Entertainment Feature of a Game Using Skin Conductance Response

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ABSTRACT

There are many computer games in the world, but generally game players challenge either the computer, or real players in the case of many person games. In view of the strong connectivity advocated between communication and entertainment in the field of entertainment computing, the use of biological signals for computer games is of interest. Here, a novel type of game using biological signals was developed as an entertainment device. The change in skin conductance caused by sweating was measured as a signal reflecting the player's agitation during the game. This type of game incorporates various characteristics relating to communication. First, players of the game challenge themselves because they are able to view their detected biological signals. In this situation, a kind of self-reference system is constructed. Second, the environments in which the game is played changed how the game was enjoyed. Third, the game system reveals differences of context between player and observer. From these characteristics, it is considered that the use of biological signals is attractive for entertainment computing.

Keywords

Game, Entertainment, Skin Conductance Response, Biological signal

1. INTRODUCTION

Electrical signals detected from various sites in the living body represent objective and quantitative data reflecting the psychological state and physiology of the human body. Such signals have been used for diagnosis and treatment in medical care and in applications such as the lie detector used in police questioning. [3]

Moreover, in the field of information technology in recent years, investigation has been initiated into interfaces which use biological signals to control machines intuitively or to reflect user's emotion in functioning of the machines. Since this is the interface which can bring new operational feelings of machines, there are great hopes that the biological signals can be utilized effectively not just in system designs, but also for arts and entertainment. However, in the present circumstances, the system using biological signals is a long way from being marketed. To make better use of the concept, it is thought that further insight is required into the nature of the effects of using the biological signals.

Therefore, we researched the effects and nature of the biological signals as applied to a computer game system. In this paper, we will discuss the entertainment possibilities of using biological signals, and propose effective usages.

1.1 Psychological Involuntary Biological Signals

Biological signals such as brain waves, pulse waves and sweat gland activity reflect psychological states of humans such as agitation, surprise and excitation. A lie detector can detect a lie from changes in these signals by evaluating the characteristics of psychological states on these signals. The biological signal used in the lie detector test is skin conductance response (SCR), which occurs due to a change in conductance on the surface of skin by sweating resulting from agitation, surprise or excitation of a person. [2, 8, 4, 5, 9]

Even though people believe that we know a lot about our body, people really know very little about the physiological functions of their own bodies. That is because almost all physiological functions of the living body are involuntary and uncontrollable. SCR is a typical example of an involuntary and uncontrollable physiological function. People are not aware that sweating occur with agitation unless the person is experiencing a considerable mental stress. Therefore, people visually observing their own SCR when their own body responds to weak stimulation without awareness describe feeling a slight strangeness as if their body is not their own but somebody else's . On these occasions, the person has an acute feeling that there is a self that is not one's conscious self.

Additionally, we believe that we can conceal our inner agitation in our communications in daily life, but SCR can reveal the concealed agitation independently of our willing-

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ness to conceal. When an SCR indicator is attached, people tend to alter their communication mode significantly. Especially, in situations such as a poker game, for which people showing a "poker face" aim to conceal their excitation; here the SCR indicator brings about large changes in their communications.

1.2 The Problems of Existing Games That Use Biological Signals

Some games using biological signals have been developed and released by a number of major game production companies. [10] However, specialized knowledge and techniques are needed to measure biological signals accurately, such as the underlying principles of biological signal measurement, knowledge of control stats physiology, anatomy and electronics and the correct positioning of electrodes. In these games, to simplify matters, indication systems have been employed which rely on the player not being particularly concerned about miss-detected signals. But such indication system tends to make the game unrelated to biological signals and, as a consequence, boring. For that reason, the user evaluation of these games was generally quite negative and production of almost all of the games was terminated soon after release. Even though people are interested in their own biological signals, it is not justifiable to use biological signals without any understanding of the nature of the entertainment of them. Depending on how the signals are reflected in the game, the signals could make the game boring or exciting.

Additionally, the sensors attached to the body generally make the players uncomfortable. Therefore, if the original game was considered very exciting even without applying the biological signal system, the sensors merely cause discomfort to the player. To entice players to the game, the biological signal system must be more interesting for the players than the original game, or else the players will simply take off the sensors.

1.3 Relation Between Communication and Entertainment

Usually, perfectness of the controllability of a machine from the standpoint of human is required as the immense value for the man-machine interface. However, a problem exists for controlling the man-machine interface by the use of biological signals because biological signals reflect involuntary psychological functions, and there are great differences between individuals.

