VisualTouch: Enhancing Affective Touch Communication with Multi-modality Stimulation

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ABSTRACT

As one of the most important non-verbal communication channel, touch plays an essential role in interpersonal affective communication. Although some researchers have started exploring the possibility of using wearable devices for conveying emotional information, most of the existing devices still lack the capability to support affective and dynamic touch in interaction. In this paper, we explore the effect of dynamic visual cues on the emotional perception of vibrotactile signals. For this purpose, we developed VisualTouch, a haptic sleeve consisting of a haptic layer and a visual layer. We hypothesized that visual cues would enhance the interpretation of tactile cues when both types of cues are congruent. We first carried out an experiment and selected 4 stimuli producing substantially different responses. Based on that, a second experiment was conducted with 12 participants rating the valence and arousal of 36 stimuli using SAM scales.

CCS CONCEPTS

• **Human-centered computing → Haptic devices**.

KEYWORDS

Social Touch, Multi-modality, Vibration, Color, Congruence

ICMI '19, October 14–18, 2019, Suzhou, China

ACM ISBN 978-1-4503-6860-5/19/10…$15.00
https://doi.org/10.1145/3340555.3353733

ACM Reference Format:
Zhuoming Zhang, Robin Héron, Eric Lecolinet, Françoise Detienne, and Stéphane Safin. 2019. VisualTouch: Enhancing Affective Touch Communication with Multi-modality Stimulation. In *2019 International Conference on Multimodal Interaction (ICMI '19), October 14–18, 2019, Suzhou, China.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3340555.3353733

1 INTRODUCTION

The popularization of mobile devices has offered various ways for people to communicate remotely and share their feelings and emotions. However, most devices and applications mostly rely on the visual and audio channels (e.g. text, emoji, voice or video calls). In contrast, touch, is sparingly used in commercial systems (mostly for notifications) and it has not yet received the same level of attention in HCI research as audition and vision. Touch is widely used in daily face to face communication for conveying emotions and there is evidence that it can increase worthiness, warmth, politeness, trigger emotional attachment and communicate physical connection [11, 19, 33]. Touch is thus one of the most important non-verbal communication channels, but this modality suffers from the difficulty of rendering touch in a realistic manner. Despite recent efforts to improve on this aspect (e.g. by using inflatable devices [32] or electrical muscle stimulation (SMS) [26]), these technologies cannot render all the subtlety of human touch [9] and they tend to be bulky and/or energy consuming, thus hardly usable in a mobile context.

In this paper, we focus on the combination of touch and vision to convey emotions between users. Taking into account the limitations of common technology, we use simple vibrotactile actuators, but in a way that allows generating 'similar' touch and visual signals. More specifically, we developed a haptic device named VisualTouch, which consists of two superimposed layers. The upper layer consists of a matrix of RGB LEDs and the lower layer in a matrix of micro vibration motors. Both matrixes are aligned, which makes it possible to generate dynamic signals that are either or not congruent on the user's forearm (e.g. a stroke or hit that is rendered haptically, visually, or both).

The prototype is made of 10*6 LEDs and as many motors. It enables controlling the duration and the intensity (or color) of both signals. Our hypothesis was that congruent tactile and visual cues would enhance the perception of emotions, both by increasing the perceived arousal/valence spectrum and by making touch signals less ambiguous. We conducted two user studies to evaluate the enhancement of emotional touch perception by adding visual cues. In the first study, we selected four tactile stimuli for the second study by evaluating Valence and Arousal. In the second study, we tested these four touch stimuli in three visual conditions on 12 participants. The results indicate that touch alone has mainly a significant influence on Arousal, while color has a significant influence on both Valence and Arousal. Adding color to the touch stimuli allows for a wider range of perceived emotions and increases the overall Arousal. Moreover, the spectrum of emotion perception is widened when the visual and tactile stimuli are congruent.

We first present the related work then the motivations of our study. We then describe the implementation of the VisualTouch device, and the two experiments we did to assess the enhancement of emotional touch perception by adding congruent visual cues.

