investigated whether social touch by a virtual agent in a collaborative setting would positively influence the participant's perception of this touching virtual agent. Results showed that the touching virtual agent was rated higher on affective adjectives than the non-touching agent.

Keywords: Simulated social touch · Touching virtual agent · Vibrotactile feedback · Augmented reality

1 Introduction

Social touches, such as handshakes, pats on the back, and hugs are an important part of human communication. Though co-located social touch occurs less frequently than other social signals (e.g. facial expressions), it is a communication modality that is known to have strong effects on the interaction. For example, social touch affects compliance to requests [13], can reduce stress [10], and can be used to communicate discrete emotions [17]. Recent findings indicate that when social touch is mediated through haptic feedback technology (i.e. mediated social touch [15]), effects similar to co-located social touch on compliance to requests [14], perception of the communication partner [16], and the communication of affect [4], can be found. What is more, early work in which social touch was simulated by a partially physically embodied virtual agent, showed that social touch by a virtual agent can influence perceptions of this agent [6].

In the current study we investigate whether simulated social touch (i.e. social touch simulated, through haptic technology, by a virtually or physically embodied agent) can positively affect participants' perceptions of a virtual agent's trustworthiness, warmth and politeness. For this purpose we designed a collaborative augmented reality game that is played together with two virtual agents, one touching agent and one non-touching agent. Touches were applied visually, and using a vibrotactile display. Because of the positive effects social touch can have on the perceptions of the toucher [18], we expected that the touching agent

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would be rated higher on trustworthiness, warmth, and politeness. To our knowledge this is the first study in which effects of casual social touch by a virtual agent in augmented reality is investigated.

2 Related Work

The development of numerous prototypes for mediated social touch (see [15] for an overview) has shown the potential of using haptic feedback for the communication of social touches. Studies indicate that mediated social touch may be perceived similarly to co-located social touch. For example, [4] found that participants could recognize certain emotions expressed using a force feedback joystick. This finding matches findings from studies into the tactile expression and recognition of emotions in co-located space [17]. Similarly, [16] found that when communicating through a haptic messenger using vibrotactile feedback, certain body areas were considered inappropriate for mediated social touch to be applied. Using a similar haptic messenger, researchers have found that mediated social touch can have a positive effect on helping behavior, similar to that in co-located situations [14]. In another study in which participants were present in a fully immersive virtual environment, a touch, through vibrotactile feedback, by an experimenter represented by a virtual avatar, failed to enhance compliance to the request to sing in public [7]. Finally, [5] found that in a collaborative desktop-sized rope-pulling game that was played over the Internet, force feedback from the other player's actions enhanced feelings of social presence.

While evidence is mounting that mediated social touch can have effects similar to co-located social touch, or can enhance certain aspects of an interaction, little research exists to date that investigates the use of simulated social touch by virtual agents or social robots. However, some noticeable exceptions deserve mentioning. One study found that participants, using a force feedback joystick, touched virtual agents differently than virtual objects. Participants applied less force to torsos compared to faces, and also applied less force to female virtual agents compared to male virtual agents [2]. Another study used a virtual representation of an agent's head, mounted on top of a physical mannequin, to investigate simulated social touch for the expression of empathy [6]. The agent was able to squeeze a participant's hand. It was found that simulated social touch enhanced the perception of the relation with the agent, but only for participants that were comfortable being touched. Simulated social touch can also be applied in interactions with physically embodied agents, such as social robots. In a study where participants observed videos of tactile interactions between a human and a social robot, it was found that social touch made the robot seem less machine-like and more dependable [9]. Other research, in which a social robot actually touched participants, found that social touch by a robot can enhance compliance to a request and the performance on a repetitive task [19].

Research on touching agents points to potential effects on compliance to requests and perceptions of the agent. What stands out is the wide variety of actuation methods that was used in different studies (e.g. force feedback joystick,

Fig. 1. Flow of the interaction with the agents, from left to right: introduction, playing the game, and sitting on the chairs to fill out the questionnaire.

squeeze bracelet, eccentric mass vibration motors). What is more, research into mediated social touch has demonstrated that vibrotactile stimulation can be perceived as a social touch [14,16]. In the current study we use a vibrotactile display with synchronized visual feedback, to simulate social touch by a virtual agent in augmented reality. The simulated social touch by the agent takes place before and after playing a collaborative game. We investigate whether simulated social touch by a virtual agent in a collaborative game can result in more favorable judgements of the personality of this agent, compared to a virtual agent that does not engage in social touch.

