Physiological Responses to Affective Tele-Touch during Induced Emotional Stimuli

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Abstract—The human touch has long been recognized to promote physical, emotional, social, and spiritual comfort. There are situations, however, when touch cannot be exchanged. Although mobile phones and web-based communication are ubiquitous, touch—a communication modality that conveys powerful messages—is inexistent in modern communications media. This paper describes a tele-touch device that transfers affective touch to another person through the internet. Commands for vibration, warmth, and tickle were sent over the internet to a haptic device at the subjects' forearm. With a heart rate (HR) monitor and a galvanic skin response (GSR) sensor, the physiological effect of the tele-touch device was evaluated as the subjects watched an emotionally-laden movie. We compared these to one group of subjects who were touched by their spouse or girlfriend and to subjects of a control group where no touch was provided. Results show that the HR of the subjects with the tele-touch device was not significantly different from those subjects who were touched by their loved ones. These results were in contrast to the subjects who were not provided with any form of touch. On the other hand, the GSR results revealed that all the three touch conditions were different from one another.

Index Terms—Affective touch, human touch, tele-touch, heart rate, galvanic skin response

1 Introduction

Affective touch is important in human relationships. Affective touches are those instances when a person touches another when hugging and caressing the arms, or the face. It is this kind of touch that can promote physical, emotional, social, and spiritual comfort [1]. This tactile contact is so powerful that a short touch can elicit strong emotional experiences: from the comforting experience of being touched by one's spouse, to the discomfort caused by a touch from a stranger [2]. Through touch, distinct emotions such as anger, fear, disgust, love, gratitude, and sympathy can be communicated [3]. Touch has also been found to be an effective means to persuade someone and to gain compliance. Inspired by the Greek mythology's King Midas, whose touch turned everything to gold, the Midas touch effect increases people's altruistic behavior and willingness to comply to a request with a brief touch on the upper arm [4], [5], [6]. The notion that "trust needs touch" [7] in closing a business deal or a treaty highlights the need for touch.

There are situations when it is most crucial to touch and to be touched. At one end, many young children who are having transplants and are undergoing cancer treatments are forced to be socially isolated in hospitals. The patients' mobility and interactions are minimized to protect them from infections due to their weak immune system. Treatments could take months for some, while for others, a couple of years. During these periods, many would have to stop school and their physical contact outside of the hospital is minimized. Lowrey [8] observed that deprivation and isolation have harmful effects on the well-being of hospitalized children. Among the ill-effects that he found were "hostile aggressiveness, temper tantrums, enuresis (bedwetting), speech defects, attention demanding behavior, shyness and sensitiveness, difficulties about food, stubbornness and negativism, selfishness, finger sucking, and excessive crying". On the contrary, Bakwin [9] and Spitz [10] showed that hospitalized children responded positively to continuous affective touch therapy, which resulted into faster recovery and good appetite.

At the other extreme end are the elderly. The United Nations estimates that people who are 60 years old or over comprise 10 percent or more of the whole population [11]. By 2050, there will be two billion elderly people living worldwide [12]. The elderly are vulnerable to experience higher rates of loneliness [13], [14] and social isolation [15]. Among the cited reasons are the broken social ties, the relocation to different types of living and care communities, and the limitations in physical and mental health [16]. An editorial in Geriatric Nursing ([17]; p. 236) highlights a serious concern stating that "Loneliness is a devastating illness—more so than any physical illness—and can be fatal. Some people can overcome a little, but the older the individual is, the more hazardous loneliness becomes. A hug or touch is so important. Hospitals and nursing homes are destroying people. There aren't enough nurses to go around."

With economic globalization comes an emerging affection-deprived sector: the migrants. In a report again by the United Nations [18], there was an estimated 214 million international migrants in 2010, an increase of 58 million since 1990. There have been documented cases where people experienced cultural shock [19] and emotional discomfort that caused

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tremendous psychological stress [20]. According to the Affection Exchange Theory [21], [22] affection deprivation has no correlation with age and no relationship with ethnicity, but men report significantly higher average affection deprivation than women. It shows positive linear associations with loneliness, depression, stress, alexithymia, preoccupied and fearful avoidant attachment styles, and numbers of personality disorders, mood and anxiety disorders, and secondary immune disorders. Affection deprivation has negative linear associations for general health, happiness, social support, relationship satisfaction, and attachment security.

Although the internet has brought us much progress, video, audio, and text alone are inadequate to fully communicate the richness of human expression. Touch is a subtle yet powerful nonverbal modality that modern communications media have missed out. Popular online communication programs like Facebook Messenger (Facebook Inc.) and Skype (Skype Communications, Microsoft Corp.) are unable to provide the 'touch factor'. There were a few notable examples: the HandJive [23] and LoveBomb [24] are mobile haptic devices that fit in one hand. They were intended to break the silence during a meeting and to anonimously send a user's state of emotion of either happiness or sadness to people at a certain distance. Interaction in HandJive is done using patterns and routines through electrical switches while LoveBomb used two buttons for two emotions (happiness and sadness) as input and two corresponding vibrations as output.

Comtouch [25] and Share2Talk [26] are independent audio-tactile interfaces intended for mobile phones. Comtouch translates finger pressure into vibration whereas in Share2Talk, a preset or created message similar to SMS is sent and mapped to a specific vibration. Haptic instant messaging [27] was designed to complement text messages with haptic effects and hapticons (small programmed patterns). These hapticons can be communicated through an interface such as FootIO device [28] to let the users send haptic messages through their feet. Wearable devices that enable users to send tactile sensations through a vest or a shirt were also previously developed. HugMe [29] is a haptic jacket that has embedded vibrotactile actuators on the upper arm and upper chest. Hug Shirt [30] is a shirt embedded with sensors where users can send "hugs" from a distance through Java-enabled mobile phones. The HaptiHug [31] combines the virtual world, Second Life (Linden Research, Inc.), to provide real time hug sensation.