2 RELATED WORK

Psychology of social touch

As the earliest sense that develops in the human embryo [12], touch is the primary sensation that the fetus and the newborn use to perceive the world and receive stimulation [5]. With all kinds of interpersonal touches, people can convey a vast amount of social information such as physical and psychological closeness or social-affective state [16]. Affective feelings like love, support, reassurance, affection or sexual attraction as well as negative feelings like anger, disappointment, frustration or confusion can all be conveyed by affective touches [19, 23]. Touch can also enhance the emotional deliverance of more complex social emotions such as trust, receptivity, affection, nurture, dependence, and affiliation [1]. Masson et al. systematically defined these dynamic interpersonal social-affective touches in a database of the perceived naturalness and valence of the various touch gestures [29].

Modalities involved in social touch

Touch can act not only as a communication channel for expressing intimate emotions but also as a modulator between different sensations and behaviors. Most researches on perception consider senses such as vision, audition, touch, olfaction, and gustation separately, but sensory modalities are not entirely separate modules. All the information we perceive from the external world is combined and processed to yield multi-modality determined perceptions [6]. For instance, when two hands are rubbed together, the feeling of the skin texture may change by changing the sound of the friction [20] and the flavor of foods and drinks can be altered by changing their color [7].

As one of the main sensory modalities, touch is influencing and influenced by other sensations. Among these sense perceptions, researchers investigated the possible relation between vision and touch and found a strong cross-model interaction [10]. Several studies showed that visual cues, even non-informative ones, can improve haptic spatial perception and enhance tactile acuity [8, 30]. Both the perception speed and accuracy of touch are increased by giving extra visual cues, and this effect is increased when more informative cues are given. The competition between neural representations and the recruitment of attentional resources result in a visual dominance effect [13], so that users generally do not perceive small conflicts between visual and tactile cues [35]. At last, researchers also found that spatially congruent visual cue can affect tactile perception [27]. They noted that visuo-tactile cross-modal links dominate the representation of near body space, and passive viewing of the body can influence the perception of somatosensory stimuli.

Generating social touch

Touch sensation involves many factors. In our skin, there are four kinds of tactile receptors: Meissner, Merkel, Pacinian, and Ruffini receptors, with different functions. The Meissner corpuscles respond to light touch and texture, the Merkel receptor ending detect sustained pressure, the Pacinian corpuscles detect rapid vibrations and the Ruffini ending detect tension. [31] So even though various technologies and actuators have been used in wearable tactile devices, generating precise and vivid touch signals remains difficult.

Among those actuators, vibration motors are still the most commonly used actuators for generating touch stimuli. Lindeman et al. used a vest with vibrotactile actuators in the context of an immersive virtual environment [25]. Similarly, Huisman et al. created a touch-sensitive vibrotactile sleeve called TaSST [17] for communicating different types of touch, which proved to be effective for dynamic touches. Wilson et al. proposed Multi-Moji [45], a tactile feedback device using mobile phone vibration motors and thermal cues. However, the expressiveness of these devices remains limited because vibrations can only trigger Pacinian corpuscles in our skin, which is only one of the four main receptors we use to perceive touch [24].

Other technologies such as biological signals and inflatable structures have also been proposed. Impacto, by Lopes et al. [26], generates a haptic sensation of being hit in a virtual reality environment. This system relies on solenoids and also uses electrical muscle stimulation to control the contraction of the user's muscles. POKE by Park et al. [32] let long-distance couples communicate through an inflatable surface. Users can transmit their index finger movements on the other user's cheek through air inflation patterns. However, these solutions remain limited to certain use cases and a general solution for communicating social touch is still lacking.

Position of the device

Human factors like user's acceptance and comfortableness are of prior importance when conceiving a wearable device. In recent research, Suvilehto et al. explored which areas are acceptable in social touch [41]. Body parts like arms, hands, shoulders have a higher possibility of been accepted in social touch compared to laps, head, and abdomen. Similarly, Wagner et al. have proposed a body-centric design space, which shows that the upper part of the body provides a higher rank of social acceptability and faster reaction time in body-involved interactions [42].

From a physiology point of view, the sensitivity of the body varies depending on the body zone. Mancini et al. used a *2-Point Discrimination Test* (2PD test) to evaluate the threshold of pain and touch on different body areas [28]. Their study shows that the fingertip, the palm, the forearm, the forehead, and the foot sole are more sensitive and have a better touch resolution compared to other body parts.

