論文 / 著書情報
Article / Book Information

論題(和文)	“ EMO ” : Design of an Emotional Communication Device based on Gestural Interactions
Title(English)	“ EMO ” : Design of an Emotional Communication Device based on Gestural Interactions
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出典(和文)	, Vol. 15, No. 2, pp. 135-142
Citation(English)	International Journal of Affective Engineering, Vol. 15, No. 2, pp. 135-142
発行日 / Pub. date	2015, 12
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International Journal of Affective Engineering
J-STAGE Advance Published Date: 2015.12.28
doi: 10.5057/ijae.IJAE-D-15-00024

ORIGINAL ARTICLE

"EMO": Design of an Emotional Communication Device based on Gestural Interactions

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Abstract: Our objective is to imagine and design concepts of tangible communication devices that allow to remotely share emotions. Tangible devices are operated by users' gestures and touch, thus, for usability purpose, it is necessary to investigate what gestures are intuitively performed by users for expressing given patterns of emotions. We conducted an experiment where participants had to perform a gestural and/or tactile interaction with device to express emotions with various levels of arousal and valence. Videos of the gestural interactions were recorded and participants completed questionnaires. The data analysis shows a large variety of gestures across the sample of participants, while there is a low inter-individual variety in the intensity and the location of the gesture used for expressing a given emotion. The results of the study were used as a source of inspiration for designing "EMO", a gesture-based emotional communication device. The interactive functional prototype and the appearance prototype are described in the paper.

Keywords: *tangible interface, tactile interaction, emotion, communication, prototyping*

1. INTRODUCTION

In order to design interactive devices, an interesting source of inspiration is the "tangible design" approach that involves human body and tactile sense to a large extent, in the interaction with products and interfaces [1, 2]. By following a tangible design approach, our objective is to generate concepts of innovative communication devices that allow to remotely share one's emotion with friends or relatives. A number of innovative communication devices have been recently designed to allow tactile interactions, as shown in a review of "143 devices for mediating intimate relationships" [3]. Indeed, it has been shown that touch is an effective way to communicate emotions [4].

In this context, the motivation of our study is to find a systematic way to design touch-based long-distance communication devices. More specifically we aim at identifying correlations between tactile interactions and emotions that are felt by the users of such a communication device.

In this paper, we first survey related studies on the link between gestures and emotions, then we report a lab-based pilot-test experiment which aims at identifying gestures used by subjects for interacting with a long-distance communication device.

1.1 Tangible Interfaces

Looking at human's history, tangible interactions already existed when hominids started using stone tools. In this view, interactions with artifacts involving tactile sense like handle, keyboard, steering wheel, and dial plate can be regarded as primary stage of tangible design approach. Technology has allowed to enrich human interactions with artifacts and to explore new tangible design approaches. Table 1 shows a few examples of artifacts or interfaces which involve a tangible interaction, like multi-touch interface, as how these new generation of tangible design approaches has brought us unprecedented possibilities within hands.

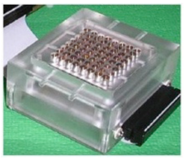
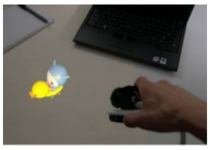
1.2 Emotional Communication

With the long-term evolution, the function of human's hands has become very sophisticated and effective. Gesture, for that reason, serves vital domains in life, including social, cognitive and physical communication [9]. Scientists pointed out that such kinds of non-verbal communication plays an important role in our interaction with others. It is suggested that approximately 60–65% of social meaning is derived from nonverbal behaviors [10].

For example, infants and children use gestures to express feelings and for non-verbal communication more than adults, supposedly because they still ignore social and cultural rules regarding gesture [11]. Related study also pointed out that infants were touched more than older children, it is possible that older children are more independent and could use more sense, for example, linguistics, to communicate [12]. Gestural languages are also evidence that people do communicate by hands, though they can be regarded as a form of linguist [13].