Haans and colleagues [32] used vibrotactile stimuli through a vest and arm straps to make participants believe that a male or female stranger was remotely touching them at different parts of the body. The authors report that touches on the stomach, arm, and wrist were significantly less pleasant than touches on the upper and lower back regions, thus providing partial support that mediated social touch is actually perceived as a real touch. Wang and Quek [33] designed a shape memory alloy-actuated haptic device that provides a contracting motion on the subjects' arms. The effects of remote touch were evaluated when subjects were asked to listen to a sad story as told by a professional actress. However, only qualitative measures were used to determine the changes in the subjects' current feelings and emotions. Teh and colleagues [34] described the Huggy Pajama system that made use of air pockets to reproduce a hug, a heating system to produce warmth, and color changing fabric display to indicate the distance of separation. There was no user evaluation that was reported in that paper. Suhonen and colleagues [35] compared the squeezing movements and the thermal feedback of their haptic device with speech-only communication. Using self-reported perceptions of the users about the system, the authors found that the added haptic modality allowed conveying emphases, emotions, and increased the feeling of closeness between the dyads of experimental subjects.

To test the Midas touch effect with devices, Haans and colleagues demonstrated that an electromechanical stimulation has similar effects to human touch in experiments where the subjects helped the experimenter pick up coins [36] or pencils [37] that were thought to have been accidentally dropped. In an economic decision-making game called Ultimatum, Spapé and colleagues [38] demonstrated that participants were more compliant (i.e., they accepted more offers) and were more generous (i.e., they offered higher amounts for sharing) when electromechanical touch were provided as compared to those subjects who did not receive the electromechanical touch.

A body-conforming tactile jacket was developed at Philips Research [39] to create an immersive movie watching experience. The blood-volume pulse (BVP) and skin conductivity levels (SCL) of 13 subjects were measured and processed. Their experiments involved making the subjects watch seven movie clips: Braveheart, When Harry met Sally, Jurassic Park III, The Lion King, My Bodyguard, Silence of the Lambs, and a Tom & Jerry cartoons. The subjects were asked to watch the clips twice, once with the tactile patterns activated on the jacket and once without. The authors claimed that an immersive experience has indeed been achieved. However, the experimental approach of allowing the subjects to watch the movie twice may have already influenced the novelty and the subsequent physiological reactions of the viewers.

Except for the body-conforming tactile jacket [39], these prior works that were mentioned have not tested the effects of wearable haptic devices to the emotional state of the subjects under a controlled laboratory condition with an emotionally-eliciting movie scene. A technology that would enable touch to be transferred and received could make social interactions in modern telecommunications more engaging. It may also have the potential to subdue the negative effects of social isolation. We aim to evaluate the effectiveness and benefits of an affective tele-touch system to people who are physically separated. To test that idea, we developed a system that can transmit and receive touch over the internet, albeit in a one-way direction for the meantime. The experimental questions of the present study are as follows: (1) Does watching an emotionally-eliciting movie create autonomic reactions on the subjects? (2) If there are physiological reactions, does the tele-touch device have similar effect like human touch on the subjects as compared to when touch was not provided? The next section presents the development of the tele-touch system. Section 3 describes the experimental procedure. Section 4 presents the findings from the heart rate (HR) monitor and galvanic skin response sensors (GSR). The concluding remarks are given in Section 5.

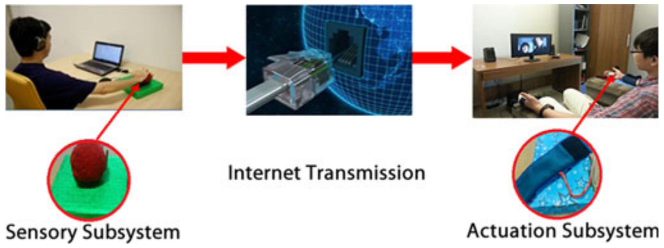

Fig. 1. Affective tele-touch system. At the sensory subsystem side (left), pressure and temperature data from the experimenter's hand are transmitted over the internet. The data are decoded and are presented as vibration, heat, and tickle to the experimental subject at the actuation subsystem side (right).

2 THE AFFECTIVE TELE-TOUCH SYSTEM

The affective tele-touch system consists of the sensory and actuation subsystems (Fig. 1). On the sensory side, a custom-designed cushioned ball acquires contact information, such as the amount of grasping force and the heat from the hand of the experimenter. The data is processed and is sent through the internet. On the actuation side, the signals for pressure and warmth are decoded and are presented to the communication partner using a tele-touch interface.

The architecture of the affective tele-touch system is shown in Fig. 2. In terms of specific hardware components, the cushioned ball has force, temperature, and flexion sensors that were embedded on soft fabric. As the ball is grasped, the surface pressure induces subsurface stresses, which the embedded sensors detect. On the actuation side, the network manager accepts the transmitted data. The data manager then processes the data to convert the binary signals to appropriate signals for producing vibrations, heat, and tickle. The interface on the recipient of the tele-touch was designed as an actuated armband.

Each subsystem was connected to a computer that communicates to each other through a network over the internet. The communication server and the client update their respective sensor and actuator softwares so that the information (i.e., server event log and sensor/actuator levels) can be viewed on the monitor. Both softwares were designed using C# programming on Visual Studio (Microsoft Corp). Two microprocessors (Arduino mega 2560, Smart Projects) were responsible for receiving sensory information from the sensors and providing actuation. These subsystems were serially connected to their respective computers so that the information can be passed from the sensory to the actuation subsystem.

