Manipulation of an Emotional Experience by Real-time Deformed Facial Feedback

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ABSTRACT
The main goals of this paper involved assessing the efficacy of computer-generated emotion and establishing a method for integrating emotional experience. Human internal processing mechanisms for evoking an emotion by a relevant stimulus have not been clarified. Therefore, there are few reliable techniques for evoking an intended emotion in order to reproduce this process.

However, in the field of cognitive science, the ability to alter a bodily response has been shown to unconsciously generate emotions. We therefore hypothesized emotional experience could be manipulated by having people recognize pseudo-generated facial expressions as changes to their own facial expressions. Our results suggest that this system was able to manipulate an emotional state via visual feedback from artificial facial expressions. We proposed the Emotion Evoking system based on the facial feedback hypothesis.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors

Keywords
Emotional control, emotion, affect, facial expression, facial feedback hypothesis.

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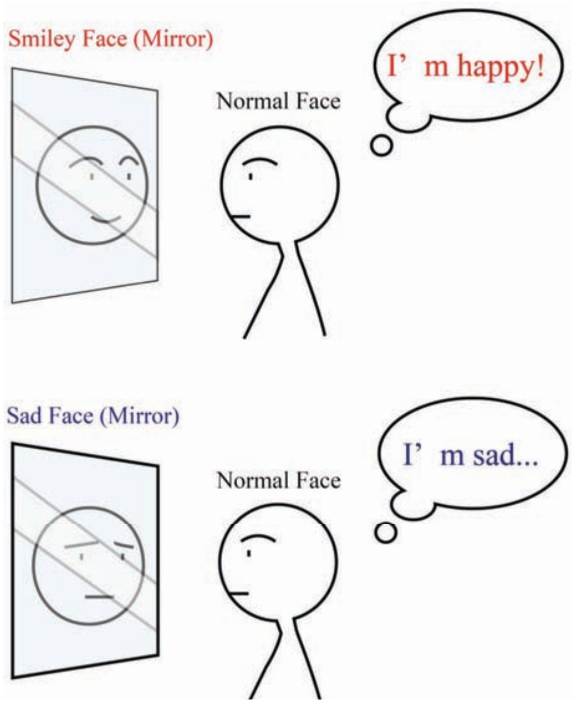

Figure 1. Evoking emotion through real-time deformed facial feedback.

1. INTRODUCTION
The purpose of this study was to examine the efficacy of a technique for evoking emotion and manipulating emotional experience via semantic interpretation of certain emotional states. With conventional human-computer interactions, the manipulation subjective elements of experienced emotion is not possible. Thus, emotional experience may not be properly conveyed in such

contexts. Emotion is assumed to result from perceiving stimulation from the external environment, such as behaviors or situations, and handling this stimulation internally. Bodily responses, such as heart rate and facial expressions, have been thought to consequently change via an evoked emotion. However, the internal processing mechanisms for evoking an emotion by a relevant stimulus have not been fully clarified. Therefore, evoking emotions by reproducing this process through engineering techniques is extremely difficult.

However, in the field of cognitive science, some researchers argue that recognition of changes within bodily responses unconsciously evokes an emotion. William James best expressed this phenomenon: "We don't laugh because we're happy - we're happy because we laugh."[1] What we determine has caused changes in our bodily reactions, referred to as an "attribution of causality," is based on our assessment of physiological changes related to the subjective elements and occurrence of particular emotions [2]. For example, the facial feedback hypothesis [3] indicates that changes to facial expressions affect emotional experience: smiling enhances pleasant feelings while attenuating unpleasant feelings.

Additional research suggests that the environment affects our interpretation of emotion based on our own bodily reactions and behaviors. Moreover, not only emotion but also preferences, such as value judgments based on emotion, are subject to environmental influences. For example, gaze biases towards a face occur in advance of a subjective judgment (gaze cascade effect [4]). Moreover, the manipulation of gaze could influence a preference decision [4].

As mentioned previously, the process by which a physiological change is attributed to a specific factor plays an important role in determining the subjective elements and occurrence of specific emotions. Furthermore, research, such as gaze cascade effect has shown that manipulating unconscious actions can influence preference decisions. Therefore, we believe it possible to establish a new technique for virtually evoking an emotion by generating an artificial stimulus to which a body reacts. From there, the user might recognize this process as changes to his/her own bodily reactions.