Received: 2015.05.28 / Accepted: 2015.10.29

Table 1: Examples of tangible devices/interfaces

Application	Device / interface	Approach to tangible interaction
Gesture recognition control	 Canesta Projection Keyboard (2003)	A visual keyboard that consists a projection system and a sensor module, provides a lightweight portable input solution. Projected on a flat surface. Each keystroke is accompanied with an audible "click".
Tactile display	 An electromagnetic integrated tactile display VITAL [6]	Based on an integrated electromagnetic actuator arranged in a (8×8) pin matrix. The independent amplitude and frequency control of each pin facilitates displaying various haptic patterns.
Visual reality	 HideOut (2013): mobile projector with tangible object and surfaces	HideOut is a custom mobile projector with an on-board camera to track hidden markers applied with infrared (IR) absorbing ink. A series of application is developed, like Photo Viewer, Shooting Game and Interactive Book.
Multi-touch screen	 Experimental platform for gestures [8]	An Android tablet- based task platform for children, involving tap, double tap, long press, drag, scale up/ down, one-finger rotation and two-finger rotation.

As technology enables new ways to communicate, people spend more time interacting with hands mailing, messaging and exploring social networking. Current mobile phone technologies provide limited tactile feedback to the users, such as vibro-tactile feedback [14]. The potential of tactile interaction for communication has recently gained a growing interest: Gesturing has been found to improve memory [15] and help users extract information from their own hands [16, 17].

Researchers also pointed out the advantages of tangible user interface over graphic user interface as for it can :

(1) enable physical interaction
(2) provide rich feedback and
(3) produce high-level of realism [18].

A wide range of emotions can be communicated by touching the whole body of a third party, i.e. at least four negative emotions (anger, fear, sadness, disgust) and four positive emotions (happiness, gratitude, sympathy and love) [4].

The literature survey emphasizes the role of gestures in human-to-human communication but has not identified any systematic relation between gestures and expression of emotions. Thus we are interested in describing gestures which people naturally use to express given patterns of emotions in the context of mediated communication. The results are expected to inform the design of a tangible device for emotional communication.

2. GESTURES AND EXPRESSION OF EMOTIONS

Although the relation between gestures and expression of emotions has not been fully clarified yet, designers have developed devices for emotion communication. For example, Rantala *et al*. [19] developed a vibro-tactile device (Figure 1) that could convey unpleasant, pleasant, relaxed or aroused emotions. The device was designed to be able to convert touch gestures of squeeze and finger touch to vibrotactile stimulation. One participant squeezed his or her device, or touched with finger(s), another participant could feel corresponding vibrotactile stimulation on his or her device via four vibrating actuators.

InTouch (Figure 2), designed by Brave and Dahley [20], is a set of two connected objects each consists of three cylindrical rollers mounted on a base. As one of the rollers mounted on a base, the corresponding rollers on the remote object rotates in the same way. CheekTouch (Figure 3), designed by Park *et al*. [21], latterly developed by the same authors, Poke (Figure 4) [22], is a pair of pads that can deliver the intensity of each finger's pressure with vibrotactile. At the back of the pad is a half-ball with inflatable surface.

One can express emotions by touching the pad during a voice call. The half-ball next to the listener's cheek would

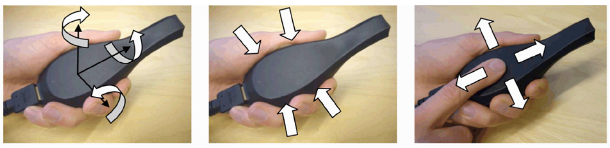


Figure 1: Vibro-tactile device [19]

Figure 2: InTouch [20]