On the other hand, people find it discomforting to adopt the high controllable interface to communication between human and human. In this situation, mutual synchronization is required rather than controlling something. [11]

Nakatsu pointed out that entertainment is closely related to communication because both entertainment and communication commonly involve the elements of "sharing of experiences", "physical experience and mental experience" and "active immersion and passive immersion". [7] Additionally, awareness of biological signals from the users body which the user was previously unaware of can shift an ordinary communication mode to a new one. From this viewpoint, it can reasonably be expected that biological signals can be applied to entertainment computing.

Therefore, by constructing a new interface which generates mutual synchronization utilizing the uncontrollability of biological signals, we considered it to be possible to produce an entertainment computing system in which both human and machine relate to each other for the user's amusement.

2. THE GAME USING A BIOLOGICAL SIGNAL

Figure 1 shows a diagram of the computer game system developed here. Information from the player's psychological agitation is sensed from the player's palm and fed back to the player by an indicator on the game display, resulting in the player becoming more agitated. In other words, a vicious cycle of agitation is often realized with this system. To succeed in the game, players have to overcome the panic within themselves.

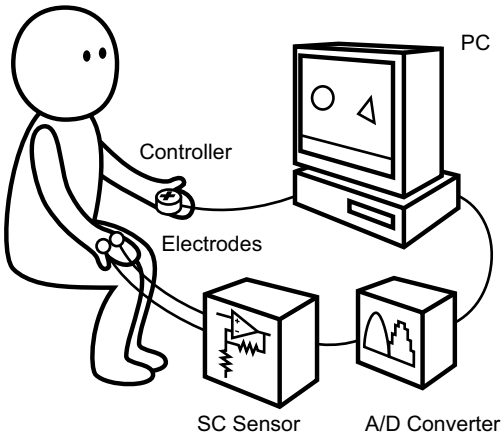


Figure 1: The system diagram of the game using SCR

2.1 Materials and Methods for Measuring SCR

SCR occurs due to a change in conductance on the surface of skin due to sweating. [2, 8, 4, 5, 9]There are two forms of sweat glands in the human body, the eccrine and the apocrine. The distinction between these two is made on the basis of location and function. Whereas apocrine sweatglands typically open into hair follicles and are found primarily in the armpits and genital areas, eccrine glands cover most of the body and are most dense on the palms and the soles of the feet. The function of the apocrine glands is not yet well understood. On the other hand, it is known that the function of eccrine sweat glands is thermoregulation and that sweating of this gland is related to emotions. [2] Therefore, the palm is a suitable place for measurement of psychophysical activity by SCR.

Two of the electrodes are attached to the palm of one hand as shown in Figure 2. Electro cardiogram electrodes (Nihon-koden co., disposable electrode J Vitrode, Ag/AgCl solid-gel form tape) were selected for this system.

The conductance on the skin of palm was transformed into a relative single-ended electro-potential signal balanced under a zero-level normal resting condition using a Wheatstone bridge circuit. The signal was amplified with a self-made amplifier, shown in Figures 3 and 4. The amplifier

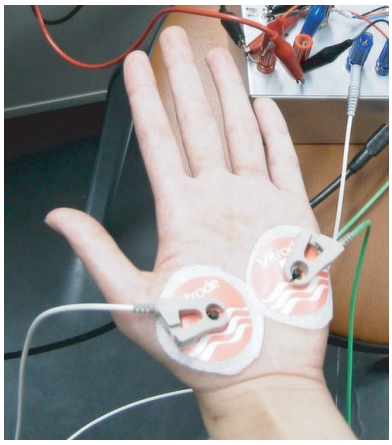


Figure 2: The electrodes attached to palm for measuring SCR

contains a 10-fold noninversion amplifier as a preamplifier, three levels of filter comprising a high-pass filter, a 50-Hz twin-T notch filter and a low-pass filter. A 1 to 100-fold noninversion amplifier was used as a final gain-controlled amplifier.

Figure 3: The picture of the exterior of self-made SCR amplifier

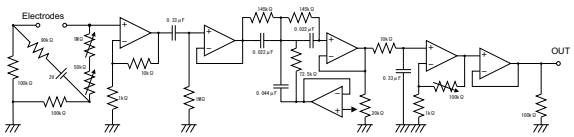


Figure 4: The electro circuit diagram of self-made SCR amplifier

An actual SCR measured by this amplifier is shown in Figure 5. It was observed after the sudden letting off of a party firecracker behind a subject. The sweating caused by the subject's psychological agitation is displayed in this graph as an SCR. Generally, an SCR wave rises at 2 seconds after stimulation and reaches a peak more than 2 seconds later. [1]The signal obtained here was typical.