Taking into account the considerations and conclusions of these studies, we decided to use the forearm to benefit from its high sensitivity, and also because this body location is generally considered to be suitable for social touch.

3 MOTIVATION

As previously mentioned, the expressiveness of most current social touch devices remains limited. This results in difficulties in precisely interpreting touch signals and their associated meaning. Moreover, touch is by essence ambiguous because similar touch signals can have different meanings depending on the context [21]. Thus, additional information may help to disambiguating touch signal and make them more expressive. Vision is the most important channel to perceive the outside world. Moreover, as shown above, there is a strong interaction between vision and touch, especially when visual and touch signals are congruent [27]. We assume that this interaction can be leveraged for improving the perception of touch [22, 30].

In particular, we consider color as it has been shown to have a strong impact on affective communication. Studies have shown a strong interaction between color and emotion. Back in 1954, Wexner et al. investigated the association between colors and mood-tones [43]. Similarly, Valdez et al. evaluated the effect of color on emotion using Valence-Arousal-Dominance scales. More recent studies, such as Suk et al. or Wilms et al. evaluated the effect of colored light using LEDs [40, 44]. Researchers also observed the cross-modal interaction between color and other perceptions, such as the perception of the flavor[38] and the perception of the temperature [34]. Similarly, Simner et al. noticed a touch–color correspondences which influences our perception on tactile qualities [37].

Considering the potential of using color to enhance the perception of emotions, we designed a prototype that allows combining tactile output with colored visual signals. More specifically, our hypothesis is that congruent visual cues can help in counterbalancing the imprecision of tactile perception (either due to inherent ambiguity or technological limitations), and thus enhance the expressiveness of affective touch.

4 IMPLEMENTATION

Concept

Based on the motivations outlined above, we designed the VisualTouch prototype (see Figure 1). VisualTouch is a wearable device that is placed on the forearm of people by wearing a polyester sleeve strapped with elastic bands and velcro. Touches can be generated with different intensity, location, and duration. When a touch signal is sent by another person, the receiver can feel the vibration on the forearm along with a congruent visual movement. In normal usage, the visual pattern thus follows the vibration pattern, with the same speed and the same intensity. It is aimed to raise the tactile attention of the receiver and to enhance the emotional perception of the tactile cue. By offering more degrees of

Figure 1: VisualTouch device

freedom (e.g. by using color), it can also provide additional information.

Visual layer

The visual layer is the top layer. This layer displays the movement of the touch on the forearm. The visual cues are displayed by a 10cm*17cm LED array consisting of sixty (10*6) RGB LEDs (Figure 2). This array consists of individually addressable RGB LED strips (*ref. WS2812B*) which incorporate intelligent digital port data latches and signal to reshape amplification drive circuits.

The sense of touch can be perceived for a few milliseconds when we are touched by others because of working memory in tactile sensation [2]. Hence, we decided to make the trace to fade away gradually during one second to simulate this persistence of touch. Although our device provides an unusually large number of LEDs, this number is still insufficient to deliver a very accurate pattern. Moreover, shape corners and other gesture discontinuities can affect the fluency of the resulting effect. We thus implemented an anti-aliasing effect, using two complementary techniques. First, an anti-aliasing algorithm decreases the intensity of LED light and blurs sharp corners. Second, we added a physical cover (made of cotton cloth, paper sheets, and cotton wool) on the LED display for obtaining an unpixelated rendering effect (Figure 1).

Vibration layer

As our main purpose was to evaluate how vision and color could enhance touch perception, we used common technology to generate tactile feedback. Located beneath the previous layer, the vibration layer consists of sixty '1027' micro-vibration motors. Both layers have the same spatial arrangement so that the motors are aligned with the LEDs of the visual layer. These motors are driven by PWM (Pulse Width Modulation) waves, to generate tactile signals with proper intensity and location. Thus the frequency of the vibration can be controlled to change the perceived intensity of touch stimuli accordingly.

All motors are attached on a polyester sleeve and covered with insulation tape to stabilize them. When a touch signal is detected, the motors corresponding to the target area vibrate 300ms (including the time to shade away). According to the results of the 2PD test [28], touch resolution on the forearm is around 2 cm. So considering the limited resolution of the sense of touch, the anti-aliasing effect is not been used on the vibration layer.