In more detail, the tele-touch system has three modalities. First, exerting a grasping force of up 10 N on the force sensors (FSR 400 series, Interlink Electronics) at the sensory side results in the activation of the vibration motors (Shaftless Vibration Motor, Pololu Corp.) in the actuation side. The sensory side has five force sensors. Each sensor has five levels of force sensing partitioned at 2 N apart (i.e., 2, 4, 6, 8, 10 N). At the actuation side, five different levels were created for each vibration motor. The motor has a maximum amplitude of 0.75 g and a maximum speed of 14,000 RPM, which gives us a maximum frequency, f, of approximately 200 Hz (i.e., $f = RPM/60$). Altogether, 25 levels of vibration can be created from the experimenter's grasp. This was an attempt to create non-identical contact forces analogous to the contact forces

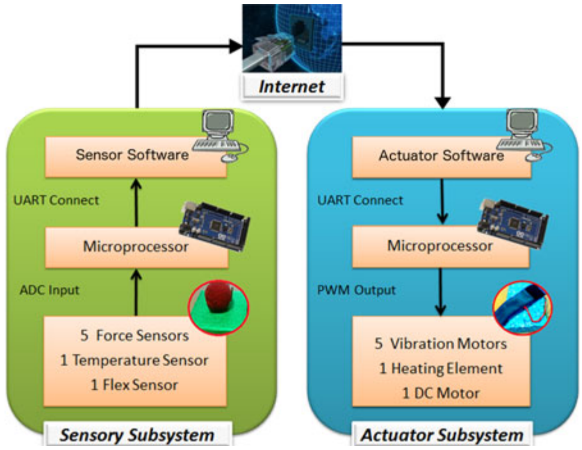

Fig. 2. The system architecture for a one-direction demonstrator. The hardware components of the sensory and actuator subsystems are shown. Sensory data are transmitted over the internet to activate the tele-touch device at the actuator side.

exerted by the human fingers in a prototypical grasping task [40]. Second, a temperature sensor (LM35, Texas Instruments; precision 0.2 °C) was located on the sensory side to measure the palm temperature. This was translated to the heat produced at the actuation end by the heating elements to replicate human warmth. The temperature of the transferred heat can reach up to 29 °C. This temperature was the most preferred temperature by the human subjects based on our work on replicating the temperatures of the palm and index fingers using synthetic skins [41]. Lastly, when the flex sensor (FS-L-0112-103-ST, Spectra Symbol) is bent at the sensory side, the DC motor at the actuation end was executed. To create a tickling sensation, the feather attached to a DC motor rotated with 5 increasing levels depending on the degree of bending from the flex sensor.

At the sensory subsystem side, the five force sensing resistors, temperature sensors, and flex sensors were connected to their own analog-to-digital converter (ADC) channels of the microcontroller. The ADC channel converts the analog voltage into a 10-bit digital data for internal processing. The microprocessor processes the input voltages from every ADC input port that were used and were split into individual sensor levels. The communication protocol between the Arduino controller to the computer on both actuator and sensory sides was implemented using universal asynchronous receiver/transmitter (UART) at 9,600 baud rate with 8 bits with no parity and one stop bit via serial cable. Every force, temperature, and tickle data were scaled to 8 bits to reduce the amount of data to be sent at one time over the internet. The sensor software sends the sensory data in the form of pXXXXXtXfX to the actuator software. The protocol pXXXXX is for pressure, where p is for the pressure data and the next 5 X values are the force levels of each finger. The protocol tX is for temperature, where t represents temperature and X is the detected temperature. The protocol fX is for tickle, where X is for the rotational speed of the motor.

At the actuation side, the computer receives the data from the sensory subsystem. The actuation software directly forwards the data through serial communications to the microprocessor. Upon receiving the data, an interrupt was immediately initiated to split the data into its respective individual levels and then stored in a global buffer. The data received was fed to the microcontroller. Pulse-width modulation (PWM) signals were sent to the five flexible heating elements made from polyimide (HK5200R5.2L12B, Minco Sensors and Heaters), to the DC motor (65 rpm max), where the feather was mounted, and to the five different vibration motors (0.75 g vibration amplitude with a supply of 3 V). Each vibration motor corresponded to each of the finger pressure data received from the sensory side.

To test the time delay during the transmission of the tele-touch signals, an experiment was conducted at the laboratory using a computer with Intel Core i3 processor, 4 GB RAM, and an Ethernet speed of 100 Mbps. The data transmission frequency was 50 Hz. We compared the delays under the conditions when a tele-touch signal was sent or not. An average time delay of 129 msec was recorded when the cushioned ball at the sensory side was squeezed. With no sensory input, the time delay was 105 ms. According to psychophysicists, the threshold for perceiving asynchrony between events can vary from 20 to 200 msec, depending on stimulus settings and sensory modality [42], [43], [44]. In the context of telemanipulation systems, it was suggested that a delay of 100 msec was allowable [45].

3 Methods

3.1 Participants

In the present study, we aim to test a teletouch device using physiological measures when subjects watch an emotionally-laden movie. Research suggests that there are gender differences in one's capacity for empathy or one's ability to understand the emotions and feelings of others in relation to oneself. The gender difference starts from birth and was shown to be consistent across the lifespan [46], [47]. Females tend to score higher than males in self-reported evaluation of empathy [48], [49], [50]. It was hypothesized that the differences may have come from the roles that males and females take throughout evolution [51]. Considering that the subjects could take the perspective of the male character in the movie, we selected male subjects for this study and recorded their physiological response.