2.2 Structure of the game system

As described, players attach two electrodes to the palm of one hand and hold the game controller in the other hand. The game involves controlling the character in the game

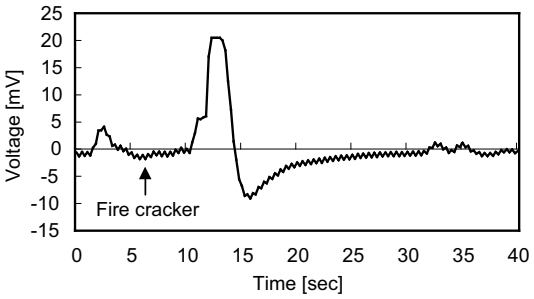


Figure 5: The example of actual SCR amplified by the circuit shown in Figure 4

screen displayed in Figure 6. To record suitable signals, players were required to put the hand with electrodes on their lap, eliminating disturbance from arm movement. Also, a shielding sheet was placed on the player's chair to reduce noise. The shield sheet was connected to the ground of the electric source. The single-ended signal amplified by the electrical circuit was transformed from analog to digital by an A/D converter: PIC16F873, 20MHz, and was transferred to the PC by serial communication interface: RS-232C.

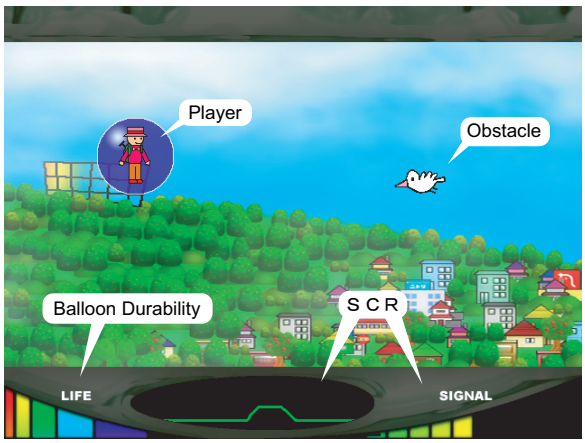
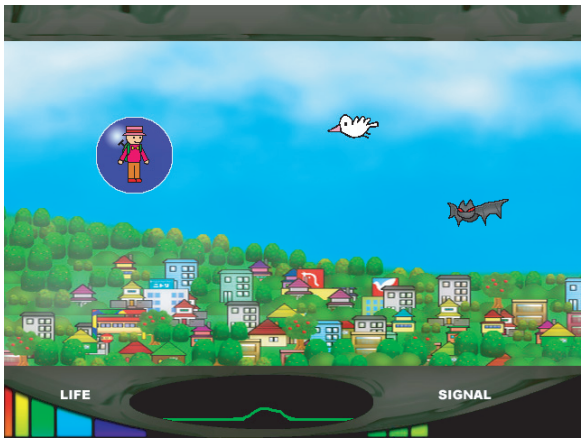


Figure 6: The layout of the game display

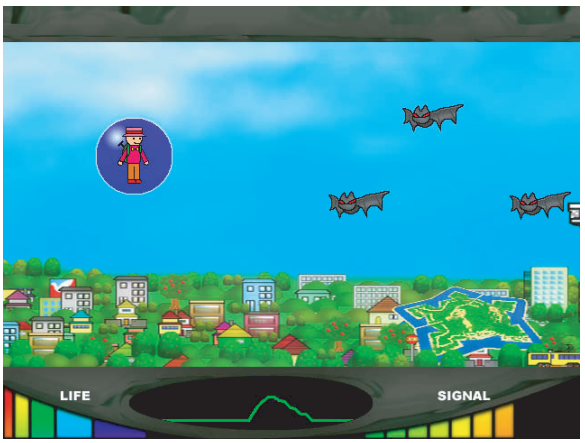
2.3 Contents of the game

With the background scrolling to the left in the screen layout shown in Figure 6, the boy character controlled by the player journeys in a balloon and must avoid obstacles. If the balloon surrounding the boy hits the obstacles five times, the game is over. The system measures SCR from the player's palm, and controls the number and kind of the obstacles depending on the degree of mental agitation. When the player panics, the number and difficulty increase as shown in Figure 7.

