Design of Positive Biofeedback Using a Robot's Behaviors as Motion Media

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Abstract. The purpose of this study is to develop a game system that uses biofeedback to provide an attractive entertaining game. In general, negative biofeedback is used for relaxing users; however, in our game system positive biofeedback is used for arousing them. We assumed that the latter biofeedback method could affect the users' emotional states effectively; that is why we call it positive biofeedback. We used skin conductance response (SCR) as a biofeedback signal in our game system because SCR can effectively reflect the mental agitation of users. Therefore, we developed a teddy bear robot to be the motion media for providing feeding back the measured SCR information to users. When the value user SCR increases during interaction with this robot, the robot starts moving its arms and head in relation to the transition of SCR values so that it appears to be agitated. We then conducted two experiments to measure the participants' SCR transitions. From the results of these experiments, we can state that the users' emotional attachment to the robot and the robot's behaviors in reaction to user biological signals are important cues that create positive biofeedback.

1 Introduction

Recently, interface systems that can reflect human emotional states by means of biological signals have been focused on, and many researchers have been working on developing this kind of interface. Presenting their own measured human biological signals back to people has been said to help them comprehend their physical and emotional states. Moreover, doing this can provide some entertainment tools for ordinary people. One example is the frequent use of lie detection equipment in various TV programs. This method is called biofeedback, a methodology that helps people perceive their own physical condition and emotion by means of numerical, visualized or audible data in response to their own measured biological signals. Currently, many self-control apparatus using biofeedback are actively being developed, e.g., visual feedback conveyed with light pulses or audible feedback using music or sounds.

In general, biofeedback is used to make patients aware of their involuntary affects or emotions by making it possible for them to perceive these states. In this way, biofeedback is used as an aspect of medical care that helps patients relax. These systems can be said to consist of negative biofeedback that offers people a means of suppressing their involuntary affects or emotions, in other words, help them relax.

This means that this negative biofeedback cannot be applied directly to entertainment because if players fall into relaxed states while playing a video game they will become bored with it and eventually quite the game. Therefore, we have previously proposed positive biofeedback as a way to incite involuntary affects or emotion, in other words, a way to make users excited or agitated. We then developed a video game that exploits such positive biofeedback [1-3].

Concretely, players' measured biological signals used as positive biofeedback dynamically affected the game environment and the behaviors of a game character. For example, when a player became agitated and experienced panic, many enemies started to appear on the computer display. As a result of these studies, we found that this positive biofeedback could stimulate players' affects or emotions, and make them excited and agitated.

The purpose of the study reported here is to propose an enhanced video game by means of positive biofeedback that will make players much more excited and agitated and sustain their agitated mental states as long as possible. Concretely, the measured biological signals are fed back not only into the game environment and the behaviors of a game character, as in our former studies, but in addition, these signals affect the behaviors of a stuffed animal robot (IP ROBOT PHONE developed by IWAYA corporation [4]). This robot looks similar to the game character appearing on the computer display. We then conducted psychological experiments to observe players' mental states during game playing and investigated the effects of presenting positive biofeedback with robot behavior as motion media, and we investigated the players' mental states in response to the information that was fed back.

2 Biological signals

Electrical signals detected from the human body are objective and quantitative data that reflect psychological states and physiological functions. Such signals have been used for diagnosis and treatment in medical care and for the lie detector used in police interrogation [5]. One of the biological signals that a lie detector uses is the skin conductance response (SCR) that occurs when mental states such as agitation, surprise, and excitement induce changes in the conductance on the skin surface [6-10].

We have little awareness of the physiological functioning of our own body because most physiological functions are involuntary, and therefore uncontrollable. The SCR is a typical example. No one is aware of the minute amounts of sweating during mental agitation unless an unusually large amount of mental stress is present.

Therefore, observing one's own SCR produces a strange feeling that this is not a feature of one's own body but rather that of another person. People generally believe that inner agitation or excitement during communication in daily life can be concealed. However, the SCR can reveal concealed agitation despite a person's intention to conceal it. The SCR indicator greatly amplifies the amount of involuntary signaling that can take place.

