Effect on Social Connectedness and Stress Levels by Using a Huggable Interface in Remote Communication

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***Abstract*—Affective communication technologies are designed to enhance awareness, social connectedness, and affectivity. Design strategies involve alternative methods to convey affection in computer-mediated scenarios, emphasizing on the importance of mediated physical contact. Therefore, we proposed a huggable interface to mediate social touch by sensing the user's hug gestures, transferring them to a paired device, and delivering them as simple cues. We investigated the effect of the huggable interface as a mediator with a physical embodiment and compared it with a similar communication interface represented by an agent with a virtual embodiment on a touch screen. During the experiments, we set up a scenario in which individuals with a close relationship watched movies and communicated with each other. Results showed the effect of both interfaces in terms of perceived social connectedness and stress levels. The discussion pointed out the potential and limitations of the proposed evaluation method, as well as of each type of interface as affective communication technology.**

***Index Terms*—Computer-mediated communication, Affective technology, Intimate communication, Touch-based interaction**

I. INTRODUCTION

The opportunities for social interaction have mostly increased with the expansion and accessibility to the internet, social networks, and mobile technologies. Nowadays, a considerable amount of social interaction is mediated by technology. Computer-mediated communication is usually compared with face-to-face communication, and their differences have been extensively explored and analyzed [1] [2]. Face-to-face communication is complemented by non-verbal cues that are commonly used to convey affective information. When we are not in front of each other, mediators are used for conveying this information instead. These technology-mediated interaction scenarios sometimes require users to interact in different ways from face-to-face interaction. As human beings, we can quickly adapt to different interaction scenarios. In those scenarios where social cues used in face-to-face interaction are not available or limited, we can observe new communication strategies that involve simple gestures or cues that convey social information. Examples of this would be the like-button used in many social network services, or the emoticons used to illustrate different affective states. Even if these gestures differ from those we use in face-to-face interaction, they have similar functions. Nevertheless, the number of cues available in computer-mediated communication is limited compared to face-to-face communication, but at the same time, new and alternative cues are exchanged.

For the new generation of communication devices researchers are exploring the effect of conveying and receiving messages through touch [3]. One possible approach involves using robots or robotic devices as social mediators. The interaction with physically embodied agents was found to be more positive, natural, and in general, and more engaging compared video-displayed robots [4] [5]. Physically embodied robots have the potential to positively affect the interaction, leading to a stronger impact on social presence [4] [6]. Robots as mediators of remote human-human communication have been reported to have favorable effects on the social aspect of the interaction [7]. In the context of remote communication, physical contact with communication media was found to have positive effects on users, such as by providing mental stress relief [8]. Regarding the design of the interface, simple objects or interfaces can prompt a response in people similar to the impact that other people would elicit [9]. Based on these potential benefits, different implementations using devices that supported touch-based interaction have been used to mediate remote communication [10] [11] [12]. Moreover, design strategies for technologies to mediate intimacy and relatedness described the importance of supporting meaningful gestures

978-1-7281-3888-6/19/$31.00 ©2019 IEEE

that convey affection, such as hugging, kissing, or stroking. [13]. Among the various touch gestures, hugs are a important part of human communication, as they can transfer comfort and give an emotional lift [14]. In previous studies, different approaches to mediate hugs by paired devices were observed. For example, the conceptual design of a huggable interface to support intimate communication [15], and a teddy bear-like designed to support bidirectional exchanges of affective communication based on hug gestures [16]. In these new technology-mediated scenarios, the first question that arises is what kind of technology should be used to mediate cues that improve remote communication? As well as, what are the cues being exchanged and how?

A. Purpose of this Research

We proposed a huggable interface designed to mediate social touch remotely [17]. The interface senses the user's hug, transfers it as a message to a paired interface and delivers on-off signals using cues made of colored lights and vibration. On-off signals contain minimal information, and it is assumed that they can be sufficient in conveying mutual affection in remote communication scenarios [13]. Based on the literature, mediating social touch is beneficial in terms of modulated physiological responses, increase trust and affection, or pro-social behavior [18]. Moreover, the lack of physical embodiment and physical presence may lead to a decreased intensity of the emotional experience and perceived social presence [4] [6]. For this reason, the purpose of this research is to investigate the effect of an interface with a physical embodiment that mediates social touch by comparing it with a similar agent represented by a virtual embodiment. Specifically, we are investigating the effect of the interface as an affective technology, and its effect on social connectedness, and on the participants' internal state measured by levels of stress. To achieve this, we proposed an experimental study that simulates a remote communication scenario involving participants with a close relationship. Based on the reported positive effect that physical contact has on stress levels [8], as well as the advantages of the on-off messages in terms on flexible interpretation [13], we hypothesized that mediating physical contact through the proposed interface would result in improved social connectedness and reduced stress levels.