First, the game starts with a few obstacles (Figure 7a). In time, the player is agitated by some incident, and that is fed back to the game resulting in the number of obstacles increasing (Figure 7b). Then the player begins to panic, and the SCR became large and as a result feeds back to the game to produce more obstacles (Figure 7c). The player is



a



b

c

Figure 7: The progress of the game

trapped in a vicious circle of panic.

In this game, to clarify the effects of using biological signals, the system was designed as simply as possible. However, in an experiment to clarify the effects of player immersion, a heart mark was introduced to the game, allowing the player to acquire points.

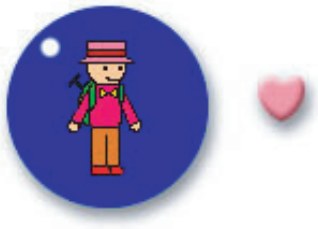


Figure 8: The boy and heart mark for extra points

3. TEST OF THE GAME AND RESULT

To clarify the nature and the effect of biological signals, the biological signal system was tested by subjects in many kinds of situation. Results for each of these situations is described.

3.1 The effect of SCR indication and audiences

To research the effects of SCR indication, the game was tested by subjects in many situations, and the SCR of the player was recorded. Also, some questionnaires were completed by the subject after the game.

For the situation where the players were in a closed room, group A containing 6 subjects played the game alone 3 times with SCR indication then 3 times without SCR indication; group B containing 6 subjects played the game alone 3 times without SCR indication then 3 times with SCR indication and group C containing 8 subjects played the game with a partner observing 3 times with SCR indication. From the SCR recorded for each subject, the number of waves of SCR, named "Number of SC changes", was estimated. Results are shown in Table 1.

The results of t-tests showed no significant differences ($P \leq 0.05$) between trials 1-3 of group A (with indication) and trials 1-3 of group B (without indication), or between trials 1-3 of group B and trials 4-6 of group B. However, there was a significant difference ($P \leq 0.05$) between trials 1-3 of group A and trials 4-6 of group A. Considering habituation to the game, it is suggested that the indication of the SCR causes player agitation. Additionally, 58% of the subjects responded that agitation was made frequently in the game with indication of SCR, 21% answered that agitation was made frequently in the game without indication of SCR, 21% answered indistinguishable, 68% responded that the game with indication of SCR was more interesting, 16% responded that the game without indication of SCR was more interesting, 16% responded that they were indistinguishable. Whereas a lot of subjects intended to play the game calmly, they became aware of their unconscious agitation from their biological signal and they were agitated further due to the perverse reaction of their own body.

Eenjoyment of the game and amusingness shifted depending on the surrounding environment. From Table 1, signifi-

Table 1: Average Number of SC change

Average Number of SC change	For Trials 1-3	For Trials 4-6
Group A: 3 times with SCR indication then 3 times without SCR indication (individual)	16.50^{*1*3}	11.78^{*2}
Group B: 3 times without SCR indication then 3 times with SCR indication (individual)	16.56^{*1}	13.39^{*2}
Group C: 3 times with SCR indication (in a pair)	22.58^{*3}	-

*1 no significant difference($p \leq 0.05$)
*2*3 significant difference ($p \leq 0.05$)

cant differences ($P \leq 0.05$) can be seen between trials 1-3 of group A and trials 1-3 of group C with group C showing greater values compared to group A. In the closed room, subjects were more agitated when their SC changes were pointed out by their friends. It was interesting to note that both player and audience enjoyed observing the change in SC after the player's friend exposed the player's secret. In this situation, whereas the players behavior remained consistent, their SC changed dynamically. They enjoyed the situation and the expression of the 'cornered' players at the same time. On the other hand, in the situation with a lot of observers viewing from galleries, SC changed frequently. Corresponding with this change, obstacles on the screen increased, raising a cheer from the galleries, which in turn caused further changes in SC. These subjects responded in questionnaires that they were agitated in the knowledge that many people were watching them.

3.2 The effects of immersion

We verified the effects on biological signals of player immersion in the game. Heart marks were introduced to the game to allow the player to receive points, and the relation between points and SC change was investigated. Results are shown in Figure 9. Even though receiving a heart mark brought no advantage to the player and the player was not required to collect them, the SC of players who tried to collect them tended to change frequently.

3.3 The effects of delayed indication

To reveal at what level players perceived their own SCR to be, we performed an experiment to research the effects of the indication of SCR with a delay. Usually, SCR is itself delayed 4 seconds after stimulation. We delayed indication by 4 seconds delay from the real signal, and attempted a comparison between normal indication and delayed indication. Figure 10 is the relation between amount of SC changes and playing time, for which the boy character come through the trip. Whereas there were no significant differences in the playing time between the normal and delayed groups, there was a significant difference in the amount of SC changes ($P \leq 0.01$).