3 Materials and Methods

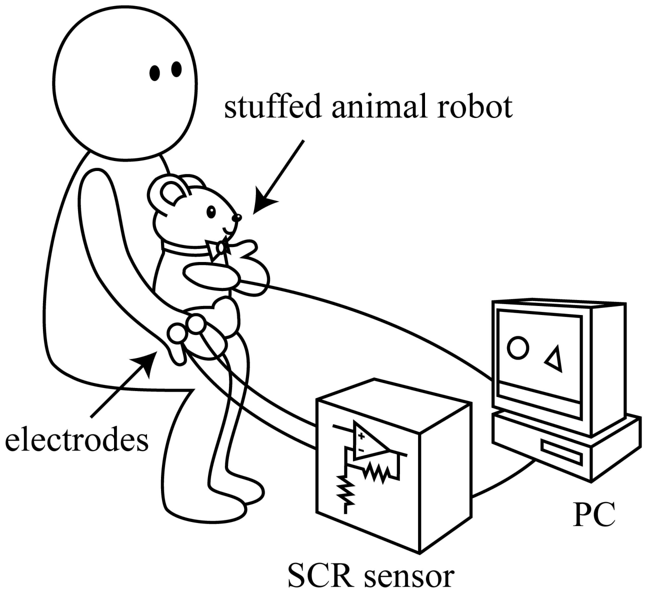


Fig. 1 Developed video game system with stuffed animal robot.

Figure 1 shows the video game system developed in this study. The SCR signal is a reaction to changes in conductance on the surface of the skin due to sweating. Since eccrine glands are most dense on the palm of the hand and sweating is an autonomic response that can be triggered by emotional stimuli, the palm is an ideal site from which to obtain measurements of psychophysical activity by using the SCR. The player provides the SCR via two electrodes. The signal was amplified by a SCR sensor, transmitted to a PC through an A/D converter, and it could be displayed at the upper-right corner of the game monitor (see the Figs. 2 (a) and 3 (a). In particular, Fig. 3 (a) displays the transition values of accumulated SCR. (In this paper, we specifically mean accumulated SCR values whenever we mention SCR values). Information from the players' psychological excitement or agitation is thus fed back to them, and this tends to cause them to become more agitated. A positive biofeedback loop of this agitation often arises within this system, and to succeed in the game players must overcome the effects of their own excitement or escalating panic.

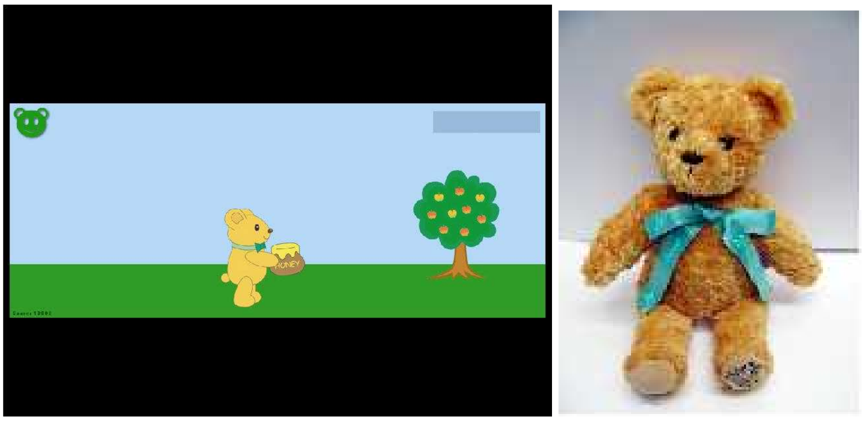
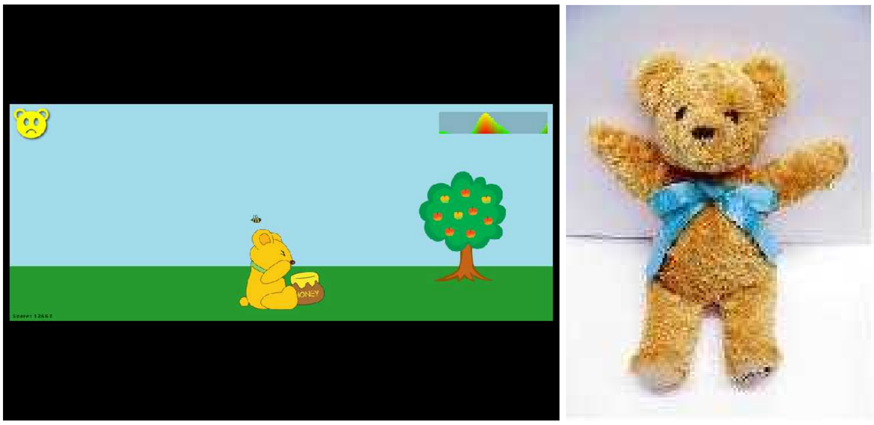