II. Experimental Study

In this study, we compared a physically embodied interface with an interface with similar characteristics but represented as a virtual agent. In a laboratory setting, we simulated a remote communication scenario in which participants were watching movies while being able to connect to their partner only through the interface. We induced emotional states to the participant by video stimuli and verified if there are differences among the different experimental conditions in terms of social connectedness and stress levels.

III. Participants

Sixteen participants joined this experiment (8 male; Average age = 28.44, SD = 4.15) grouped into eight pairs. During the recruiting process, we asked one of the participants from each pair to invite someone "with whom you consider to have a close relationship." From the eight pairs, five described themselves to be in a romantic relationship, two defined themselves as close friends, and one pair were relatives (siblings).

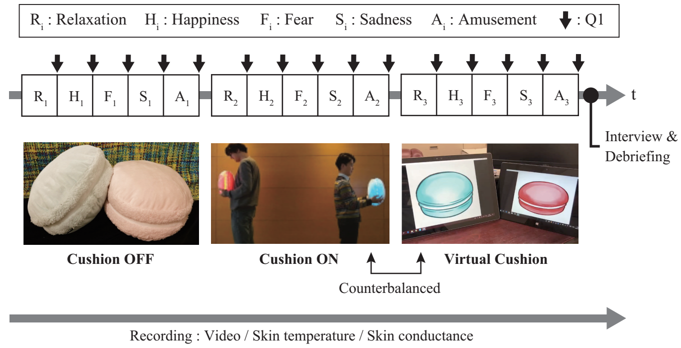

Fig. 1. Experiment Flow: three conditions defined by the type of interface being used. Each condition involved watching a set of videos while freely using the interface.

IV. Experiment Design

The overview of the experiment is illustrated in Figure 1. It consisted of 3 conditions: 1) Cushion OFF, 2) Cushion ON, and 3) Virtual Cushion. The experiment followed a within-subjects design; thus, all the participants tried all the conditions. The sessions always started by the Cushion OFF condition, followed by the two other conditions counterbalanced among the group. The study explores the comparison of conditions Cushion ON and Virtual Cushion, and condition Cushion OFF was included to counter the effect of the cushion's characteristics. During each condition, participants only received instructions through a computer display. The description of each condition is as follows:

- Cushion OFF: participants received a cushion module that does not deliver feedback. From the participant's point of view, the modules represented a simple cushion.
- Cushion ON: participants received a cushion module (Figure 2), and they were instructed about the meaning of the colored lights patterns as well as how to operate the device.
- Virtual Cushion: participants received a touch screen module (Figure 3), and they were instructed about the meaning of the colored lights patterns as well as how to operate the device.

V. Stimuli

As illustrated in Figure 1, on every condition, participants watched a set of four short films. These movies were displayed simultaneously to both participants on different rooms. The stimuli, including content and duration, were selected from libraries of video material that were validated to elicit emotional responses [19]–[22]. Four emotions were targeted, two positives (Happiness and amusement) and two negatives (Fear and sadness), and three sets of films were made. For the stimulus of happiness we chose Marie Antoinette (2006) [19], 500 days of summer (2009) [21], and Deep Blue (2003) [19]. Fear was elicited using Road kill (2001) [19], Red Eye (2005) [19], and Silence of the Lambs (1991) [22]. For sadness we used Sylvia (2003) [19], The Shawshank Redemption (1994) [20], and My girl (1991) [19]. Amusement was represented by Mr. bean goes to town episode (1990) [19], The hangover (2009) [20], and When Harry met Sally (1989) [22].

VI. Measurements

A. Questionnaires: Form Q1

Form Q1 was filled 15 times by each participant, and it provides information about the quality of the interaction. The form contained four items. The first item was a modified version of Inclusion of Others in Self Scale (IOS), which asked the participants to "select the diagram that represents how close you felt to your partner while watching the movie". Participants answered using a 7-points scale made of two circles overlapped to different extends. The IOS is a metric of perceived intimacy, a component that relates to the quality of social connectedness [23].

The next three items were taken from a previous study that evaluated the quality aspect of the interaction through an affective communication technology [24]. Participants were asked "what did you think of the method of interaction.". They answered using a 7-point scale ranging from Unsociable to Sociable, from Very Cold to Very Warm, and from Impersonal to Personal.