Input and control

Touch patterns can be produced computationally or by using a user interface that was developed for this purpose. This interface captures the movement and the pressure of a movement on a touch-sensitive surface such as a touchscreen. This feature makes it possible to create realistic touch patterns as it can capture the characteristics of actual human touch gestures. Gestures are encoded as a sequence of points with their corresponding location, timestamp and pressure values. In addition, a color can be attributed to the whole gesture. The stimuli are captured using a OnePlus 5T smartphone. The VisualTouch prototype can also work with any sort of compatible data, obtained for instance through pressure-sensitive fabrics [14], a tactile suit [18], etc.

Lastly, a JavaScript robotics and IoT platform called Johnny-Five [3] controls the VisualTouch prototype in real-time. The received data is transferred to Arduino with *Firmata* format under the *StandardFirmata* protocol. The vision layer receives the data from a digital port and the vibration layer through the I2C bus. Four PCA9685 16 channel PWM driver boards are used to control the 60 motors. A simple amplifying circuit, consisting of a 220 Ohm resistance and a BC547B transistor, is attached to each motor. The PWM frequency is 980Hz. The duty cycle is 90% for Intense touch and 60% for Mild touch.

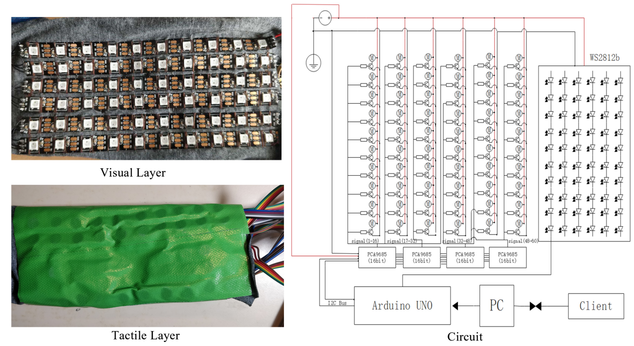

Figure 2: Structure of VisualTouch device

5 TACTILE EMOTIONAL RESPONSE

As previously explained, our goal is to investigate whether colored visual cues improve the perception of tactile cues. We conducted two studies for this purpose. The first study, which is presented in this section, was conducted to select appropriate tactile stimuli for the second study (i.e. stimuli that produce sufficiently different emotional responses). The second study, which will be presented in the next section, compared the emotional response when visual stimuli were present or not.

Stimuli

Taking previous research into consideration [17, 45], we used three dimensions, and two values on each dimension, to generate the vibrotactile stimuli: Duration (L: Long or S: Short), Intensity (I: Intense or M: Mild), and Dynamism (S: Static or D: Dynamic). Eight different stimuli were thus obtained by crossing these dimensions: LIS, LID, LMS, LMD, SIS, SID, SMS, and SMD. The duration was, respectively, 2500ms and 1000ms for Long and Short touch stimuli. The Intensity of the stimuli was controlled through PWM wave. The PWM frequency is 980Hz. The duty cycle is 90% for Intense touch and 60% for Mild touch. The last factor, Dynamism, depends on whether the stimulus involves movement (Dynamic) or not (Static). The stimuli captured through the smartphone were manually modified to match the previously described parameters.

Emotion assessment

Emotions can be assessed through not only physiological or behavioral data but also verbally. A first particularly used method for assessing emotions consists in asking the participant to select affect words from a list [15, 16, 39]. Another method ask participants to rate their feeling over two scales (Valence and Arousal) ratings which can later be represented on the circumplex model of emotions developed by Russell et al. [36, 45]. In our experiments, we used the Self-Assesment Manikin (SAM), which provides visual clues (cartoon-like images) to help participants to rate Valence and Arousal on a scale [4, 40, 44]. Thus, a sheet with two SAM scales (one for Valence and one for Arousal) and affect words representing each pole was provided to participants before each experiment [4] (Figure 3). To answer, participants were asked to circle one number on each scale.