Fig. 2. (a) Game character, yellow bear, on computer display (Normal condition), (b). Stuffed animal robot that is put on the participants' laps.



(a) (b)

Fig 3. (a) Game character stung by a wasp, (b) robot bear's corresponding reaction when game character in computer display is stung by wasp. Showing that the character and robot expressed similar behaviors.

The specific game story is as follows. The game character is a yellow bear. This bear is continuously walking from left to right on a plane to take a honey pot into her home. The player's task is to watch this bear calmly. When the player's SCR values are lower than a certain value for specific durations, the bear can reach her house and the player successfully completes the game. On the other hand, if the game player is agitated (e.g., their SCR values increase more than the specified value), the bear also becomes agitated and drops the honey pot. Immediately after the honey pot is dropped, a wasp appears, notices that the bear has the honey pot, and stings the bear. When the wasp stings the bear three times the game session ends without success. The number of wasp stings is displayed at the upper-left corner of the game monitor as a bear face icon; a green face means the bear was stung zero times (Fig. 2 (a)), yellow means one time (Fig. 3 (a)), and red means two times. The duration of this game is designed to be one minute.

While playing this game, players hold a stuffed animal robot on their laps (see Fig. 2 (b)) that is similar in appearance to the game character, the yellow bear, that appears on the game monitor; this robot moves in the same way as the game character (Fig. 3 (b)). For example, when the players' SCR values are increasing, the robot opens its arms and its body trembles as if it feels the pain from a wasp sting. Thus, this game system gives the players feedback in the form of the game character's behavior as visual feedback and the robot's behaviors as tactile feedback.

4 Experiments

We conducted the two psychological experiments. The purposes of the first experiment (Experiment 1) were to investigate the effects of the robot's behaviors on participant excitement or agitation and to achieve positive biofeedback. We set up two experimental sessions; one is Session A in which the robot moves in relation to the participants' SCR values, while in the other, Session B, the robot does not. The purpose of this experiment was to compare the SCR values observed in Session A with those from Session B.

Participants were 14 university students (6 men and 8 women: 19 – 25 years old). These participants were randomly assigned to the following two groups:

- **Group A**: who experienced 6 trials that were pairs of Sessions A and B for three turns in the same order, Session A then Session B; each time, and
- **Group B**: who experienced the sessions in reversed order, Session B then Session A; for three turns

The purposes of the second experiment (Experiment 2) were to investigate the effects of participants' emotional attachment to the robot on their excitement or agitation and to achieve positive biofeedback. In this experiment, the participants were asked to hold the robot as if holding some waste or an object they disliked and to avoid feeling emotional attachment, while the participants in Experiment 1 held the robot on their laps. The participants in Experiment 2 were 7 university students (3 men and 4 women; 19-25 years old); no members of this group participated in Experiment 1, and they were designated as **Group C**. The participants in Group C experienced the same session order as Group A in Experiment 1, 6 trials that were pairs of Sessions A and B for three turns in the same order, Session A then Session

B; each time. Concretely, we compared the measured SCR values of the participants in Group C with those of participants in Group A in Experiment 1.