We focus on the effect of facial expressions on evoked emotion . In this paper we developed the Emotion Evoking System (Figure 1), which can evoke positive and negative affect and manipulate preference decisions. This is part of cognitive experience through visual feedback of generated pseudo-facial expressions. We test the validity of this system through exploratory studies.

2. CHANGES IN THE SUBJECTIVE PERCEPTION OF BODILY REACTIONS

2.1 Emotion

Emotion is used as a term referring to mental phenomenon relating to people and things. Several debates and discussions over the years have focused on defining emotion. Ekman proposed that six emotions—"happiness," "surprise," "fear," "sadness," "disgust," and "anger"—are fundamental and universal human emotions, as determined by the reorganization of facial expressions [5].

Sometimes, "affect" and "mood" are also used as equivalent terms with "emotion." "Affect" refers to a short-term and momentary feeling. "Mood," as represented along a "positive-negative" or "pleasant-unpleasant" dimension, refers to a more long-term mindset and changes gradually, and mood responses are not as strong as would be suggested for "affect."

In the current study, we treat "emotion" as comprising three emotional states: "emotion," "affect," and "mood." We define emotion as "subjective experience and action, which are caused by changes in bodily responses, including facial expressions and physiological reactions." Subjective experiences and behaviors that are caused by changes in bodily responses consist of reactions that are closely tied to moods, such as sadness, happiness, anger, positive-negative feelings, and pleasant-unpleasant feelings, as well as subjective elements (i.e., value judgments based on affect).

2.2 Emotion and bodily responses

Emotion is also considered as a subjective experience or physical expression caused by specific mental states. For example, physical phenomenon, such as heart rate, palpitations, and perspiration can be indicative of an emotional/affective reaction [6].

The James–Lange theory states that physiological changes occur prior to an emotional experience. This means that an emotion results from physiological changes rather than the cause of the reaction. The facial feedback hypothesis was derived from the James–Lange theory. The facial feedback hypothesis states that emotion can elicit changes in facial expressions, but facial feedback from an expression can influence an individual's emotional state [3]. This effect can be observed when expressions are posed (i.e., when an individual holds a pen between their lips for a frown, holds a pen between their teeth for a smile, or imitates the expression of another person) [7]. In addition, Klienke et al. observed that facial feedback enhances facial expressions when a person poses an expression in front of a mirror [8].

The two-factor theory of emotion, advocated by Schachter et al., states that changes to bodily responses can be common to several emotions; thus, discreet emotions cannot be completely determined by changes in bodily responses [2]. Recognition of changes to bodily responses, such as nervousness, sedation, raised heart rate, elevated blood pressure, or tremors, referred to as the "attribution of causality," determines the type of emotion experienced. Therefore, different emotions may be evoked according to the way we interpret our own environments, even when similar circumstances and bodily responses arise. Dutton et al.'s Capilano Suspension Bridge experiment illustrates this point. In that study, men misattributed the physiological strain resulting from going across a scary bridge to the emotional excitement of meeting an attractive woman [9]. In this way, a process attributable to changes in bodily responses to different factors plays an important role in the type of emotion evoked.

Conversely, another requirement for emotion evocation is not actual changes in bodily response but the recognition of those bodily responses. Valins et al. confirmed this notion through a false heart-rate feedback study [10]. In this experiment, male participants were led to believe that they were going to hear their own heart rate while viewing images of a woman. The heart rate sounds were actually a recording and alternated (quicker or slower rates) based on the picture they saw. When viewing a picture and hearing a rapid heart rate, participants rated the woman as more attractive than when viewing the picture and hearing a slower heart rate. Thus, changes in specific bodily responses, and the recognition of those changes, unconsciously evoked an emotional response. These results suggest the existence of the following process regarding emotional evocation:

- First, bodily responses occur before people realize the corresponding emotion.
- The implicit recognition of specific bodily responses evokes an emotion. Both bodily responses and pseudo-bodily responses influence emotion evocation.

Therefore, a specific emotion and action might be evoked by showing an individual the physical sensation related to that emotion. Through feedback from a pseudo-bodily response and action, created using computer vision and computer graphics techniques, a subjective reality called the emotion or the value judgment along with the emotion, may be able to be evoked.