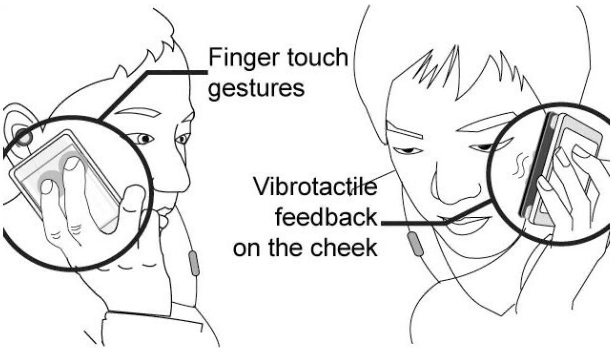


Figure 3: Schematic view of CheekTouch [21]

Figure 4: Poke [22]

make corresponding motions such as poked or vibration to achieve this nonverbal communication. Although the aims of communication are validated, it is not clear whether the relationship within dyads of participants would affect the results.

The aforementioned studies show that tactile interactions might support emotional communication. By following the Circumplex Model of Emotions [23] (Figure 5), one can point out the role of tactile gestures in emotion communication. First, tactile gestures can communicate the arousal value of emotion; second, tactile gestures can amplify the valence of emotion display, as compared with facial and vocal emotion display [24-26]. Through this study, we hope to clarify whether gestural interactions can be recognized. We formulate the hypothesis that certain gestural patterns can be used to express certain emotional patterns.

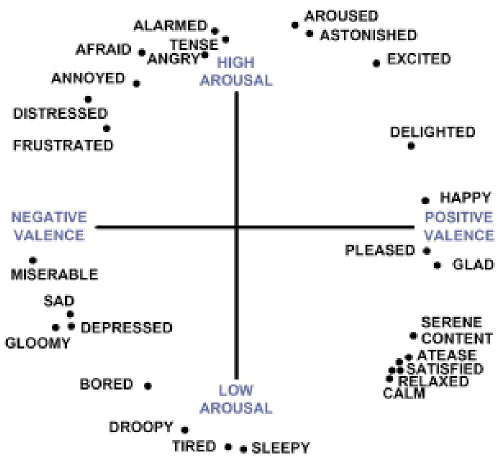


Figure 5: Circumplex Model of Emotions [23]

3. EXPERIMENTAL METHOD

3.1 Data collection: Materials and Procedure

A sample of fifteen participants, aged 20 to 24, were individually involved in the experiment. The participants were asked to express four emotional patterns: a positive intense emotion, a positive calm emotion, a negative calm emotion and a negative intense emotion (Table 2), by touching a device provided by the experimenter.

Participants were asked to use one of their hands to interact with the upper part of a soft elastic balloon mounted on a cardboard cylinder (Figure 6). They were given one minute to think about what gesture they would do, before actually performing the gesture. After each gesture, the participant had to complete a questionnaire for describing their gesture, i.e. location of the contact area and intensity of the gesture (Figure 7). The interactions between the hand of participants and the balloon were video-recorded.

3.2 Data analysis: Description of gestures

According to Hertenstein *et al*. [4], gestures have the following characteristics:

Table 2: Emotion patterns participants were asked to express

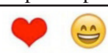
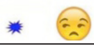
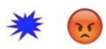
#	arousal	valence	illustration given to the participants
1	high	positive	
2	low	positive	
3	low	negative	
4	high	negative	

Figure 6: Balloon used for observing gestural interactions

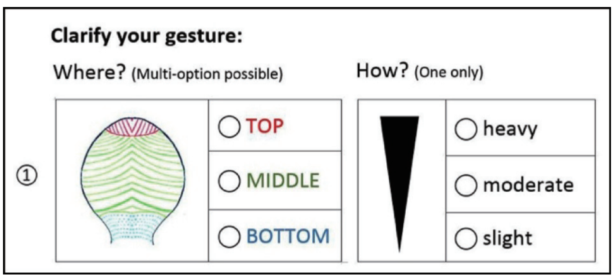


Figure 7: Extract of the questionnaire

- Action (specific movement)
- Intensity (from slight to heavy)
- Velocity (fast or smooth)
- Abruptness (acceleration or deceleration)
- Temperature (frictional heat, body temperature etc.)
- Location
- Duration

In our study, the videos enabled to describe: action, velocity and abruptness, while the questionnaire allowed us to clarify the intensity and location. Temperature and duration were not included in our study.