5 Results

5.1 Experiment 1

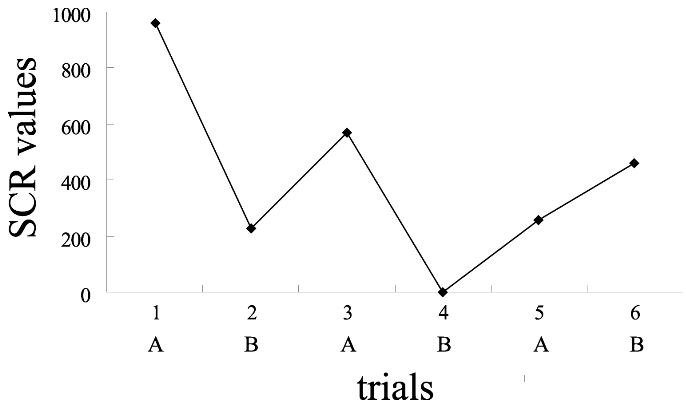


Fig. 4. Typical transition of SCR values in each trial of one participant in Group A.

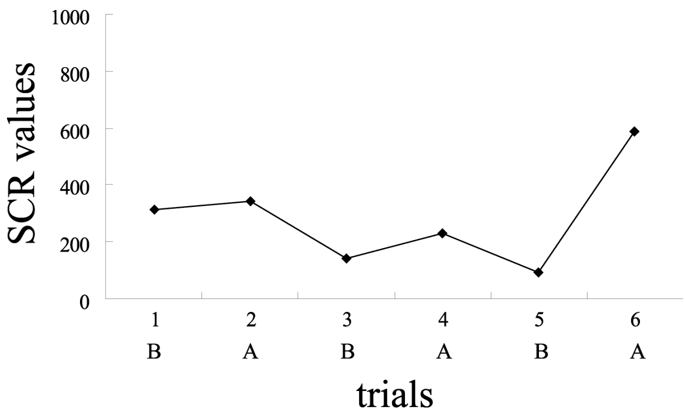


Fig. 5. Typical transition of SCR values in each trial of one participant in Group B.

Figs. 4 and 5 show the typical transitions of SCR values in each trial of one participant in Group A and one participant in Group B, respectively. These figures show that the SCR values were higher when the participants played this game in conditions of Session A, while these values were lower when they played in Session B. However, the SCR values in the 6th trial in both groups showed rather higher values than those for the other trials. A possible reason for this phenomenon is that some participants reported, “I got excited about winning this game because it was the final trial in this experiment.” Thus, the attitudes of these participants toward the experiment affected the SCR values in the 6th sessions.

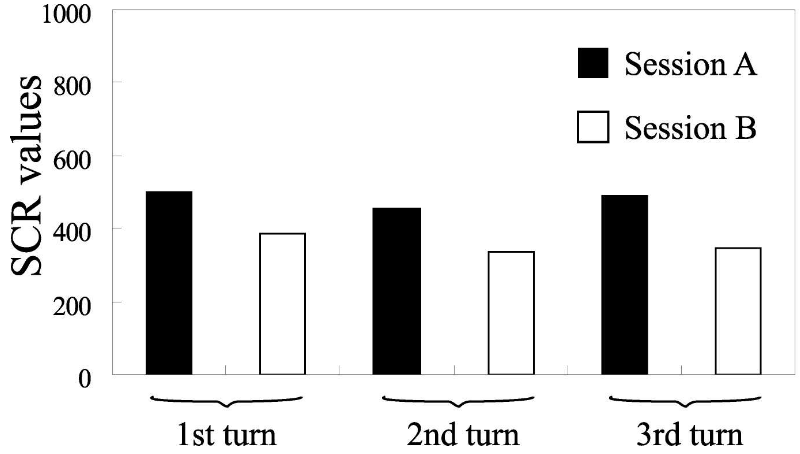


Fig. 6. Averages of SCR values in Session A and Session B within each turn of Experiment 1.

Fig.6 shows the average of SCR values in Session A and Session B within each turn for Experiment 1. This figure reveals that SCR values of participants playing in Session A were higher than those in Session B for every turn. Additionally, this figure shows a gradually downward trend of SCR values; that is, the first turn revealed higher SCR values in both Session A and B, while the last turn resulted in lower values. This phenomenon is evidence that the participants became habituated to the game, or lost interest in the game environment and/or the robot behavior. Actually, even though individual differences in measured SCR values were found for participants, out of the total of 14 participants, 11 participants exhibited higher SCR values in Session A compared to Session B. Therefore, we believe most participants were affected by the positive biofeedback of robot behaviors when the robot was placed on their laps.