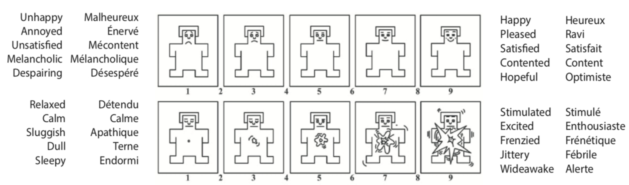

Figure 3: SAM presentation sheet

Participants

The study featured 16 participants (22-45 years old; mean: 26.4). No participant reported sensorimotor impairments.

Procedure

The participants were asked to sit in front of a desk and the experiment was explained to them. They were then asked to read and sign an informed consent form, and the VisualTouch prototype was strapped on their non-dominant arm. The objective of the study was to explore the general emotional interpretation of visuo-tactile signals and whether multimodality channels can enhance the emotional perception of tactile signals. Following previous research in emotional haptic communication studies [15, 45], we told the participants 1) that the stimuli had been recorded by another person who intended to convey certain emotions through these stimuli, 2) that their task was to assess the intended emotion of each stimulus. In other words, the task was to evaluate the interpretation of the emotion expressed by a sender.

After clarifying the procedure, four training stimuli were displayed to familiarize participants with the device, as well as SAM scales. The eight previously described stimuli were then presented twice to the participants, in random order. The participants were asked to rate the Valence and Arousal after each stimulus, using the SAM scale. A short interview was conducted at the end of the experiment. Throughout the experiment, participants wore headphones playing white noise, at a comfortable volume so they would not hear motor noise. The visual layer of the VisualTouch prototype was not activated in this experiment.

Results

The mean score for each touch stimulus on Valence and Arousal are presented in Table 1. As shown in the table, larger differences were obtained for Arousal than for Valence. The results of a MANOVA for Valence and Arousal show a significant effect (Pillai’s Trace = .54, $F(14, 496) = 12.9$, $p < .001$)). A repeated-measures ANOVA on both Valence and Arousal scores showed no significant effect on Valence, but a significant main effect on Arousal ($F(7,8) = 78.49$, $p < .001$).

As the goal of this first study was to find a few stimuli producing a substantially different response, we mainly took Arousal into consideration to select them. First, we selected the LID and SMS stimuli because they have the highest and lowest Arousal scores. Then we added the LMD stimulus, which had the highest Valence score and a medium Arousal score. Finally, we selected a fourth stimulus, SIS, to balance stimuli in terms of Duration, Intensity, and Dynamism. This choice resulted in having two stimuli for each value of the (Duration, Intensity, Dynamism) dimensions: two with a Short Duration, two with a Long Duration, two with a Mild Intensity, etc.

Another advantage of selecting these specific stimuli is that they correspond to well-known touch gestures: LID (Long, Intense, Dynamic) corresponds to a Rub, LMD (Long, Mild, Dynamic) to a Stroke, SIS (Short, Intense, Static) to a Hit, and SMS (Short, Mild, Static) to a Pat gesture (for the sake of clarity, we will use these naming in the rest of the paper). As this selection provided a reasonable coverage of common touch gestures, we did not retain more stimuli to avoid making the next experiment too long.

6 VISUOTACTILE EMOTIONAL RESPONSE

The objective of this second study was to investigate the interaction between visual and tactile cues. For this purpose, we considered and combined three factors: Tactile Output,

Table 1: Mean and standard deviation for Valence and Arousal of the eight touch stimuli

Valence			Arousal		
touch	m	sd	touch	m	sd
LMD	5.62	2.20	LID	7.78	1.48
LMS	5.03	2.02	LIS	7.56	1.44
SMS	4.97	2.07	SID	7.12	1.48
SID	4.94	2.45	SIS	5.31	1.57
SMD	4.87	1.79	LMD	4.91	1.65
SIS	4.59	1.86	LMS	4.91	2.02
LIS	4.53	2.77	SMD	4.41	1.48
LID	4.31	2.84	SMS	2.81	1.60

Color, and Visuo-Tactile Congruence. We considered two factors for the visual modality: 1) Color because of its impact on emotional response, and 2) Congruence between tactile and visual signals, as this factor may reinforce the perception of tactile stimuli.