3. RELATED WORK

Recent research has examined how affective interfaces influence a user's emotional state. In these studies, the manipulation of emotional states and behaviors is accomplished by allowing people to recognize bodily responses.

For example, Nishimura et al. created a tactile device that attempts to control affective feelings through artificial autonomous physiological reactions [11]. The device is attached to the left side of a participant's chest, and the device presents a participant's heart rate variability through pseudo-heart rate vibrations. Results showed that artificial heart rate variability influenced ratings of attractiveness, similar to Valins et al [10]. Thus, subjective evaluations can be controlled by recognizing changes in pseudo-generated bodily reactions.

"Thermotaxis: society" is a piece of artwork used to create psychological distance between participants [12]. This artwork creates thermal sensory spots within an open space, and earmuff-like, wearable devices provide thermal sensation depending on a participant's location. Thus, this piece of artwork suggests that not only the position of a participant within space but also mental aspects of psychological distance within interpersonal relations can be unconsciously controlled.

Tsujita et al. proposed a HappinessCounter system that encourages the act of smiling and promotes a more positive mood [13]. This system detects a user's smile, counts the number of smiles, and records the user's mental state. After detecting a smile, the system displays visual feedback in the form of a "smile" icon in the corner of a mirror. If users do not smile regularly, the system notifies the user by displaying a "sad" icon. As previously mentioned, Kleinke [8] pointed out that positive emotional states can be enhanced when participants view their smile in a mirror. This work examines the evocation of emotional states by prompting participants to consciously pose a smile. In contrast, we focus on implicitly evoking an emotion and determining whether desired emotional states can emerge automatically.

The Tear Machine is also a piece of interactive artwork that can induce a powerful distressed emotional state [14]. This artwork looks like a mirror. However, participants see tears streaming down their face in the mirror. The participant is directed to feel distress and sadness in response to strong empathic cues. In this way, we believe that both the user's natural facial expression and the pseudo-changes applied to his/her appearance can influence a user's emotional state.

Based on this knowledge, we believe that having users recognize pseudo-generated facial expressions as the participant's actual bodily response can evoke an emotion. Moreover, our research proposes an evocative emotion system by facial expression feedback. We argue that the expression of emotion via facial expressions does not depend on culture but on universal features of emotions [15]. Additionally, several studies have already established the correspondence between facial expressions and emotions [16]. We believe that basic emotions, such as "happiness," "sadness," "anger," "fear," and so forth can be evoked by manipulating facial expressions.

4. EVOKED EMOTIONAL SYSTEM VIA REAL-TIME DEFORMED FACIAL FEEDBACK

We have explained how an emotion can be induced by visual feedback of artificially generated facial expressions. Thus, we developed a prototype system that deforms a user's facial expression in real time and gives visual feedback to the user. As we mentioned in the previous section, we attempted to generate a natural facial expression and allow a user to naturally recognize the pseudo-facial expression.

In this system, a user sits in front of a monitor display that includes an attached camera. We used a Logicool HD Pro Webcam C920 to capture and track a user's face. The system gives feedback of a deformed facial expression by using a mirror-like display (Figure 2).

We develop a method for deforming a user's face and transforming a user's facial expression in real time, using an image-processing technique referred to as Image Deformation. In order to obtain accurate eye, nose, mouth, etc. features from the image of the user's face, we used the FaceTracker library developed by Saragih et al. [17]. Next, we deformed the face image by using a rigid MLS (Moving Least Squares) method [18]. Using this algorithm, we easily and naturally deformed the appearance of a user's face through more than three control points.

We generated two facial expressions ("Smiley Face" and "Sad Face") which represent the positive-negative affect dimension

Figure 2. Prototype system: a user sits in front of a display and a camera is on top of the display.

Figure 3. Deformation of the two types of facial expressions: "Smiley Face" and "Sad Face".

(Figure 3). We deformed the face image to create a “Smiley Face” by raising the corners of the mouth and cheek and lifting the lower eyelids. As for the “Sad Face,” we deformed the face image by lowering the corner of the mouth and lifting the inside of the upper eyelid and inside of the eyebrow. As referenced in [19], the change applied to the user’s facial expression was fixed, regardless of the user’s attributes.

5. EVALUATION OF THE EFFECTS OF DEFORMED FACIAL FEEDBACK ON POSITIVE-NEGATIVE AFFECT

We conducted a user study to investigate how manipulating facial expressions through feedback could influence positive-negative affect.