4. RESULTS AND DISCUSSION

We report the outcomes of the questionnaire that was completed by the participants and clarification from video observation by researchers to describe participants' gestures during their interactions with the balloon.

4.1 Characteristics of gestures

Table 3 shows the number of gestures and their characteristics the participants chose for each one of the four emotional patterns. Also, a visual distribution (Figure 8 a, b) representing the gestures chosen by the participants is shown below. The number of lines is equivalent to the number of participants who selected the given gesture. For each emotional pattern, some participants touched the device in more than one location.

Table 3: Number of gestures and their characteristics

Intensity / Position	slight	moderate	heavy
Emotional pattern 1: positive intense			
top	*	5 (4)	5 (2)
middle	*	6 (4)	6 (3)
bottom	*	*	2 (2)
Emotional pattern 2: positive calm			
top	4 (2)	2 (1)	*
middle	3 (2)	8 (2)	1
bottom	*	1 (1)	*
Emotional pattern 3: negative calm			
top	*	6 (2)	3
middle	*	5 (3)	1
bottom	*	1 (1)	1
Emotional pattern 4: negative intense			
top	*	*	9 (8)
middle	*	*	13 (11)
bottom	*	*	12 (11)

**( ) means participant touched more than one part of the device*

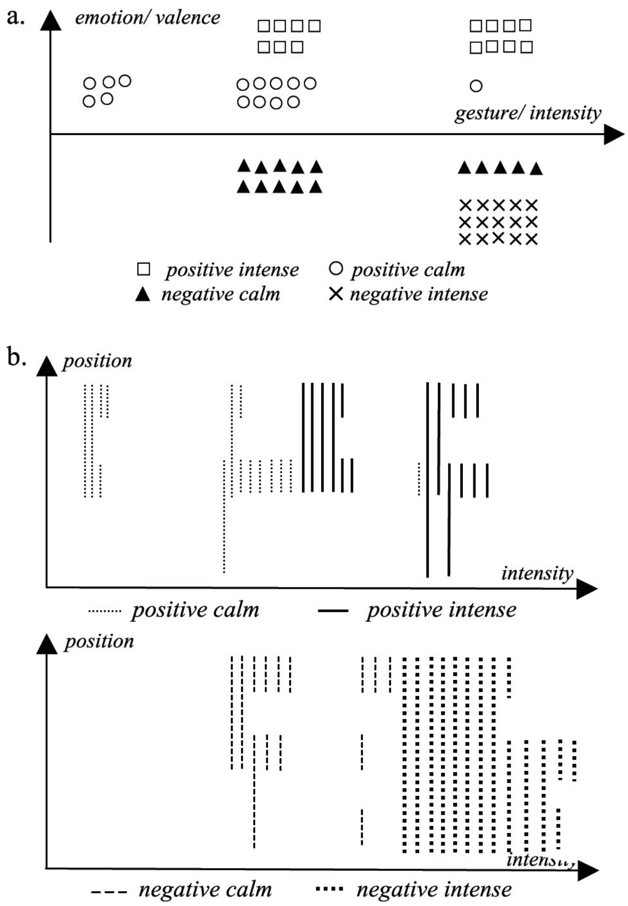


Figure 8: Visual distribution of the gestures

4.2 Types of gestures

Gestural movements contain a high degree of flexibility that makes it challenging to identify the types of gestures that are conveying certain emotion states. For our purpose, only significant cues of gestural expression are necessary. Thus, from the videos of the experiment, 12 kinds of gestures were recognized as basic forms of gesture (Figure 9). An axis of these gestures' intensity is given below.