Thirty healthy male subjects were recruited for the experiment by email. All participants were undergraduate or graduate students (18-30 years old) at the National University of Singapore. The subjects were divided into three groups with 10 subjects each. Subjects for the control group, the *no-touch* (NT) group, were not provided with any form of touch during the experiment. The subjects for the *human touch* (HT) group were accompanied by their spouse or girlfriend, who will then touch the subject during the experiment. For the last group, the experimenter assisted the subjects of the *tele-touch* (TT) group in mounting the device at the start of the experiment. He left the room afterwards in order to activate the device from another room. The subjects from these last two groups were touched at the hairy part of their forearm. It is at this location where C-tactile (CT) afferents are known to be concentrated [52]. CT afferents are responsible for the sensation of pleasurable touch [53], [54].

For the HT group, the spouse or girlfriend was chosen to touch the subject because our pilot tests [55] showed that touch from a stranger resulted into the discomfort of the subjects, which led to ambiguous readings from the physiological sensors. Moreover, earlier works showed that the touch received by couples in stressful activities resulted into lower systolic and diastolic heart pressure as compared to those couples who did not touch each other [56]. Since the majority of our subjects were undergraduate students, a further exclusion criterion was to choose subjects without children in order to have a balance in the three groups.

We conducted a sensitivity power analysis [57] to determine the effect size that we could detect given our sample size. With an alpha of 0.05 and a recommended power of 0.80, the calculated effect size was 0.60 for three groups having a total sample size of 30. We compared this effect size to an earlier study on the detection of physiological measures from movie watching [58]. The calculated effect size was 0.51 using the same alpha and power for two groups (male and female) for a total sample size of 32. Both effect sizes can be considered as large using Cohen's criteria [59], where a large effect size implies large observable difference among the groups.

The experimental procedures consisted of purely physiological data collection (heart rate and skin conductance). The procedures did not include invasive or potentially dangerous methods and were in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Data were stored and analyzed anonymously. All participants gave written informed consent and were reimbursed $8 each for their participation.

3.2 Experimental Procedure

To test the variations across the three groups (i.e., NT, HT and TT), we compared the subjects' physiological data using cardiovascular and electrodermal measures. These types of measures were chosen because these are the most used for autonomic nervous system (ANS) activity in emotion. The ANS, also known as the involuntary nervous system, innervates cardiac muscle, smooth muscle, and various endocrine and exocrine glands and functions without conscious, voluntary control [60]. While there is still no scientific convergence on the relationship between emotions and the ANS, there have been numerous experiments that have investigated the response of the ANS in manipulated emotions under laboratory conditions using cardiovascular and electrodermal measures. Heart rate or heart rate variability has a link with sympatho/vagal balance [61], [62], [63]. Galvanic skin response activity was viewed as a sensitive and convenient measure of indexing changes in sympathetic arousal associated with emotion, cognition, and attention [64]. Given that males show less empathy than females and that males have more deliberate control over their emotional expressions [65], [66], we excluded self-reports. Due to the societal expectations in expressing emotions, male subjects may have some reluctance in reporting empathic experiences [67], which could introduce biases in the results.

In a review of 134 literatures on the activity of the ANS on emotion, Kreibig [68] reported that the commonly investigated negative emotions were anger, anxiety, disgust, embarrassment, fear, and sadness while the positive emotions were affection, amusement, contentment, happiness, joy, anticipatory pleasure, pride, and relief. In that survey, it

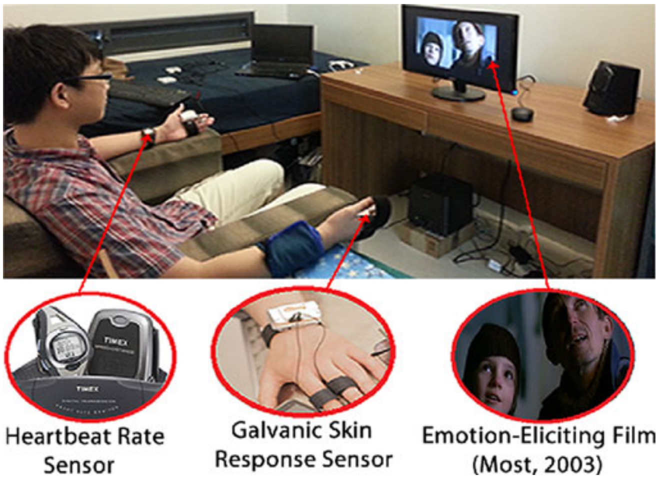

Fig. 3. Experimental setup for a subject under the 'tele-touch' group. Physiological measures in the form of heart rate and galvanic skin response were taken as the subject watched an emotionally-eliciting movie.

was also reported that images [69], [70], music [71], [72] and movies [73], [74], [75] were successful to stimulate emotion. Among these, movie clips have been most utilized [76]. Schaefer [76] argues that movie clips have distinct advantages, firstly because these are seen to be more effective in sustained affective processing for longer periods of time at both the subjective and physiological levels and secondly, the participants are exposed to potential real-life scenarios without the ethical constraints. Moreover, the typical response measures were within 60 sec intervals [68].

It has earlier been demonstrated that film clips can induce emotional stimuli [58]. A database of 52 film clips were categorized according to horror, erotic, scenery, social positive, social negative, and object manipulation. In this database, social negative and positive clips depict social interactions but the content is clearly positive or negative and with low appetitive or defensive motivation while object manipulation depict categories without clear appetitive or defensive motivation. Multiple pairwise comparisons showed that both the emotionally-arousing horror and erotic film clips have caused significantly decreased heart rate and significantly increased electrodermal responses in the subjects as compared to the other film clip categories.