Additionally, questionnaires were provided to the subjects after the experiment. To the question regarding the number of times that the subject observed involuntary SCR indication, 20% of subjects playing the game with normal SCR indication responded that it occurred about 10 times; 20%, about 5 times; 40%, about 3 times and 20% zero times. For the subjects playing with delayed SCR, 12.5% of subjects playing the game indicated about 10 times, 25%, about 5 times, 50%, about 3 times and 12.5% answered as zero. To the question regarding the number of times for which there was no SCR indicated yet the subject still felt agitated, 20% of subjects playing the game with normal SCR indication answered responded about 3 times, and 80%, zero times. For the subjects playing the game with delayed SCR indication, 25% responded about 3 times, and 75%, zero times. Furthermore, no subjects detected that there was a delay time.

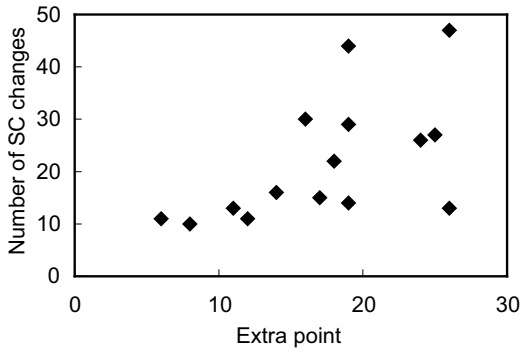


Figure 9: Relation between point and number of SC changes

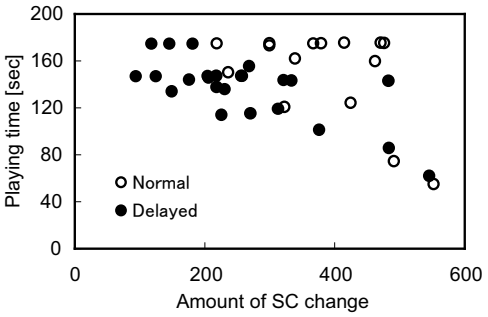


Figure 10: Relation between playing time and amount of SC change

4. DISCUSSION

Generally, computer games require significant manipulative skills from the controller. However, the game system developed here did not require them. A wide variety of people from 5 to 68 years old could enjoy this game, because this game using the the body's biological signal provides a new style of communication that is distinctive and unfamiliar.

As described in section 3.1, it was found that SCR indication increased the player's own SCR in the game. In other words, the player was more agitated observing their own SCR.

Also, when the subject played the game with the signal indicator delayed (section 3.3), whereas the SC change decreased, the player recognized the signal as the player's self with no conflict in their conscious.

The system created new communication by exposing the conflict between involuntary actions of the body and the perception of one's mind.

In the overall system, players simultaneously perceive their involuntary actions such as physical experience, and their conscious activities such as psychological experience. The player recognizes the discrepancy by integration of these two kinds of perception as a self-reference concept, one of the characteristics of a living system. The requirement to solve the discrepancy produced here became the motivation to continue the game, in other words, this is the distinct nature of game entertainment using biological signals.

Additionally, it was found that the way of enjoying the game and the level of amusement shifted depending on the surrounding environment. In the experiments including audience galleries, third person observers were seen in the game system as enemies. This system includes not only the computer and player, but also the environment. As such, the system involves the sharing of experiences between the player and third persons and is a kind of communication system.

Also, in the relation between observing and being observed,i.e. as an audience and a player, the system exposed the mutual differences of the two contexts and provided opportunity for communication to make up the difference as funny common experiences.

In section 3.2, the desire to collect heart marks, which were not required, was considered active immersion. In contrast, the feeling of agitation is considered passive immersion. The more heart marks a player received, the more player SCR increased and the greater the difference was between individuals. These results suggest that active immersion occurred in the game system using the feed back of the biological signal.

As just described here, from the aspect of communication, use of biological signals in game entertainment contains the elements of "sharing of experiences", "physical experience and physiological experience" and "active immersion", referred to by Nakatsu. [7, 6] Therefore, using biological signals in a computer game has an added entertainment value and can be used in a variety of ways. The future direction of this work will be application of the feature of biological signals to communications. For example, we would now like to go on to develop online chat interface using biological signals.

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