The gestures are broken down into finger and palm movements, independently from their intensity, e.g. fillip: finger, high intensity; pat: palm, low intensity.

For expressing positive intense emotion, people tend to use grip, which can be pointed out its character as "warm, hold, support"; for positive calm, pinch is the most popular gesture, it can be regarded as a way of playing

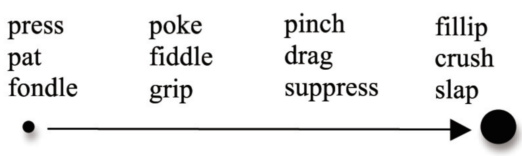
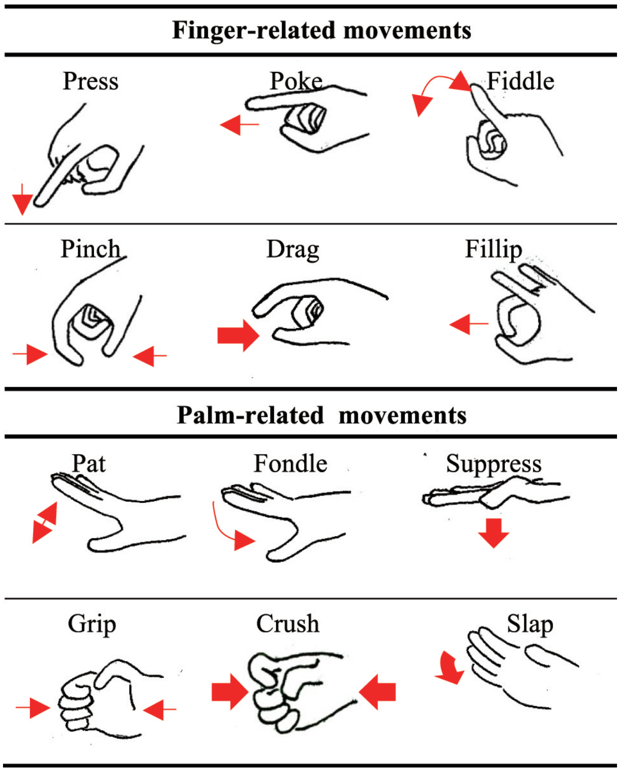


Figure 9: Axis of gestures intensity

Table 4: Identification of basic forms of gestures



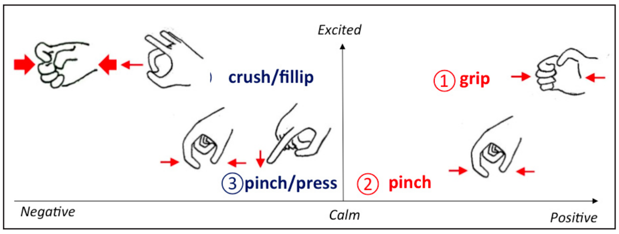


Figure 10: Representative gesture for each emotional pattern

games; for negative calm emotion, pinch and press have similar quantities, in this case, pinch is a behavior of punishment, press is close to the concrete meaning of "stress"; at last, people used heavy gesture to express negative intense emotion, such as crush and fillip, which can be defined as a behavior of abreaction.

The results showed that participants tend to use gestural movements with same "location" and "intensity" characteristics to express given emotions. The most popular gesture for each emotion also shows itself off among the numerous "performance".

Although the limited size of our sample of participants does not allow to compute any statistically significant correlations between gestures and emotions, this preliminary experiment serves our purpose of identifying major characteristics of gestural interactions in emotional communication. The findings are relevant as a source of inspiration for designing a communication device.