Stimuli

Tactile Output: We used the four stimuli which were selected in the previous study, i.e., Rub, Stroke, Hit, and Pat, using the same (Duration, Intensity, Dynamism) characteristics.
Color: We chose to use the Red, Green, Blue and White colors because these colors have been widely considered in previous literature and have been shown to significantly impact Valence and Arousal [40, 43].
Congruence: Congruence here means that the tactile and the visual signal follow the same movement on the two layers of the VisualTouch prototype (Figure 4, left and middle). In the non-congruent condition (Figure 4, right), eight LEDs were displayed at a fixed position that is not related to the tactile signal. This visual signal was sufficiently large to be easily noticed. It was never similar to the tactile signal, even for static tactile stimuli, because the LEDs were not at the same locations than the motors that were vibrating. In both

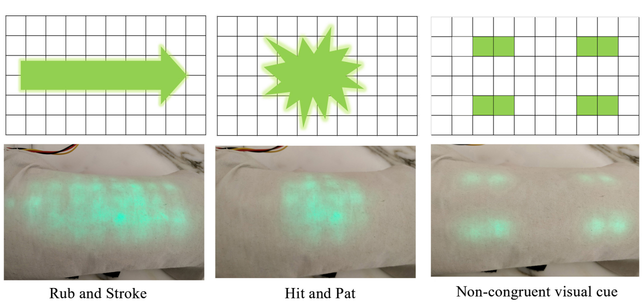

Figure 4: Three visual conditions (congruent dynamic or static visual and non-congruent visual)

conditions (either congruent or non-congruent), the duration and the intensity of the LEDs followed the duration and the intensity of the tactile stimuli, so that the only difference was whether the movement of the two signals was the same or not.

Combining of these three factors led to three types of multi-modal stimuli: Touch Only (4 tactile stimuli without visual feedback), Congruent Visual Movement (4 tactile stimuli x 4 colors = 16 stimuli), Non-Congruent Visual Movement (4 tactile stimuli x 4 colors = 16 stimuli). This study thus involved a total of 36 stimuli (4 + 4x4 + 4x4).

Participants

The study featured 12 participants (22-36 years old; mean: 26.4). No participants were color-blind or reported sensorimotor impairments. None of them participated to the previous experiment.

Procedure

This study was conducted under the same conditions as the previous one, except that the visual layer was used. After four training stimuli, the 36 stimuli were presented twice in random order. After each stimulus, the participant was asked to rate Valence and Arousal with the SAM scale. A short interview was conducted at the end of the experiment.

Results

First, we obtained similar results as in the first study (see section 5) for Touch only stimuli by conducted a one-way repeated-measures ANOVA only on this data. We then conducted a MANOVA on the whole data set. The results show significant effect for *Touch* (Pillai's Trace = .61, $F(6, 1656) = 121.08$), $p < .001$), *Color* (Pillai's Trace = .18, $F(8, 1656) = 20.36$), $p < .001$), *Congruence* (Pillai's Trace = .03, $F(2, 827) = 11.62$), $p < .001$) as well as for the interaction *Touch*Congruence* (Pillai's Trace = .03, $F(6, 1656) = 4.26$), $p < .001$). In order to assess the effect of our three factors on Valence and Arousal more precisely, we divided our statistical analysis into two parts:

Touch and Color: Congruent stimuli are not included in this analysis so that the results only depend on tactile stimuli and color (LEDs at a fixed position, no visual movement). Touch Only signals (thus not involving color) were taken into account in this analysis. A 4 x 5 repeated-measures ANOVA was performed on both Valence and Arousal scores, then Post-hoc t-tests for pairwise comparisons, with Bonferroni correction. The within-subject factors were Touch and Color.

Congruence and interactions: This second part analyzes the effect of Visuo-Tactile Congruence and the interactions between all the factors. As they do not involve visual feedback, Touch Only signals are irrelevant for evaluating congruence and were thus discarded in this analysis. We performed, a 4 x 4 x 2 (Touch x Color x Congruence) repeated-measures ANOVAs on Valence and Arousal, then Post-hoc t-tests for pairwise comparisons with Bonferroni correction. The within-subject factors were Touch, Color and Visuo-Tactile Congruence. Table 2 summarizes the significant effects of the factors on Valence and Arousal.