5.1 Hypothesis

We hypothesized that participants’ emotional states would be influenced by feedback from deformed facial expressions, and evaluations of positive and negative affect after a task would differ for each set. More specifically, we thought that during “Smiley Face” feedback, participants would feel more positive than during “Sad Face” feedback. By contrast, during “Sad Face” feedback, participants would feel more negative than during “Smiley Face” feedback. Positive and negative affect would fall in the middle range during “Normal Face” feedback.

5.2 Participants

The study had 21 participants (14 males and 7 females; mean age = 23.2 years; range: 21–30). Participants were not informed of the actual purpose of the study.

5.3 Experimental design

The experiment used a within-subjects design. Participants were asked to click on targets that appeared around their own face, which was shown on the display, with a mouse (mouse-click task). There were 30 targets in total. Targets appeared at random positions around the user’s face (Figure 4). The waiting time between targets was randomly set, ranging from 0 to 3 seconds. This task was conducted in order to create a situation where participants implicitly processed their own face, while the primary task was to search for the targets. Next, we evaluated whether emotional states changed in response to the influence of implicit facial feedback while concentrating on the mouse-click task.

Participants were asked to rate their emotional state immediately after the task. We evaluated participants’ emotional state with the Japanese version of the Positive and Negative Affect Schedule (J-PANAS) [20, 21, 22]. The J-PANAS consists of two 11-item scales measuring positive affect and negative affect, respectively. Each item was answered on a five-point scale (*1 = strongly disagree*; *5 = strongly agree*).

Each participant performed three sets of mouse-click task sessions and evaluation sessions. During each mouse-click task session, participants were presented with one of three facial expression changes: “Sad Face,” “Normal Face” (no deformation), and “Smiley Face.”

To eliminate any effects of presentation order on facial expressions, the presentation order was randomly assigned and counterbalanced across participants using a Latin-square design. Given the fixed deformation of the facial expressions, some differences emerged within the facial expressions depending on the size of the participant’s face. Thus, we adjusted the distance between the display and the participant in order to make the size of each participant’s face uniform before the experiment.

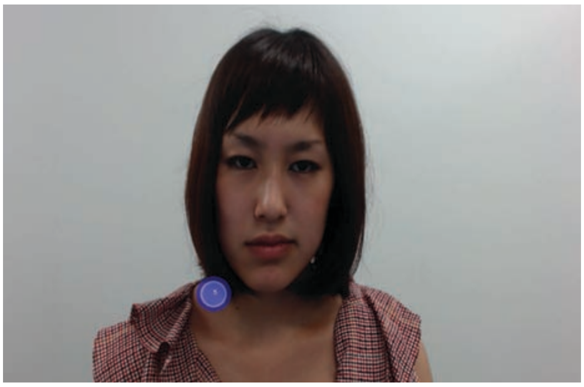

Figure 4. A target appearing around the face.

Participants were asked not to speak during the experiment and to avoid changing their facial expression on their own volition. One reason for this instruction was to eliminate the effect of facial feedback from actual changes in participants’ facial expressions. We also wanted to prevent unintended changes to facial expressions. We wanted to ensure that the influence of changes in affect were due to our manipulation of expressions.

At the end of the experiment, we asked participants to write what they noticed during the experiment and checked whether participants were aware as to the purpose of this experiment.

5.4 Results

Two female participants greatly changed their actual facial expressions during the mouse-click task. We eliminated their data from the final results. We calculated the average of evaluated values from the positive and negative affect scales for all participants. Figures 5 and 6 show the average positive and negative affect scores during each feedback condition.

We used a repeated-measures ANOVA and Wilcoxon signed-rank tests with Bonferroni-Holm corrections. This analysis revealed a significant main effect of “Sad Face” feedback ($F(2,36) = 6.49$, $p < .01$), but the main effect of “Smiley Face” feedback was not significant ($F(2,36) = 2.74$, $p < .10$). The result shows a tendency toward “Smiley Face” feedback provides positive affect. Bonferroni-Holm correction showed a significant difference in negative affect in the “Smiley Face” versus the “Sad Face” condition ($p < .05$).

These results indicated that with visual feedback of pseudo-facial expressions could influence participants’ emotional state. Pseudo “Smiley Faces” can enhance positive affect, and pseudo “Sad Faces” can enhance negative affect. However, there was no significant difference in positive and negative affect between the “Smiley Faces” or “Sad Faces” in comparison to “Normal Faces.”