3 Method

A study with a within-subjects design was conducted in which the participant used a tablet computer to interact with two female virtual agents (Anna and Belle) in an augmented reality space, during a collaborative game (Fig. 1). During the interaction, one of the agents would touch the participant on three separate occasions. To measure participants' response to the agents we used a questionnaire consisting of 13 adjectives [3]. This questionnaire was selected because it has been successfully used to measure perceptions of traits in both human and virtual human communication partners [3,12]. Because of the importance of politeness in communication with embodied conversational agents, we decided to add the adjective 'polite' (see also [20]), for a total of 14 adjectives (see Table 1). For both agents the participant indicated his or her agreement with statements like "I thought Anna was likeable" on a 7-point Likert scale, ranging from 1 "strongly disagree" to 7 "strongly agree". It was hypothesized that, because social touch positively influences perceptions of the toucher [18], the touching virtual agent would receive overall significantly higher ratings on the personality traits than the non-touching agent. The participant also completed a touch receptivity (i.e. a measure of how comfortable a participant is with being touched in general) questionnaire adapted from [6], with two healthcare-specific items removed (7-point Likert scale, ranging from 1 "strongly disagree" to 7 "strongly agree"). This questionnaire was added to assess whether touch receptivity would influence the judgement of the touching virtual agent. Finally, a behavioral measurement was employed, to assess the influence of the agent's touch on prosocial behavior [18]. After the final interaction with the participant, the agents both sat down on two of four physical chairs present in the room. The participant was asked to sit down on any of the four chairs. It was hypothesized that participants, on average, would sit next to the touching agent more than next to the non-touching agent.

3.1 Simulated Social Touch and Agent Interaction

Prior to playing the game, one of the agents, using synthesized speech played through the tablet's speakers, explained the game to the participant and wished them luck. While wishing the participant luck the agent touched the participant on his or her arm. After completing the game, the same agent would congratulate the participant and touch him or her on the arm again. Finally, the agent stated that they should play the game again some other time, and touched the participant a final time, for a total of three touch moments. The touches by the agent were felt by the participant through a vibrotactile display, synchronized to the agent's visible arm movement. In order to control for the assertiveness of the agent, the touching agent started the interaction for half of the participants. For the other half, the non-touching agent would start the interaction. After the agents congratulated the participant, the agents sat down, opposite of each other, on two of four actual chairs present in the room (Fig. 1).

To generate the tactile sensation of the virtual agent's touch we opted for vibrotactile actuators, because of their successful application in mediated social touch studies [14,16]. Note that our aim was not to create the most realistic touch sensation by a virtual agent, but to produce a sensation that could reasonably be perceived by participants as a touch by the virtual agent. In this regard vibrotactile actuators offered the most straightforward method of actuation. We used an Elitac Science Suit[1] consisting of several eccentric mass vibration motors that can be attached to elastic bands of different sizes using Velcro. The intensity of vibration of each vibration motor can be individually controlled, with sixteen levels of vibration intensity. Three actuators, with approximately 10 cm spacing between them, were placed in a triangular position, and were attached to each upper arm of the participant. The upper arm was chosen, because it is an appropriate location for social touch to occur [17]. An additional six actuators (two rows of three, with approximately 10 cm spacing between them vertically, and approximately 20 cm spacing between them horizontally) were placed on the participant's abdomen. The touches by the agent on the participant's arm were simulated by having the three actuators gradually increase to 70 % of the actuators maximum vibration intensity, and then gradually decrease again. This represented a brief "pressing" type of touch. The total duration of the agent's touch was 880 ms. The actuators on the abdomen were used to give feedback during the game.

[1] http://elitac.org/products/sciencesuit.html

3.2 Collaborative Coin-Collecting Game

The participant played a collaborative game in which he or she had to collect coins by aiming the tablet and touching the screen. The total number of coins collected was the combined number of the coins collected by both agents and the participant. The game presented a three-dimensional cube, consisting of individual coins (5 by 5 by 4 coins) which was displayed on the tablet, and appeared to be floating in the room the participant was present in (Fig. 1). It was the participant's task to aim the tablet at a coin, touch the screen to 'shoot' the coin, thus collecting it. Each time the participant collected a coin, a sound would play, and he or she would feel a brief vibration (485 ms in total) on his or her abdomen, where the outer four actuators would activate first, followed by the middle two. If a participant shot and missed a coin the actuators on the abdomen would vibrate briefly three times (100 ms each with 100 ms interval). This feature was implemented to not make the agents' touches stand out too much during interaction. To make the game more interesting to play, the participant's view of the coins was partially blocked by bricks that moved up and down in front of the coins. The two virtual agents were shown on the participant's screen, and used the same technique as the participant to collect the coins. The game was designed so that it would be impossible to collect all coins during the game's duration (40 s). The time was shown counting down at the top of the screen. After the time ran out, the participant received feedback about his or her performance compared to the agents'. This feedback was the same for all participants.

3.3 Participants

In total 20 people participated in the study. There were 11 male participants and 9 female participants. The average age was 21.5 ($SD = 3.2$). Participants were all students or employees of the University of Twente.