B. Physiological Data

Besides questionnaires, we evaluated the user's experience based on their physiological data collected by E4 wristbands from Empatica [25]. Among the different signals collected by the E4 wristband, we were primarily interested in skin temperature (ST), and electrodermal activity (EDA):

Skin temperature (ST):

1) Analysis: the raw data were trimmed, and the target segments (during each stimulus) were extracted. In total, for each participant, we analyzed 12 data set (3 conditions, four videos). We compared the segments with the data during the relaxing video in the first condition (baseline), to obtain how much ST levels changed on each segment. Then, we calculated the average and standard deviation, a method that has been used in the past to analyze ST data [26].
2) Interpretation: "During a state of increased exertion, excitement and stress, the muscles are forced to contract, causing a stenosis of vasculature. This leads to a reduction of skin temperature, since the blood circulation of the tissue is reduced" [27]. In other words, increase levels of skin temperature are related to a relaxed state.

Electrodermal activity (EDA):

1) Analysis: the raw data were trimmed, and the target segments (during each stimulus) were extracted. In total, for each participant, we analyzed 12 data set (3 conditions, four videos). To analyze EDA data, we used the toolbox from Ledalab, and the method of Continuous Decomposition Analysis [28], to extract the phasic and tonic components of the signal.
2) Interpretation: "EDA has been closely linked to autonomic emotional and cognitive processing, and EDA is a widely used as a sensitive index of emotional processing and sympathetic activity. The most common measure of this component is the Skin Conductance Level (SCL) and changes in the SCL are thought to reflect general changes in autonomic arousal. The other component is the phasic component and this refers to the faster changing elements of the signal - the Skin Conductance Response (SCR)" [29]. SCL is also known as the tonic component, and SCR is known as the phasic component. In other words, higher levels of SCL and SCR are related to higher arousal.

Fig. 2. Cushion-type communication interface: Interactive cushions displaying cues described by the proposed interaction rule.

VII. Apparatus

The experiment was conducted in two adjacent rooms. Each room contained a desk, a chair, and a computer's display on which participants received instructions and contents of the experiment. Video cameras were set in front of the desks to record participant's interaction with the interface. A mirror was placed on a white panel behind the participants to reflect the contents of the displays and facilitate data synchronization. The computers for data collection were located outside the experiment area. A different computer was used to feed videos and audio to both participant's displays and headphones. Each participant wore an E4 sensor, and they evaluated their experience using questionnaires placed on the desks. On different segments of the experiment, participants communicate with their partners through two different types of communication interface: 1) Cushion-type communication interface, and 2) Touch screen-type communication interface.

A. Cushion-type Communication Interface

The cushion-type interface is the representation of the communication interface with a physical embodiment. It looks like a simple cushion that can be found at home. Previous studies

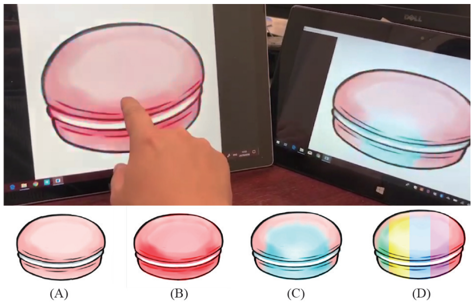

Fig. 3. Touch screen-type communication interface: a set of paired touch screen that display a graphical representation of the cushion interface.

Fig. 4. Two participants during Cushion ON condition: participants were in different rooms only interacting with each others through the interfaces.

pointed out the importance of making huggable mediators of physical contact with a form familiar to the user [30], [31]. The proposed interface is composed of three elements: sensing, feedback, and communication. Sensing involves a sensor designed to detect hugs [17], the feedback is made with colored lights patterns, and the communication is managed by a server connected via Bluetooth with each cushion module. Heartbeat-like vibrations (two 350ms square pulse, separated by a 700ms pause) were used to complement the cues made by colored lights, especially on well-illuminated environments.