Based on those findings, we measured the physiological responses of the subjects using a heart rate sensor (Iron Man Heart Rate Monitor with Data Recorder 2, Timex) and a galvanic skin response sensor (also known as Skin Conductance Rate (SCR) sensor [77]; model 2r, GSR Development Kit, Shimmer), as shown in Fig. 3. Through a transmitter strapped at the chest and a receiver at the wrist, the HR monitor picks up the electrical impulses generated by the polarization and depolarization of cardiac tissue, which then translates into a waveform. Built-in microprocessors then analyse the electrocardiogram signals to determine the heart rate. The GSR measures the skin resistance between electrodes. The electrodes were attached to the palmar side of the middle phalanges of the index and middle fingers by a velcro fastener. The sweat glands react with stimulus, thus increasing skin moisture. Skin conductance increases (or skin resistance decreases) due to the current flow that arise from the changes in the balance of positive and negative ions in the secreted fluid.

To further test the tele-touch system, we made each subject watch an emotion-eliciting movie titled the "Most", a Czech film released in 2003. A shorter version of the movie was edited to 9 minutes long (see Supplementary Material, which can be found on the Computer Society Digital Library at http://doi.ieeecomputersociety.org/10.1109/TAFFC.2015.2509985 and Fig. 4). No one among the subjects has seen the movie before. The movie clip was selected to induce strong emotions in a controlled laboratory condition. The movie was displayed on a 22.5 inch monitor, in a dimly lit room of approximately 40 m^2. The audio consisted of a desktop speaker system (SRS D4; 27 Watts, Sony, Inc.). The participants were seated facing the monitor.

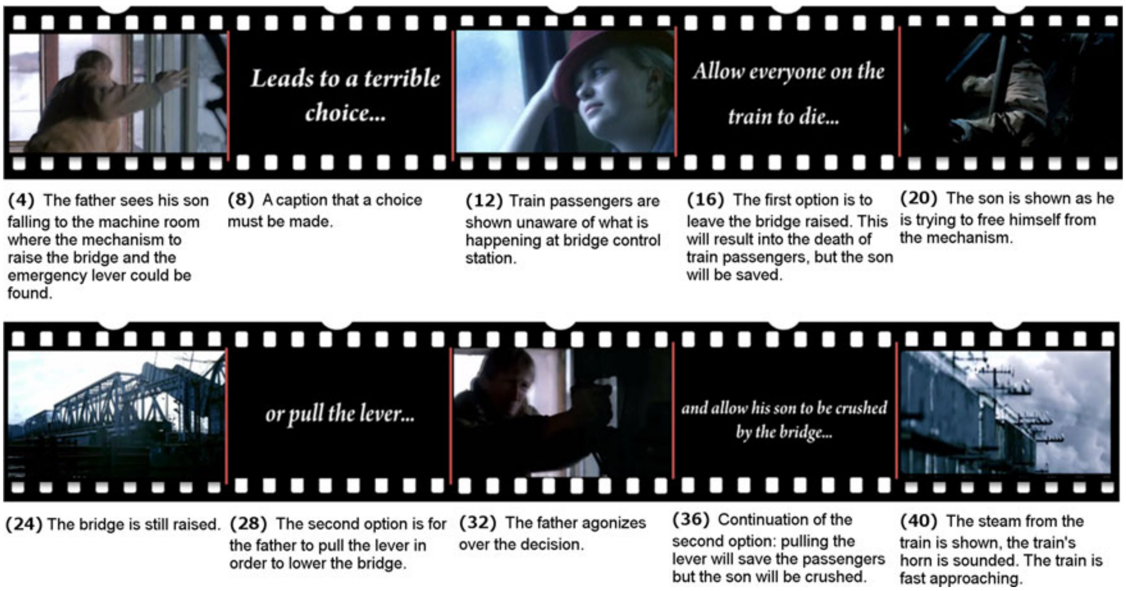

Fig. 4. Major scenes from the movie stimuli. These scenes evoked the highest variations in physiological measures. Human and tele-touches were provided at the 20th second, which is at the 5:48 scene of the whole movie. No touches were applied to the control group.

In summary, the movie was about a father and his only son. The father works as an operator of a moveable bridge. The bridge must be raised when a boat passes by and lowered every time a train would pass. One day, his son was playing in the vicinity of the control station. As a train was getting closer to the bridge, the son noticed that the bridge was not being lowered as it was supposed to. The son attempted to lower the bridge on his own through an emergency mechanism but he fell inside the machine room. The father was faced with a dilemma of pulling a lever that will have two possible outcomes. By leaving the bridge raised as it is, he will be able to save his son, who was trapped at the bridge mechanism, but the passengers from the passing train will die. Alternatively, by lowering the bridge, the passengers will be saved but his son will die. The father chose to save the passengers. He pulled the lever to lower the bridge. The son was crushed under the bridge.

Each subject went through a sequence of three phases in the experiment: relaxation, video, and recovery. All throughout the experiment, the HR and GSR data were continuously collected because physiological reactions to the movie tend to fluctuate throughout the experiment. For the relaxation phase, the subjects were asked to rest for the baseline data to be obtained. The subjects then watched the movie during the video phase. Lastly, the recovery phase gave time for the subjects to calm down. These phases took 5, 9.17 and 5 minutes, respectively. In our pilot studies [55], we found that heart rate readings became most elevated at 5:48 that showed the father struggling to make a choice on pulling the lever or not. Thus, the human touch and the tele-touch were applied at that scene. Touching was stopped only at the end of the movie.