5.5 Discussion

In the post-experiment questionnaire, most participants were not aware of changes to their facial expressions. These results suggest that our proposed system was effective in influencing emotion generation. We believe that our method for deforming facial expressions was natural enough for participants to implicitly recognize the changes to their expressions given the significant result observed between the “Smiley Face” and “Sad Face” condition. However, there was no significant difference between either the “Sad” or “Smiley” face condition with the “Normal Face” condition. Furthermore, the “Smiley Face” feedback factor

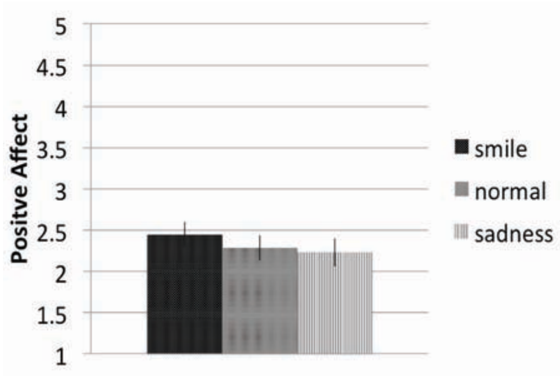

Figure 5. Mean positive affect scores (error bars denote standard errors)

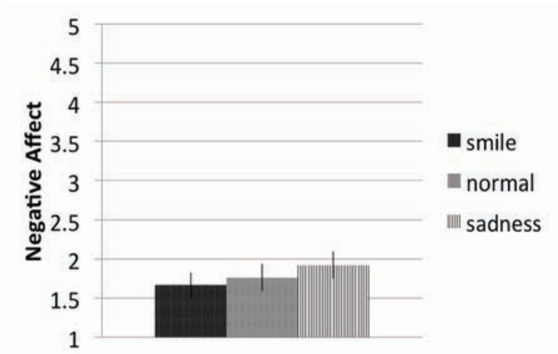

Figure 6. Mean negative affect scores (error bars denote standard errors)

was not significant. We thought that the amount of deformation in facial expressions was so small that some participants were not affected by slight changes to the expressions.

However, two female participants were aware of the changes in their facial expressions and changed their actual facial expressions in response to their awareness. The two participants mentioned that they felt uncomfortable and laughed at the differences in eyebrow shape, something for which they were familiar, given their experience in applying eye make up in a mirror. However, these two participants also noted that changes to the deforming face were natural, and when these participants changed their facial expressions, they produced the same expressions as was shown with the feedback.

6. EVALUATION OF THE EFFECTS OF DEFORMED FACIAL FEEDBACK ON PREFERENCES

In the previous section, we showed that feedback from pseudo-facial expressions could evoke positive and negative affect. Next, we examine whether preferences can be manipulated via evoked emotions with our method. Therefore, we investigate how preferences might change according to pseudo-facial feedback.

6.1 Hypothesis

We predicted that preference would be tied to the “Smiley Face” feedback (increased preference for a target thing if paired with a smiley face and decreased preference when paired with a sad face). We also expected that participants would choose a thing when positive affect was evoked or if negative affect was not evoked. Conversely, participants would not choose a thing in the absence of positive affect or if negative affect was evoked.

6.2 Participants

The sample consisted of 6 participants (3 male and 3 female; mean age = 24.2 years; range: 22–27). Participants were not informed as to the actual purpose of the study.

6.3 Experimental design

Participants were instructed to choose a favorite muffler (muffler-wearing task). Since the muffler does not hide a face, and people usually wear a muffler close to their face, we used mufflers (Figure 7) in this experiment. Participants were asked to select their favorite between two mufflers. We used 8 mufflers, which consisted of different colors and patterns; this task was performed 28 times with combinations of different mufflers.

On 2 separate days, participants came to our laboratory to perform the muffler-wearing task. Test days were separated by at least 1 day in order to eliminate possible remembering of previous muffler choices. During each task, we provided participants with 2 mufflers and asked participants to wear one muffler after another and view themselves through the system for 15 seconds. After wearing the 2 mufflers, participants selected the muffler that they preferred. We asked participants to wear the muffler around their neck and to not cover their face. Deformed facial expression feedback was performed with 12–14 muffler combinations, extracted at random out of the 28 muffler combinations. During other muffler combinations, participants' actual faces were used to give feedback. The muffler order was the same on both test days. However, the order of deformed facial expressions was reversed.