As illustrated in Figure 2, this interface supports communication between two users using a paired devices configuration. The cushions display a combination of colored lights patterns according to the users' actions. Communicating based on ambiguous messages made of colors were meant to be open to interpretation, following the on-off strategy proposed by [13], which assumes that a minimal amount of information is enough to convey affection. By following this, we proposed the following interaction rule for the interactive cushions: The sending cushion (the one being hugged) is represented with red color, which relates to the warm feeling of hugging. The receiving cushion was indicated with blue, referring to it as "it cooled down, and it needs to be hugged again". Following this reasoning, when one of the interfaces detects the user's hug, the interface starts blinking with a red pattern. At the same time, the receiving interface blinks with a blue pattern, indicating a message was received. When a sending cushion is being hugged and then released, it changes from blinking red to display a static red color, indicating that the last action was a detected hug. Similarly, the receiving cushion changes from blinking blue to display a static blue color, indicating by this that the last registered action was a message received. A different kind of color pattern was used to indicate synchronized actions: when both cushions are being hugged, simultaneously both of them display a multicolored lights pattern.

B. Touch Screen-type Communication Interface

To represent the cushion with a virtual embodiment, we used a set set of tablet computers as presented in Figure 3. On the screen was displayed an illustration of the cushion interface (Figure 3 A). The touch-screen was selected based on the familiarity to the users, simulating the way the people communicate using emoticons. This cushion's image delivers cues using the same rule as the one used for the cushion interface. Instead of detecting hugs, the cushion's images detect when the user touches the screen. Similar to the cushion interface, when a user touches the cushion's image on the screen, this starts blinking red (Figure 3 B). After the user releases the gesture, the cushion's image stays red to indicate that the last action was a touch detected. When the partner touches the cushion's image, the receiving interface displays a blue blinking pattern to indicate a message is received (Figure 3 C) After the partner releases the gesture, the receiving interface stays blue. If two users touch the cushion's images at the same time, simultaneously, both interfaces display a multicolored pattern (Figure 3 D).

VIII. Procedure

Participants in pairs arrived at the laboratory together. They entered one of the experiment rooms where one experimenter explained an overview of the study. After signing the consent forms, they were asked to wear the E4 sensors. Then, an experimenter explained the content of the questionnaires to make participants familiar with them. Following this, participants were asked to sit in front of a computer display, each one placed in different rooms. As illustrated in Figure 4, during the sessions, participants were watching videos on a display while manipulating the interface. Each condition started with a 1.5 minutes long video to induce relaxation. The videos to induce relaxation were the same as the ones used on the work of [24]. After the relaxing video, participants answered the form Q1. From here, we simulated a situation where participants are watching movies at the same time. Participants were asked to imagine they were in different countries watching movies simultaneously, and that they could use the provided interface freely during the session. Participants were aware that both of them were watching the same content simultaneously and that both of them were using the same type of interface. Each set of video used on each of the three conditions contained a stimulus for happiness, fear, sadness, and amusement. After each video, participants had one minute to fill the form Q1. At the end of each condition, participants took a five minutes break before starting the next condition. During the complete duration of the session, video data and physiological data were collected. The sessions ended with an interview to collect participants' impressions and debriefing. The total duration of each session was about 2 hours.

IX. Results

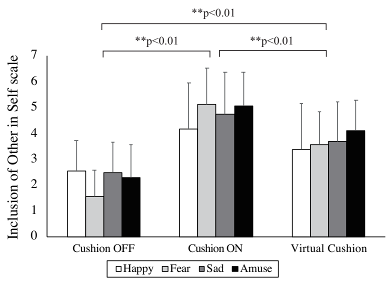

Fig. 5. IOS questionnaire: perceived intimacy.

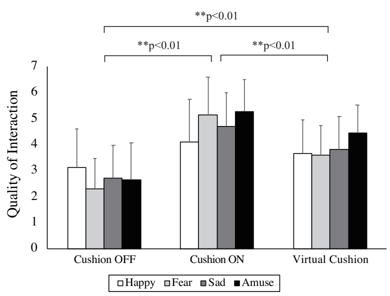

Fig. 6. Quality of the interaction.

For the analysis presented in this section, we used the non-parametric Friedman test of differences among repeated measures, and we applied pairwise comparison with Bonferroni adjustment as a posthoc test. Figure 5 summarizes the result from the IOS item. The test rendered a Chi-square value of 66.454, which was significant ($p < 0.01$). The results of each combination were: Cushion OFF - Cushion ON ($p < 0.01$), Cushion ON - Virtual Cushion ($p < 0.01$), Cushion OFF - Virtual Cushion ($p < 0.01$). A similar tendency was observed on the items that evaluate the quality of interaction. From each participant, we used the average of the three items score. Main effect regarding condition was confirmed ($p < 0.01$) with a Chi-square value of 162.449. As shown in the figure 6, significant differences between: Cushion ON and Cushion OFF ($p < 0.01$), Cushion ON and Virtual Cushion ($p < 0.01$), and Cushion OFF and Virtual Cushion ($p < 0.01$) were found.