3.3 Data Processing

The HR and GSR data for the three experimental phases were processed in MATLAB (v12b, Mathworks). We employed a Hanning window band-pass filter (cf. [78], [79]) to the raw measurement signals to filter the noise. Specific filters were designed for HR or GSR data. For the HR filter design, a band-pass of low cut-off frequency of 0.02 Hz and high cut-off frequency of 0.6 Hz were applied to filter off the frequency components associated with thermoregulatory cycles, analyzing only those due to variations of sympathetic and parasympathetic nervous system [80], [81]. For the GSR filter design, we used a band-pass filter with a low cut-off frequency of 0.2 Hz to split the phasic component of the electrodermal activity from the tonic one and a high cut-off frequency of 1 Hz to reduce artifacts caused by Ebbecke waves [82] and to remove noise [80], [82]. Similar to procedures in [78], [83], the filtered GSR signals were then normalized according to equation (1):

$$GSR_{i,0to1} = \frac{GSR_i - GSR_{mean}}{GSR_{max} - GSR_{min}}, \quad (1)$$

where $GSR_{i,0to1}$ is the GSR value, GSR_i is the GSR value at a given point i, GSR_{mean}, GSR_{max} and GSR_{min} are the mean, maximum, and minimum value of GSR for a given subject in each group, respectively. This process was performed only on GSR signals to resolve the larger baseline fluctuations among the subjects [78].

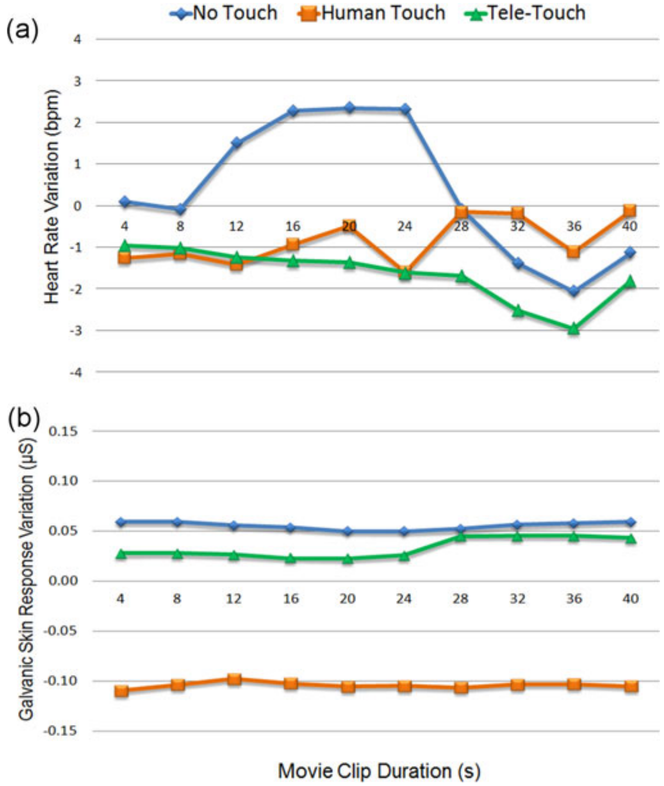

Fig. 5. Physiological responses of the experimental groups for the 40 second duration of the movie. (a) Heart rate variation and (b) galvanic skin response variation.

The baseline was set as the last 60 sec of the relaxation phase just before the presentation of the movie (cf. [73], [84]). The mean HR and GSR data at the baseline for each subject were obtained.

In an earlier work, Carvalho et al. [58] made use of a 40 sec segment of a film, which was already sufficient to evoke an emotional response. Similarly, we also selected a 40 sec segment in the movie. For our data, we made use of the 20 sec scenes before the father held the lever and 20 sec after. The scene where the father held the lever was at the 20th second in the movie clip in Fig. 4.

From this 40 sec segment, the HR and GSR beyond two SDs from the mean were excluded from the analysis (cf. [85]). For the HR analysis, all the data of one participant in the NT group and another in the HT group were excluded due to the high percentage of excluded data (i.e., >15 percent). For the remaining heart rate data, there were 0.51 percent of the data that were not included due to the exclusion criterion. For the GSR analysis, all the data of one participant in the NT group and two participants in the HT group were excluded due to high percentage of excluded data (i.e., >15 percent). There were 0.29 percent of the data that were excluded for the remaining data.

Following the data analysis in [58], the mean HR and GSR data for each subject were acquired for the consecutive 4 second epochs during the entire 40 seconds of film clip exposure. To achieve meaningful comparisons between participants, the baseline mean was subtracted from the mean HR and GSR data (cf. [73], [58]). HR responses are shown in Fig. 5a while GSR responses are shown in Fig. 5b for every 4 sec epochs of the movie clip.

The mean HR and GSR data for each 4 sec epoch for each group were then submitted to a one-way analysis of variance (ANOVA). The level for statistical significance was set at $p < 0.05$ and all analyses were performed using SPSS (v22, IBM, Chicago, USA).

4 Results

The movie clip that we selected created a stress-inducing emotion due to the threat of an impending danger that could lead to the serious injury or death of either the child or the train passengers. The experiment aimed to answer (1) whether the movie has an effect on physiological reactions of the subjects, and (2) if there is an effect, would the tele-touch be similar to the human touch, but not with the no-touch condition?

4.1 Effects of the Movie on the Physiological Responses

To investigate the effect of the movie scene on the physiological measures, we computed for the slope of the three touch conditions in Fig. 5 for the current 4 sec epoch to the next 4 sec epoch. The resulting slopes were normalized with respect to the maximum magnitudes of HR and GSR (see results in Fig. 6).

For the no-touch condition, Fig. 6a shows that when the heart rate data are increasing, the skin response data are decreasing and vice versa. A Pearson product-moment correlation coefficient confirms a strong negative correlation between the subjects' HR and GSR responses for the movie segment, $r = -0.683$, $n = 9$, $p = 0.042$. Results also indicate that if the HR data were on the positive half of the chart, the skin response data were on the negative half and vice versa. The data crossed the zero slope at the 20 to 24 sec period. This was the period when the father first held the lever that would result into the death of his son. The scene was followed by the caption: "or pull the lever" (see Fig. 4). After these, the scene of the trapped child was shown followed by the scene where the father was in a high state of distress (32 sec).