3.4 Procedure

After obtaining written consent, the experimenter explained the study's general procedure. Next, the vibrotactile displays were attached to the participant's body, and the participant received the tablet computer. Instructions on how to hold and use the tablet were given by the experimenter. The experimenter also stressed the collaborative nature of the game. The principle of the coin game was introduced and the working of the tactile display was tested in a trial version of the game. All further instructions were given on the tablet computer. After completing the game, and receiving feedback, the participant was asked to sit down on one of the four chairs to fill out the agent perception questionnaire, demographics, and touch receptivity questionnaire using the tablet computer. The touch receptivity questionnaire was given at the end of the session as to not to prime the participant to the agents' touches. After completing all questionnaires the participant was debriefed about the aim of the study. The total duration of the study was approximately 20 min.

Table 1. Principal component analysis of 14 adjectives

Factor	Item	Factor loading
Trustworthiness (α = .82)	Honest	.76
	Informed	.75
	Competent	.71
	Trustworthy	.71
	Sincere	.67
	Credible	.62
	Interesting	.48
Warmth (α = .81)	Approachable	.76
	Warm	.74
	Confident	.73
	Friendly	.65
	Likeable	.59
Politeness (α = .69)	Polite	.83
	Modest	.80

3.5 Results

A principal component analysis with varimax rotation and Kaiser normalization for the 14 adjectives revealed a three factor structure that explained 59.5 % of the total variance. Table 1 shows the factors, items, and factor loadings. The first factor describes the trustworthiness of the agent, which consists of items such as trustworthy, and competent. The second factor, warmth, deals with more affective interpersonal aspects of the agent, such as its friendliness and likeability. Finally, the third factor describes the agent's politeness, with the items polite and modest. This factor structure is comparable to earlier work with the same list of adjectives [3]. The touch receptivity questionnaire had an acceptable internal consistency (α = .69). A median split procedure was used to divide participants into 'touch receptive' and 'non-touch receptive' groups.

Frequencies showed that all participants sat on a chair not occupied by an agent. The division between sitting next to the touching agent or not, was equal (i.e. 10 participants sat next to the touching agent). We ran a repeated measures ANOVA with touching agent/non-touching agent as the within-subjects variable and agent's assertiveness, and touch receptivity of the participant as between subjects variables. We found a main effect for the touching agent/non-touching agent ($F(5, 80) = 3.22$, $p < .011$). No interaction effects for agent's assertiveness or touch avoidance were found ($p > .05$). Pairwise comparison revealed that participants gave significantly higher ratings for 'Warmth' ($t(19) = 3.65$, $p < .011$) to the touching agent ($M = 4.83$) compared to the non-touching agent ($M = 4.21$).

4 Discussion and Conclusions

Results of our study indicate that simulated social touch by a virtual agent can potentially enhance perceptions of certain personality traits of this agent. Though the behavioral measure showed no preference for sitting next to the touching agent, participants rated the touching agent higher on ‘warmth’, compared to the non-touching agent. Touch by the agent did not influence perceived trustworthiness or politeness of the agent. This partially supports our hypotheses. It makes sense that perceptions of the agent’s warmth, describing more affective, interpersonal aspects of the agent, are positively affected by the agent’s touch, considering the role of social touch in the forming of affiliative bonds [11], and the communication of intimate-relationship emotions [1]. It therefore seems that simulated social touch by a virtual agent does not make the agent seem more trustworthy or polite, but touch does seem to serve as a cue in the perception of more affective, relational aspects of the agent (i.e. warmth). Indeed, a previous study suggested that touch by a virtual agent for the expression of empathy (i.e. understanding of another’s emotional state) may enhance the perception of the relation with the agent [6]. Our study supports the idea of using simulated social touch as a way to add affective expressivity to a virtual agent.

What is more, the effect of the agent’s touch was not mediated by the agent’s assertiveness, nor by participants trait touch receptivity. Previous research [6] found differences in responses to a virtual agent’s touch based on trait touch receptivity. However, it could be argued that the touches applied in our study were more casual, and that the focus of the study appeared to be less on the touches per se, making them less intimidating. Furthermore, the collaborative context in which the touches took place in our study might be considered ideal for the elicitation of positive effects of social touch [8]. It would be of interest to investigate whether identical touches in a competitive context would result in more aversive evaluations of the agent, as research suggests [8].

The results obtained in our study suggest that there might be similarities between the way co-located and mediated social touch on the one hand, and simulated social touch on the other hand, are perceived. Research on co-located and mediated social touch has found similar beneficial effects of touches on the evaluation of the one initiating the touch [11,15]. The fact that our results were obtained with social touches simulated by a relatively crude actuation method (i.e. vibrotactile feedback through eccentric mass vibration motors) and initiated by a non-human social entity (i.e. virtual agent), bodes well for the inclusion of haptic feedback for simulated social touch in communication with virtual agents.

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