Touch and Color. There is a significant main effect of *Touch* on *Valence* ($F(3,33) = 9.53$, $p < .001$). Stroke is perceived as significantly more positive than Rub or Hit (<.001). Pat is perceived as significantly more positive than Rub or Hit ($p < .02$). There is also a significant main effect of *Touch* on *Arousal* ($F(3,33) = 278.65$, $p < .001$) with significant differences between every stimuli ($p < .001$) except between Hit and Stroke.

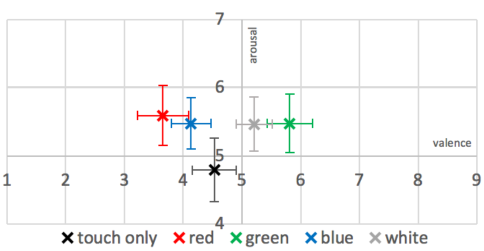

Figure 5: Distributions of Colors split by Visual-Tactile Congruence on the Circumplex model of emotion

Concerning *Color*, there is a significant main effect on *Valence* ($F(3,33) = 33.20$, $p < .001$) with Red (m = 3.66, sd = 2.01), Blue (m = 4.14, sd = 1.66), Touch Only (m = 4.53, sd = 1.86), White (m = 5.21, sd = 1.58) and Green (m = 5.81, sd = 1.91). The Red and Blue colors are perceived significantly more negative than the White and Green colors ($p < .001$). Touch Only stimuli are perceived significantly more positive than stimuli with Red color ($p = .001$) and significantly more negative than stimuli with Green color ($p<.001$).

There is also a significant main effect of *Color* on *Arousal* ($F(3,33) = 4.89$, $p = .002$) with Touch Only (m = 4.79, sd = 2.30), White (m = 5.47, sd = 1.94), Green and Blue (m = 5.48, sd = 2.11 and 1.87) and Red (m = 5.59, sd = 2.16). Colored stimuli are perceived significantly more intense than Touch Only stimuli ($p<.05$).

In short, *Color* impacts Valence progressively, with the Touch Only condition having a neutral value. *Color* also impacts Arousal, but the Touch Only condition then has the lowest effect. This suggests that *Color* can be used as an effective means for improving the emotional response, especially for Arousal, as shown in Figure 5.

Visuo-Tactile Congruence. We observed a main effect of *Congruence* on Valence ($F(1,11) = 15.65$, $p = .002$), with Non-Congruent (m = 4.70, sd = 1.98) and Congruent (m = 5.26, sd = 2.08). There is also a main effect of Congruence on Arousal ($F(1,11) = 17.06$, $p = .001$), with Congruent (m = 5.23, sd = 2.25) and Non-Congruent (m = 5.53, sd = 2.02). Congruent stimuli appear to increase Valence, but to decrease Arousal.

A more in-depth analysis clarified this effect. As shown in Figure 6, there are interaction effects on Valence and Arousal between Touch and Congruence. First, there is an interaction effect on Valence ($F(3,33) = 4.97$, $p = .005$), but significant differences between Congruent and Non-Congruent stimuli only for Rub ($p = .02$) and Stroke ($p = .002$), as can be seen on Figure 6. Second, there is also an interaction effect on Arousal ($F(3,33) = 6.77$, $p < .001$), but significant differences for tactile stimuli Hit ($p = .005$) and Pat ($p = .007$).

Hence, it seems that congruent *dynamic* stimuli (Rub, Stroke) increase Valence, but congruent *static* stimuli (Hit, Pat) decrease Arousal. This result is interesting as it opens a way to widen the spectrum of emotions.

Evaluating emotions. We also got some interesting feedback from the interview. First, most of participants tended to associate Valence with Color (7/12 participants): the Red color being mostly seen as negative (10/12), and the Green color as positive (8/12). White was rather seen as neutral positive (5/12), and Blue as neutral negative (5/12). In contrast, Arousal was more often associated with Touch (9/12), and was also influenced by the intensity of the Color and the length of the pattern (6/12), with longer patterns were perceived as more aroused (4/12). Interestingly, two participants also associated non-congruent color movement with eyes movement (jovial or frightening).