Six participants were divided into 3 groups: Group A (“Smiley Face” and “Normal Face” feedback group), Group B (“Normal Face” and “Sad Face” feedback group), and Group C (“Smiley Face” and “Sad Face” feedback group). For example, on the first day of Group A, a participant was given “Smiley Face” feedback while wearing the first muffler and given “Normal Face” feedback while wearing the second one. In contrast, on the second day of Group A, the participant was given “Normal Face” feedback while wearing the first muffler and “Smiley Face” feedback while wearing the second one.

To eliminate effects of facial expression presentation order, the muffler-wearing order was randomly assigned and

Figure 7. Mufflers used for the muffler-wearing task.

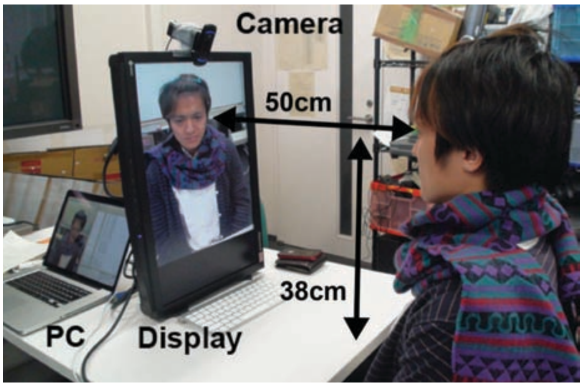

Figure 8. Experimental setup for the preference evaluation.

counterbalanced across participants. We adjusted the distance between the display and participants (Figure 8). After they finished the muffler-wearing tasks, we asked participants to provide their criteria of selecting the mufflers and write what they noticed during the experiment.

6.4 Evaluation indicators

We employed three indicators for investigating the effect of artificial facial expression feedback on muffler preference.

(i):

$$\frac{\begin{array}{c}\text{The number of combinations}\\ \text{with a change in preference}\\ \text{according to our hypothesis}\\ \text{within the facial expression combinations}\end{array}}{\begin{array}{c}\text{The number of combinations}\\ \text{where facial expressions changed}\end{array}} \times 100$$

(ii):

$$\frac{\begin{array}{c}\text{The number of combinations}\\ \text{with a change in preference}\\ \text{opposite to our hypothesis}\\ \text{within the facial expression combinations}\end{array}}{\begin{array}{c}\text{The number of combinations}\\ \text{where facial expressions changed}\end{array}} \times 100$$

(iii):

$$\frac{\begin{array}{c}\text{The number of combinations}\\ \text{with a change in preference}\\ \text{combinations}\\ \text{where the expression is not changed}\end{array}}{\begin{array}{c}\text{The number of combinations}\\ \text{where expressions did not change}\end{array}} \times 100$$

(i) is the percentage of preferences changed according to our hypothesis. Facial expression feedback influences positive and negative affect. In this case, the “Smiley Face” influences participants to become more positive and increases preferences. The “Sad Face” elicits negative affect and decreases preferences. This indicates how our facial feedback system influences participants’ preferences based on our hypothesis.

(ii) is the percentage of preferences that changed contrary to our hypothesis. This means that facial feedback influences positive and negative affect; however, the effects would be opposite to our expectations. For example, the “Smiley Face” influences participants to become more negative and decreases preferences. However, the “Sad Face” elicits positive affect and increases preferences. This indicates how our facial feedback system influenced participants’ preferences in contrast to our expectations.

(iii) is the percentage of preferences that changed, even though the facial expression did not change. This refers to factors other than facial expressions that influenced participants’ preferences. We consider this as the chance preference level.

If *(i)* is larger than *(iii)* (chance level), and *(ii)* is lower than *(iii)*, we can conclude that facial feedback dominantly interferes with preferences as expected (the “Smiley Face” influences participants to become more positive and increases preferences, and the “Sad Face” influences participants to become more negative and decreases preferences). This result would indicate that our facial feedback system is effective in influencing preferences.

6.5 Results

Figure 9 illustrates the relationship between changes in preferences and changes in facial expressions.