For the human touch condition, the subject's spouse or girlfriend was instructed to touch the arm of the subject starting at 5:48 of the movie (20 sec in Fig. 4), which is the scene where the father held the lever. There was a moderate negative correlation between subjects' HR and GSR responses for the movie segment, $r = -0.397$, $n = 9$, $p = 0.290$ (Fig. 6b). The HT condition's HR and GSR data appear to lag at the 12 to 20 sec period as compared to the NT control condition. When human touch was applied at the 20 to 24 sec period, both the HR and GSR data takes the opposite pattern as compared to the control condition. The slopes seem to return to the typical pattern as the control experiment starting at the 28th sec.

For the tele-touch condition, both the HR and GSR responses appear to be attenuated from 4 to 20 sec or before the tele-touch was activated by the experimenter (Fig. 6c). When the tele-touch was applied starting at the 20th sec, notice that the HR data were on the negative half while the GSR data were on the positive half. This trend was similar to the NT control condition and to the latter part of the HT condition. When the tele-touch was initially applied from 20 to 32 sec, there was a very strong positive correlation between the HR and GSR data, $r = 0.776$, $n = 3$, $p = 0.435$. When compared to the NT control condition, the increasing slope of the tele-touch was steeper immediately after the touch was activated at 20 to 28 sec period. There was an equally steep decrease in slope at the 28 to 32 sec period. After this, the TT's increasing HR slope and decreasing GSR slope follows the pattern of NT and HT. However, for the entire 40 sec movie segment, the correlation coefficient shows a negligible relationship between the subjects' HR and GSR responses, $r = -0.062$, $n = 9$, $p = 0.875$.

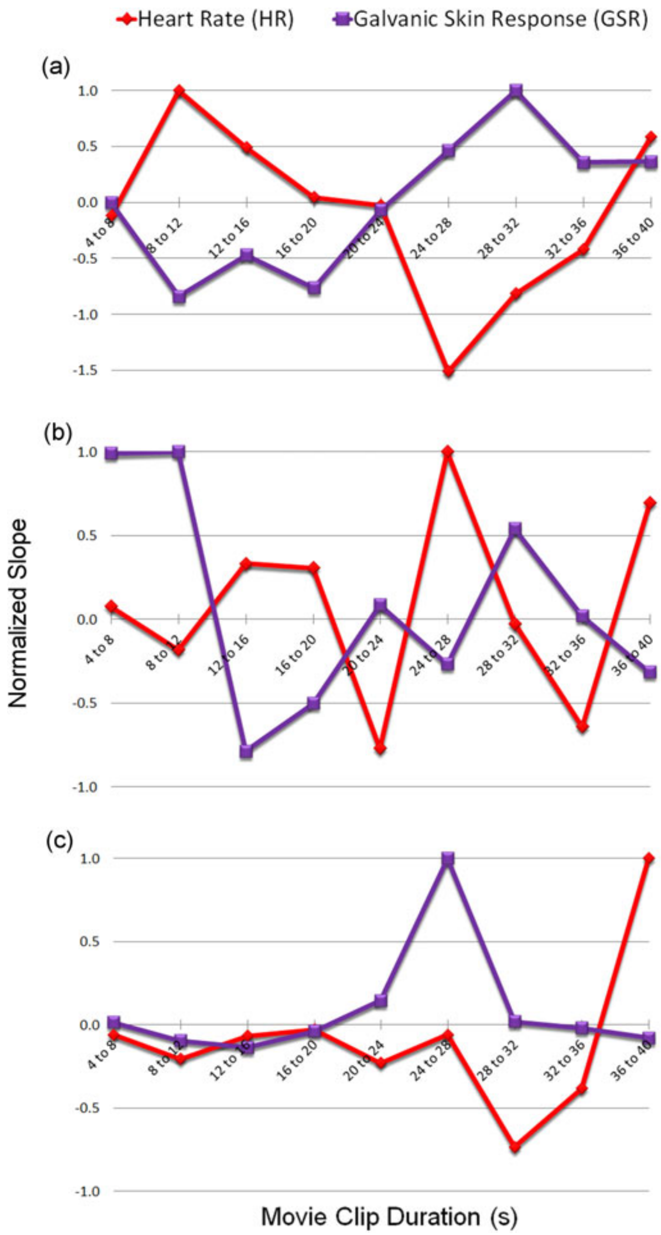

Fig. 6. Normailized slope of the physiological measures for the three experimental groups. (a) No-Touch, (b) Human Touch, and (c) Tele-Touch.

4.2 Effects of the Touch Conditions

The HR and GSR data for each 4 sec epoch in Fig. 5 were subjected to statistical analysis. For the heart rate variations (Fig. 7a), the ANOVA showed statistically significant effect