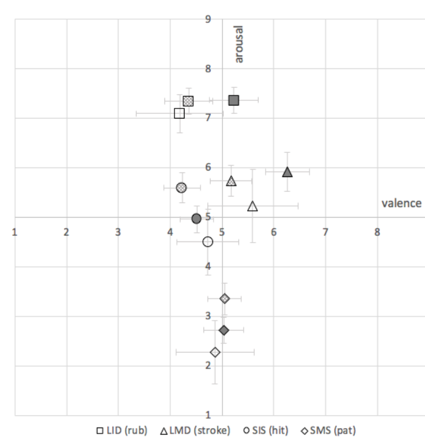

Figure 6: Visuo-Tactile Congruence effect on the touch distribution on the Circumplex model of emotion (grey - congruent, hashed - non-congruent, white - touch only)

Table 2: Factors effects on Valence and Arousal

Factors	Effect on Valence	Comments	Effect on Arousal	Comments
Touch	$p < .001$	the higher the intensity the lower the Valence, the higher the duration the higher the Valence	$p < .001$	the higher the intensity and the duration the higher the Arousal
Color	$p < .001$	red and blue are perceived as negative while green and white as positive	$p = .002$	the addition of color increases the Arousal
V-T Congruence	$p = .002$	congruent stimuli are perceived as more positive	$p = .001$	congruent stimuli are perceived as less aroused
V-T Congruence x Touch	$p = .005$	effect only present with dynamic stimuli	$p < .001$	effect only present with static stimuli

7 DISCUSSION

Our observations tend to confirm our main hypothesis that the visual layer enhances the communication of emotion in mediated social touch. In the first study, we observed that the type of tactile stimuli has only a significant effect on Arousal. This means that different types of Touch stimuli succeed in conveying only a partial emotional information: the intensity of the perceived emotion, but not the Valence.

Adding a visual layer strengthens the variety and the amplitude of the emotional feeling of the participants. There is a significant effect of color on Valence scores, with Red and Blue (lowering), Green and White (increasing) significantly modifying the Valence of the interpreted emotion. The interviews confirm that Red and Blue are associated with more negative emotion (anger, sadness), and White and Green with more positive emotion (happiness, enthusiasm). This could be linked with the cultural background as these results are similar to those of previous researches on color and emotion [40, 44, 45].

Although we also observe an effect of color on Arousal, it is only the presence of the visual display of a color that increases the perceived Arousal of the stimulus, no matter which color. This would mean that in the VisualTouch setting, the tactile stimuli can determine the Arousal, and the Color the Valence. Moreover, Visuo-Tactile Congruence increases the expressive capabilities of the device. The interaction effect between Touch and Visuo-Tactile Congruence shows that Congruent stimuli allow a widening of the distribution of the scores on the Circumplex model.

These results support the idea that adding a congruent visual layer can help expressing more subtle stimuli by a sender using color purposely, thus allowing greater variations on the emotional response of the receiver.

The present study involves some limitations that are worth considering in future work. First, our task is somehow decontextualized and it focuses on the interpretation of an intended emotion expressed by a sender, rather than on the evaluation of perceived emotion by the wearer. This first step was needed to explore if there is a general emotional interpretation of visuo-tactile signals that multi-modality could enhance. In future work, we plan to study not only how people interpret signals, but also their perceived emotion in real interactional contexts (e.g. while maintaining contact, supporting discussions, etc.) Moreover, the prototype we created uses a vibration motor as an actuator, a technology which has already been proved lacking expressiveness [24]. We plan using actuators that allow rendering touch in a more realistic manner in order to provide support for larger amplitude in emotional judgment.

8 CONCLUSION

In this paper, we presented a haptic device that helps emotional communication by using multi-modality cues. Our aim was to assess the emotional enhancement of touch feedback with the addition of the visual modality. We contribute a novel design by combining vibrotactile stimuli and a congruent visual effect. The results indicate that touch alone has mainly a significant influence on Arousal, while color has a significant influence on both Valence and Arousal. Adding Color to the touch stimuli allows for a wider range of perceived emotion and increases the overall Arousal. Moreover, using congruent and non congruent signals helps widening the spectrum of emotion perception. Based on these results, we conclude that using additional visual cues is a promising approach to support emotional communication in social touch.

9 ACKNOWLEDGEMENTS

This work was supported by a grant from the French Agence Nationale de la Recherche (ANR-17-CE33-0006 SocialTouch).

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