Table 5: Identification of location and intensity of gestures

Emotional pattern	Location of gestural interaction	Intensity of gestural interaction
① Positive intense	Top /Middle	Heavy
② Positive calm	Top /Middle	Moderate /Slight
③ Negative calm	Top /Middle	Moderate
④ Negative intense	Middle /Bottom	Heavy

5. APPLICATION TO THE DESIGN OF "EMO", A TANGIBLE EMOTION MEDIUM

5.1 Development of the device

The results from the preliminary experiment were used as a source of inspiration for designing a gesture-based emotional communication device. The device consists in two parts, a "sender" part and a "receiver" part that are connected to each other through the Internet (Figure 11).

The users' gestural interactions with the "sender" part is detected by a number of sensors, the information is transmitted through the Internet to the connected "receiver" part. The receiver part would move in a way that imitates human body movements, which are significantly correlated to emotions [27].

The interactions have been design using Arduino micro-controllers toolkit, motion sensors, light sensors, servo-motor and vibrator, as shown below. For example,

Figure 11: Overview of "EMO", "sender" part on the left, "receiver" part on the right

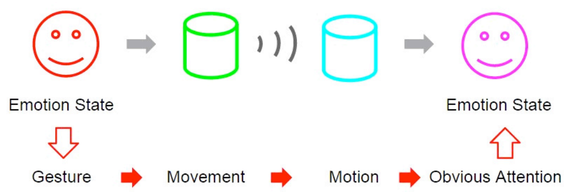


Figure 12: Interaction flow of the device

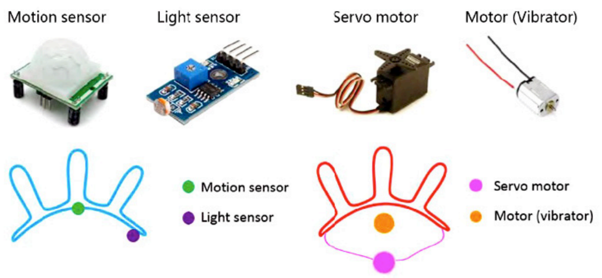


Figure 13: Arduino parts used for designing the interactions

the motion sensors can detect the speed of the hand motion when a person is touching the device.

An Arduino-based interactive device has been developed as a "critical function prototype" whose main goal was to test the flow of interactions, i.e. whether gestural inputs with the sender part could properly be transformed into motion outputs with the receiver part. To make the sender part and receiver part, Arduino sensors and motors have been inserted into a paper cup and plastic straws, both parts being controlled by the main Arduino box located inserted inside the cardboard box. After having decided the functions of the device, we attempted to give it an attractive appearance, in the form of a succulent plant. The balloon-like leaves of the "sender" part enable gestural interactions such as "pinching" and "crushing". A vibration sensor can detect gestures like "filliping" and "fondling". The resulting interactive functional prototype is shown below (Figure 16).

The device can be controlled through gestural interactions, a natural way to interact with electronic devices. Thus it is expected that gestural interactions can lead to an enjoyable and user-friendly communication and thus generate richer interactions between people.