The analysis from E4 sensors includes skin temperature (ST), and skin conductance (EDA). Regarding ST, Figure 7 shows an example of the segmented raw data from one participant and used for the analysis, The changes of ST from the baseline (relax-Cushion OFF) was computed for each segment (4 emotions) of the experiment, and compared in terms of condition. The statistical test resulted in a Chi-square value of 35.656, which was significant ($p < 0.01$). The result shows that there was a significant increase of ST in

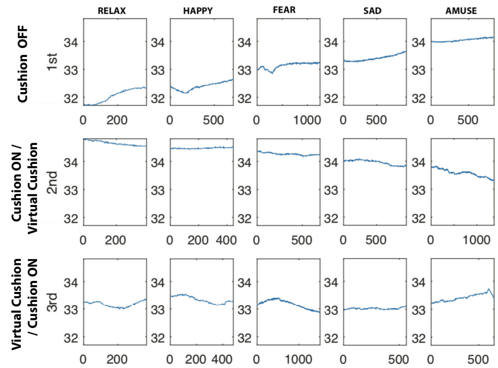

Fig. 7. Skin Temperature: raw data from one participant. We used as baseline the first segment of each session (relax, Cushion OFF).

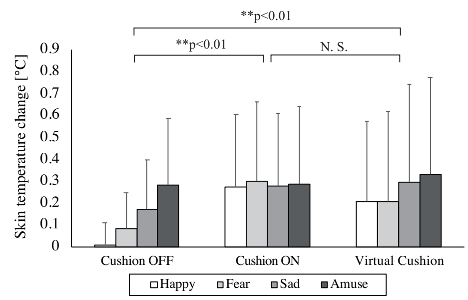

Fig. 8. Average and standard deviation of skin temperature values from all participants during the three conditions.

Cushion ON condition compared to Cushion OFF ($p < 0.01$), and Virtual Cushion compared to Cushion OFF ($p < 0.01$), whereas no significant difference between Virtual Cushion and Cushion ON was observed (Figure 8).

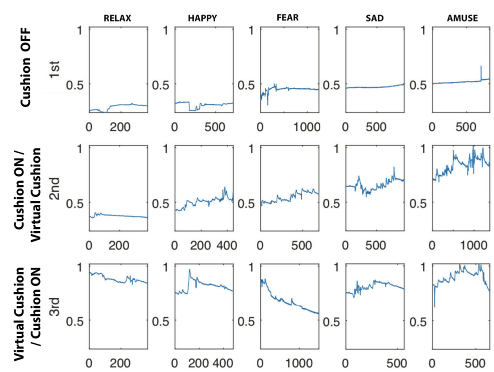

Fig. 9. Skin conductance: raw data from one participant.

Regarding EDA, Figure 9 shows an example of the segmented raw data from one participant and used for the analysis. In terms of the tonic component of EDA (Figure 10), while not significantly different, there was a tendency in reducing the level during Cushion ON and Virtual Cushion condition compared to Cushion OFF condition ($p = 0.078$) with a Chi-square value of 5.094. On the other hand, the phasic

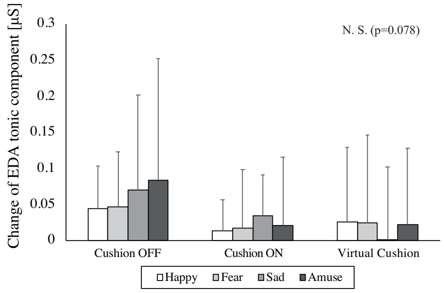

Fig. 10. Average and standard deviation of the tonic component of skin conductance data from all participants during the three conditions.

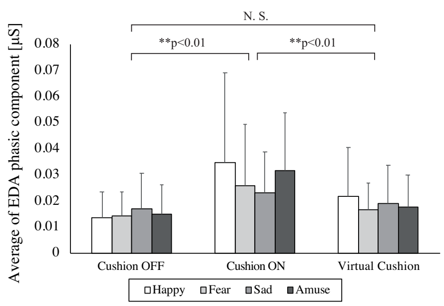

Fig. 11. Average and standard deviation of the phasic component of skin conductance data from all participants during the three conditions.

component of EDA (Figure 11) resulted in a Chi-square value of 32.844 with a significant difference between Cushion OFF and Cushion ON condition ($p < 0.01$), Cushion ON and Virtual Cushion condition ($p < 0.01$).