In addition, some participants reported, “I had a warm feeling for the bear robot because it was dynamically affected by my excitement and agitation.” or “I hated for the wasp to sting the pretty bear.” Thus, we can say that the positive biofeedback from SCR values greatly affected those participants’ feelings about the robot.

5.1 Experiment 2

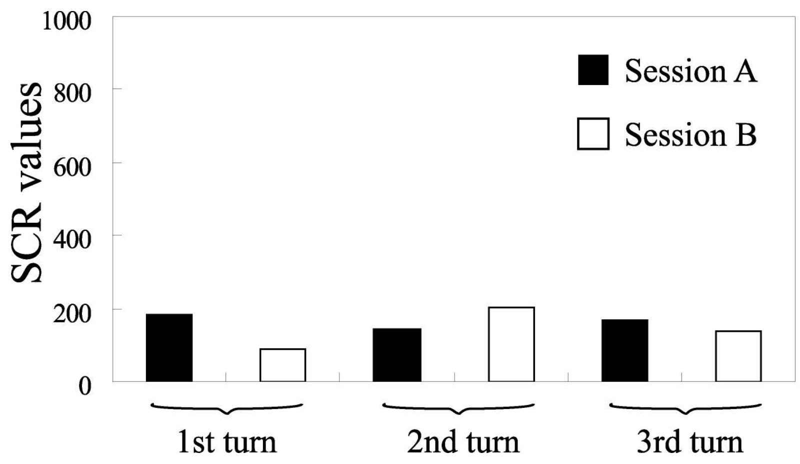


Fig. 7. Average of SCR values in Session A and Session B within each turn of Experiment 2

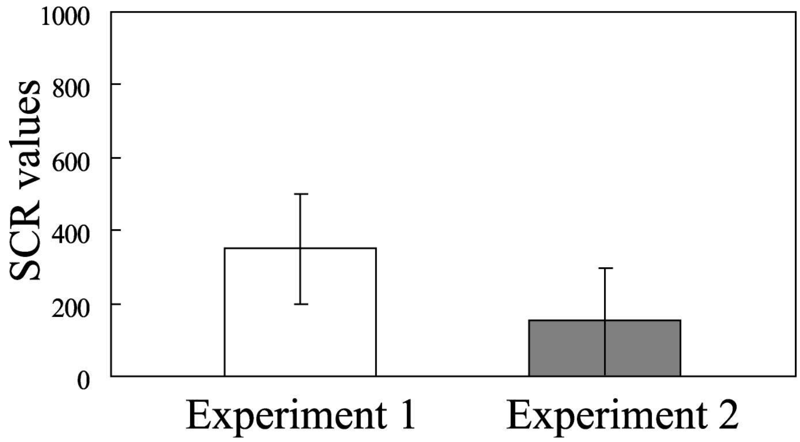


Fig. 8. Average of SCR values in all trials of participants in Experiments 1 and 2.

Fig.7 shows the average of participant SCR values in Sessions A and B during each turn in Experiment 2. From this figure, one can see that the SCR values of Session A and Session B revealed practically no difference in every turn. Moreover, a gradually decreasing trend that we observed in Experiment 1 was not found in the transition of SCR values in Experiment 2. Therefore, we can say that these participants were not affected by the positive biofeedback from the robot when it was held without emotional attachment.

Fig.8 shows the average of SCR values for all trials of participants in Experiments 1 and 2. This result revealed that the SCR values for participants in Experiment 2 were lower than the participants in Experiment 1; a significant difference ($p<0.01$) between them is shown.

6 Discussion and Conclusions

From the results of the two experiments described above, we found the following phenomena:

- The SCR values of the participants in Experiment 1 were higher when the participants played this game in the conditions set for Session A;
- The SCR values of the participants in Experiment 2 were lower than those of participants in Experiment 1; and
- The participants in Experiment 2 were not affected by the positive biofeedback derived from the behaviors of the robot because they had no emotional attachment to the robot.

Thus, we can say that the robot's behaviors displayed by means of the positive biofeedback and the act of holding the robot with emotional attachment influenced the excitement or agitation of participants.