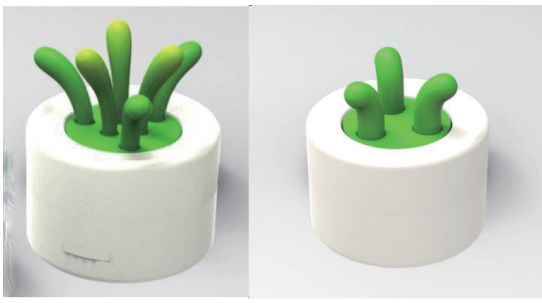


Figure 14: Concepts of prototype appearance

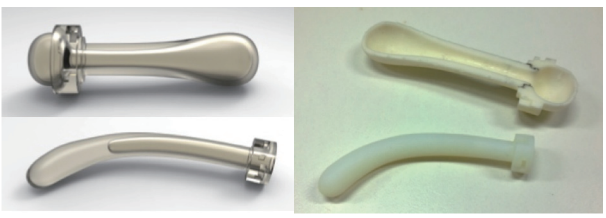


Figure 15: Rendered and 3D-printed parts

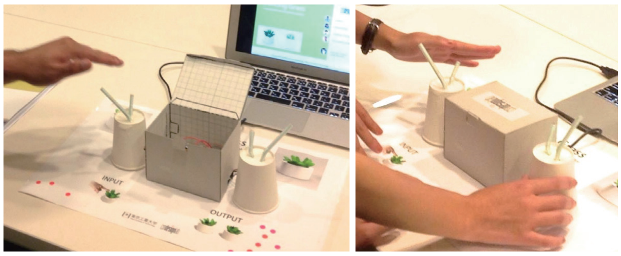


Figure 16: People using the prototype at a conference

5.2 User feedback

In order to get feedback from potential users, usability tests were conducted with the prototype. The objective was to investigate the acceptability of our device, as compared to the most common way of sharing emotions in long-distance communication, i.e. using pictographs of facial expressions on a mobile phone.

10 university students participated in the tests, on a voluntary basis. They were shown two videos: Two people sending text message to each other with a mobile phone, including pictograph of facial expressions, as shown in Figure 17; a person performing a hand gesture on EMO device, then another EMO device reacting and moving, as shown in Figure 18.

Participants were asked to complete a questionnaire about the current use of phone pictographs and expected use of EMO device; questions include usefulness, easiness-to-use, efficiency, pleasurability, willing to use and other comments on the potential use.

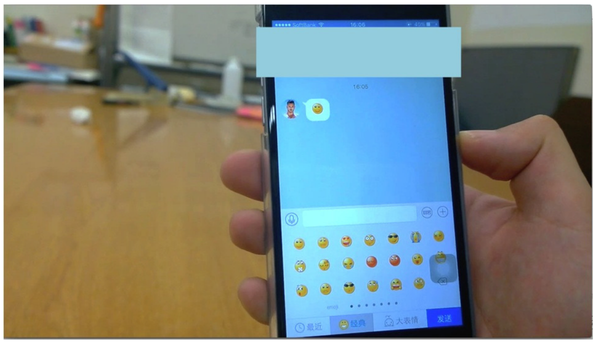


Figure 17: Screenshot of "phone / emoji" video

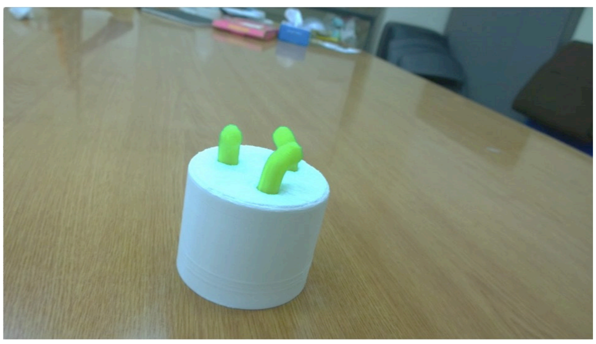


Figure 18: Screenshot of "EMO" video

The results show that most people found it easier and more efficient as using emojis on phone to express their emotion states. But some of them also pointed out the potential usage of EMO as a tangible communication tool. Participants usually found it difficult to understand the function of the device, as compared to words or images. Furthermore, using tactile sense expressing emotions is usually more abstract than words, although direct interaction through tactile sense is frequently used in daily life. Nevertheless, participants spoke highly of the interesting interaction, and found it attractive to use.

Participants commented: 'Is this a toy?', 'It would be fun as letting kids to play with it.', which highlighted a possibility as developing this method of interaction as a kids-targeted toys or teaching tools.

Overall this study about emotion communication device on gestural interaction pointed out the potential usage of communication as it provides an enriched experience of multi-dimension information, and raise up a possibility of teaching method for kids.

ACKNOWLEDGEMENTS

This work is partially supported by the Japan Science and Technology Agency (JST) through a grant-in-aid for tenure-track researchers.

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