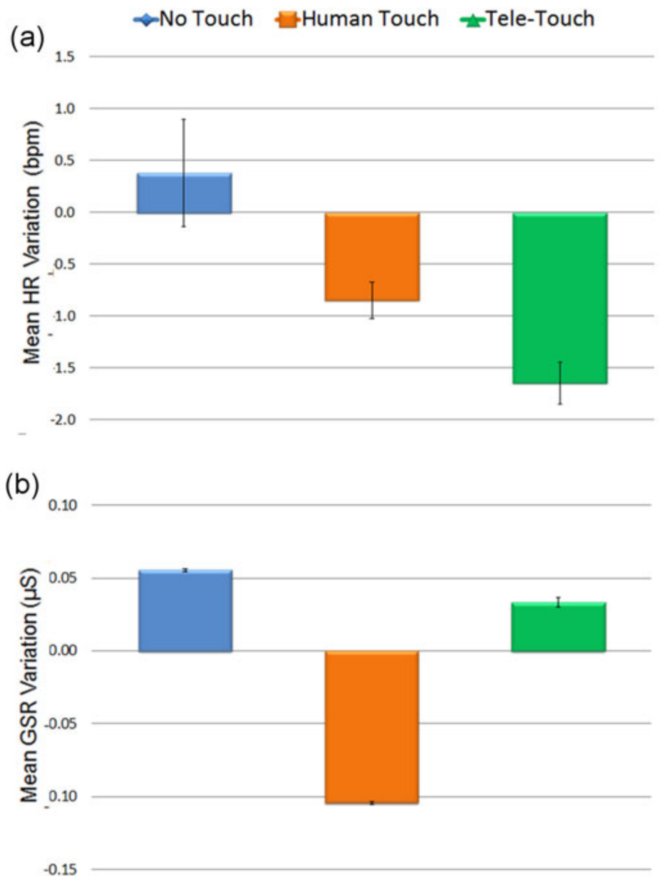

Fig. 7. Mean of the variations in physiological measures. (a) Mean HR variation and (b) mean GSR variation. Error bars represent standard error of the mean.

of the factor touch type categories [$F(2,27) = 9.139$, $p = 0.001$]. Post hoc Tukey HSD comparisons revealed that the no-touch group ($M = 0.3808$ bpm, $SD = 1.6451$ bpm) had an increased heart rate compared to both the human touch ($M = -0.8490$ bpm, $SD = 0.5585$ bpm, $p = 0.041$) and the tele-touch ($M = -1.6487$ bpm, $SD = 0.6424$ bpm; $p = 0.001$) groups. No statistically significant difference was found between the human touch and the tele-touch ($p = 0.234$).

For the galvanic skin response variations (Fig. 7b), results showed statistically significant effect of the factor touch type categories [$F(2,27) = 3534.12$, $p < 0.001$]. The post hoc Tukey HSD comparisons revealed that the GSR variations for the three groups were statistically significant from one another ($p < 0.001$) with the no-touch group having the highest GSR reading ($M = 0.0553$ μS, $SD = 0.0037$ μS) followed by the tele-touch ($M = 0.0334$ μS, $SD = 0.0099$ μS) and the human touch group ($M = -0.1042$ μS, $SD = 0.0031$ μS) with the least GSR reaction.

Taken together, the analysis on the heart rate variations showed that the artificially-generated touch did not have statistically significant difference compared to those who were touched by their spouse or girlfriend, but both touch conditions were different from the no-touch condition. On the other hand, the analysis on the galvanic skin response variations revealed that all the three touch conditions were different from one another although the mean GSR of the tele-touch was closer to the no-touch condition than to the human touch.

5 Conclusion

"Without touch, a baby dies, the human heart aches, the soul withers. Touch is communication on the most basic level. The need for touch is a necessity throughout our lives, from birth to death, which serves to sustain us emotionally and physically" [86]. Considering the ill-effects of touch deprivation in society today, the current paper investigated whether artificially-generated affective touch, which was passed over the internet, can produce similar results just like when the touch is made by another person as if the person were there. We developed a tele-touch system that was able to transmit pressure and heat information from the sender of the touch to the receiver of the touch in the form of vibration, warmth, and tickling sensations through a haptic device. We evaluated the tele-touch system by comparing it with the condition where one group of subjects was not touched and another group of subjects was touched by their spouse or girlfriend. We measured their cardivascular and electrodermal responses as they watched a stress-inducing film where the father had to make a decision that can save either his son or the train passengers from serious bodily harm or death.

The current paper aimed to answer two questions. Firstly, we wanted to confirm whether a stressful movie can influence physiological changes in the subjects. Indeed, we were able to show that there was a strong negative correlation between the HR and GSR responses of the subjects, particularly for the no-touch control condition. Our results were consistent with earlier reported results in [87], [88], [89], [90]. Movies that show impending injury, blood or mutilation cause a deceleration in HR and an increase in GSR activity. This pattern represents a stimulus-specific aversive response where there is an increased sensory intake and attentional processing as well as more sustained attention [91], [89], [90].

Secondly, we wanted to evaluate the effects of the tele-touch device and compare this to a control condition without touch and to another condition where human touch was provided to the subjects. Our findings showed that the tele-touch did not have a significant difference with the human touch for the heart rate variation (Fig. 7a). Importantly, we found that both the human and tele-touches were significantly different with the no-touch condition. For the variations in the galvanic skin response, we found that the GSR responses were significantly different for all the three groups (Fig. 7b). The no-touch condition has the highest GSR variation, followed by the tele-touch and human touch. It appears that the GSR response was attenuated by the human touch as shown by the least GSR value among the three conditions.

Certain limitations of this study must be recognized and can be addressed in future works. First, a confound may have been introduced when the experimenter touched the subjects in the TT condition while the spouse or girlfriend touched the subjects in the HT condition. Experiments that involve touch from another human naturally introduce additional confounding variables [37], [92]. For instance, eye gaze, physical proximity, or the contact pressure of the touch could have an effect on the results. Future experiments could investigate on how to disentangle the confounding variables that might have been introduced by the confederate or the experimenter. Second, the generalizability of the results would be restricted to the background and culture of the subjects. There could be variation if subjects of other nationality would have participated. Third, with regard to gender differences on watching emotional films, it has been suggested that there are differences on the subjective level but not on the physiological measures [84]. It would be interesting to investigate the physiological responses within the same gender and between genders using the current experimental design. Lastly, the effects of the tele-touch might have been different for other genre of movies. Other researchers have investigated the effects of horror, erotic, social positive, social negative, scenery, and objects on HR and GSR responses [73], [58], [84], [93]. A future work could look into the physiological reactions when human or tele-touch interventions are provided.

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