In Experiment 1, the participants felt some responsibility to help the game character and the robot avoid the punishments; this was because it seemed to them that drastic transition of their SCR values directly hurt the character and the robot. Furthermore, we can say that the robot's trembling behaviors caused it to look as if is suffered from pain, and this action increased their feeling of responsibility. Therefore, the fact that the participants reacted sensitively to the robot's behaviors was made apparent.

On the other hand, the SCR values of participants in Experiment 2 were lower than those of participants in Experiment 1. Specifically, we can say that the SCR values were not affected by the robot's behaviors. Although the important issue in this game is to avoid punishment of the game character and robot, i.e., their being stung by a wasp, the participants in Experiment 2 seemed not to consider doing this. Therefore, we assumed that these participants did not feel any emotional attachment to the robot.

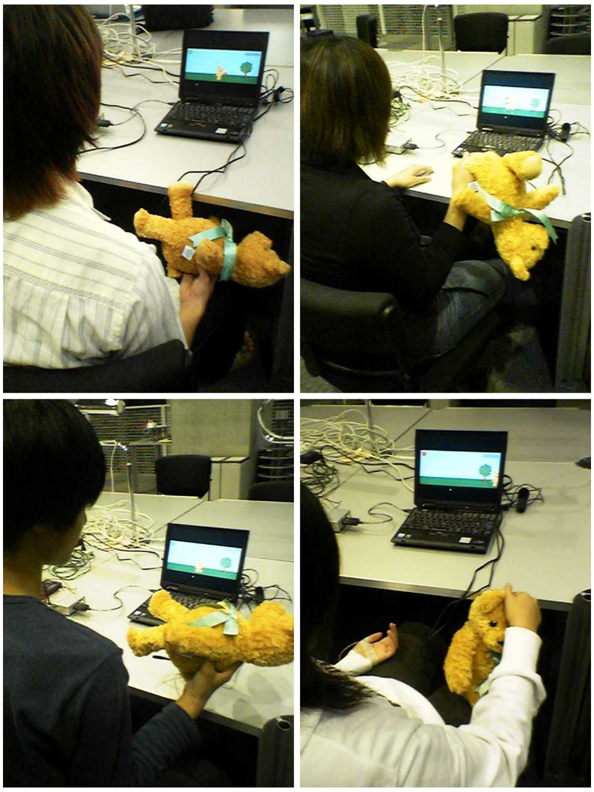


Fig. 9 Participants in Experiment 2 (Group C) holding the robot without emotional attachment.

This phenomenon, that some participants did not form an emotional attachment for the robot, could be explained by detailed analysis of the results of Experiment 2. Fig. 9 consists of some snapshots taken when the participants in Experiment 2 were holding the robot without emotional attachment. This figure reveals that these participants accepted the experimenter's instruction, i.e., "holding this robot as if it is waste or a disliked thing." Apparently, they started thinking of the robot as just an appliance that produces a vibration, and did not care about its behaviors. In this case, these participants could not create an appropriate positive biofeedback with the game system; that is, they were unaware of the meanings of the robot's behaviors even though the robot's behaviors reflected the users' biological signals just as in Experiment 1, in which most participants did recognize the meaning of the robot's behaviors.

We found another reason that some participants did not form emotional attachment to the robot, and this reason was not directly related to the experimental conditions of Experiment 2. Some participants reported introspections, such as, "I hate this stuffed animal." and "The robot's behaviors look very eerie." In fact, in the results for these participants, no differences in their SCR values for Session A and B were found, and their average SCR values in all trials were lower than those of other participants in the same group. Thus, if the participants were not interested in the robot itself, they were not affected by the positive biofeedback. Apparently, they did not have any initial emotional attachment with this robot, even though they held it on their laps. We considered that these participants' lack of interest was rooted in their personalities.

In sum, this study described our findings that the emotional attachment of the participants to the robot and the robot's behavior as motion media had significant influences on the participants' excitement or agitation and that we had achieved positive biofeedback in our game environment. Therefore, positive feedback obtained by using the behaviors of robot to which users have emotional attachment would be a key technology to achieve interactive systems that make players excited or agitated. This result should provide some guidance for the design and development of entertainment tools that provide positive biofeedback by using robots as motion media.

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