X. Discussion

Affective communication technologies are meant to convey emotions and affectivity, allowing us to create or strengthen intimate connections, and in general, to improve well-being. Based on the reviewed literature, we designed a huggable interface for conveying affective messages remotely. Initially, we assumed that communicating through touch-based gestures using a physically embodied interface would enhance the feeling of social connectedness. On the experiment, we used questionnaires to measure intimacy and different social aspects of the interaction. We observed that participants perceived the interaction more intimate (Figure 5) and social (Figure 6) during the Cushion ON condition compared to the Screen condition and Cushion OFF condition. The main difference between the two conditions were the features of the two interfaces that participants used to communicate with each other while watching movies. In terms of affordances, the cushions required users to hug it to activate the sensors and send a message which, compared to pressing a bottom, is an action with strong affective connotation. Participants reported that the action of sending messages by hugging a pillow felt like "touching the other". In terms of usability, participants reported that even though the communication through a touch-screen was more familiar for them than the cushion, it divided the attention between the content of the movie and the screen, while a fully lighted up cushion was easier to use while watching movies. It was observed that the characteristics of the cushion interface could contribute to creating a more intimate communication and a stronger feeling of social connectedness.

Besides evaluating the quality aspects of the communication, we were interested in investigating the effect of both communication interfaces on the users' stress levels. Indicators of stress reduction such as increased ST did not show differences between the two types of interfaces, but it was observed a significant difference between the Cushion OFF condition compared to Cushion ON condition and Virtual Cushion condition (Figure 8). The OFF condition worked as a baseline, and it was always presented before the other two conditions for every participant. Participants showed to be more relaxed when they were communicating by either the cushion or the screen interface (higher ST), but they did not show a significant difference between the two communication conditions. Regarding the EDA data, the tonic component of EDA (Figure 10 was not found significantly different among conditions, but the tendency of the data showing lower levels of the tonic component during both communication conditions was consistent with the ST results. However, we also observed a higher phasic component level when participants were communicating using the cushion compared to the screen. In particular, the phasic response during the positive stimuli is stronger during the Cushion ON condition compared to the Virtual cushion condition (Figure 11). We assumed that if we consider the context (a positive stimulus), a higher arousal could be related to being able to feel each other through the cushion interface. However, an analysis of the valence component is necessary to determine if these higher arousal values during specific stimuli, are for example, indicators of excitement or distress. Comments from the interviews complemented the interpretation of these results. Participants reported they related the messages received with the content they were watching at that particular moment. For example, if the scene was funny or scary and the participant received a message, they mentioned that it felt like the partner was feeling the same as them. Moreover, it was observed that participants could relate the messages and the content of the movies with shared past experiences. This interpretation goes in line with the assumptions that simple and abstract messages (on-off type of communication) can contribute to the feeling of intimacy [13]. This extra meaning is perceived only during the communication conditions, and it could be one of the causes of the higher levels of the phasic component. The phasic component is a fast response to external stimuli, and this response was stronger when participants could feel each others through the huggable interface. Even though participants were more relaxed during the Cushion ON condition (based on ST and tonic component of EDA), their affective response to the stimuli was stronger when they communicated through the huggable interface.

This study represents the first step in exploring the potential of affective technologies represented as a physically embodied interface that mediates hugs. We chose a movie-watching setting as it represents a social activity that is commonly done with others and can potentially elicit emotions. This setting provides a controlled and ecologically valid environment, suitable for this type of investigation [24]. One of the limitations of this study is the sample we used, as it consisted only of participants with a close relationship. The comments from the interview showed that the relationship and history between the two users influenced the perception of the interface. It is unclear how these results will translate to a population with different characteristics. Moreover, randomizing the order of the type of stimuli for each condition could help to limit the cross-over effect from the previous videos. On the other hand, the use of physiological data as markers of emotional experience is growing in popularity. It can be argued that more accurate measurement instruments for physiological data could be used in this study. However, since we are evaluating participants' experience, the sensors should not obstruct the interaction with the interface, and it is preferable if they look familiar to the participant to reduce negative effects of laboratory settings. Future studies could consider combining this type of affective technology with other means of communication used in everyday life, to better understand the potential of these interfaces. Additionally, as reported by [13], the potential positive effect of this type of affective technology showed to be highly dependent on the context of the interaction; thus future studies should involve the context (stimuli) as a factor of the analysis. So far, these results show the potential of sharing affective information through a physically embodied interface that mediated social touch. They also provide insights for developers related to the effect that each type of embodiment has on the communication of affective messages.

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