The average for *(i)* was 39.5%, the average for *(ii)* was 4.8%, and the average for *(iii)* was 23.8%. We used a repeated-measures ANOVA and Wilcoxon signed-rank tests with Bonferroni-Holm corrections. This analysis revealed a significant main effect for the feedback factor ($F(2,10) = 7.88$, $p < .01$). Bonferroni-Holm correction showed a significant difference between *(i)* and *(ii)* ($p < .05$).

These results showed that a tendency toward manipulating preferences was changed by visual feedback from facial expressions. The “Smiley Face” was able to increase the attractiveness of the respective muffler and the “Sad Face” decreased the attractiveness of the respective muffler. However, there were no significant differences between *(i)* and *(iii)* and between *(ii)* and *(iii)*.

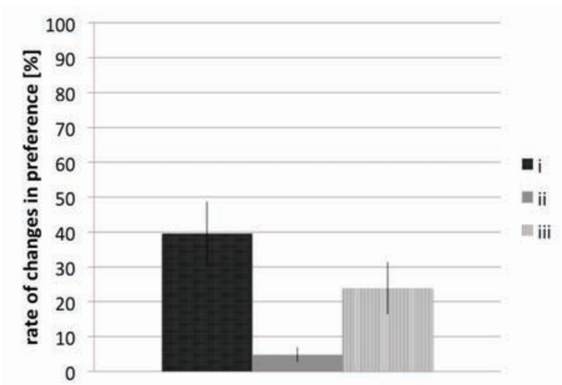

Figure 9. Percentage of changes in preferences. (error bars denote standard errors)

6.6 Discussion

Five participants were aware of the differences between each set of the experimental conditions. We believe that the task was not as clearly defined as the mouse-click task; therefore, conscious looking time toward the participant's own face was longer than in the previous experiment. Nevertheless, some participants noted, "I was likely to select the muffler when I smiled" and "I thought that my feelings changed a little by noticing changes in my facial expression." Therefore, our method seems to be effective, either with or without an awareness of changes in facial expressions. Overall, our results suggest a valid possibility that preferences can be manipulated through facial expression feedback.

However, 3 participants noted that they seemed to be influenced by their preference decisions based on differences in their clothing between the first and second day. This indicates that our system does not fully influence preferences in this context. Participants' clothes should be better controlled in order to procure more precise evaluations as to the effect of the pseudo-facial feedback system in future work.

In this experiment, we prepared a pseudo-mirror using a camera and a display. Unlike a mirror, participants' gaze direction and their gaze direction shown on the display weren't correct exactly in this system configuration. Thus some participants felt uncomfortable. We believe that gaze correction techniques [23, 24, 25] used in video conference can reduce the discomfort.

7. CONCLUSION

We proposed a method for manipulating emotional states through feedback of deformed facial expressions in real time. Our facial feedback system was based on previous studies in the field of cognitive science. We were able to change facial expressions perceived by a participant on the basis of natural changes to those expressions. The "natural" changes enabled participants to recognize these changes; this was effective for creating the illusion of influencing the emotional state and evoking the intended emotion or subjective elements.

We developed a prototype system for implementing the proposed method. Furthermore, we conducted a user study to evaluate the effectiveness of this system. Our results showed that our system could change emotional states, not only positive affect and negative affect but also preference. This suggested that we could artificially manipulate emotional states.

From an applied perspective, we consider that our system can be used to relive subjective emotional elements, such as others' feelings. In the traditional lifelog system, objective information, such as photos and videos, has been recorded. Our system might allow us to restage a particular situation, objectively, based on these records. However, we can only influence the objective components not the subjective elements. Estimating and recording emotional states related to specific events has been studied in recent years. However, methods for reproducing emotional states have rarely been studied. We believe our work could be used to assess the reliving of particular situations, including emotional states.

We also think that our system could be applied to entertainment technology, such as movies, amusement attractions, museum exhibitions, and games, as a direct way to evoke emotion. Moreover, we believe this system could be used to manipulate impressions on consumer products. For example, if this system was installed in a clothing store fitting room, someone could use this system while trying on clothes; s/he might think that certain clothes are more attractive if s/he is experiencing "Smiley face" feedback.

Finally, this system might enable people to be happier, in general. For instance, installing this system at home might encourage individuals to spend time engaging with positive facial expressions in order to encourage positive affect.

8. ACKNOWLEDGMENTS

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