Ergonomic evaluation of portable videogame software

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ABSTRACT
In this study, the authors evaluated the psychophysiological effects of video games on users. Although video games affect users in various ways, this study focused on the short-term and direct effects. In an experiment, subjects played five kinds of video games on portable game machines for fifteen minutes. While each subject played a game, the authors measured the potential skin reaction during game play and profiled the subject's mood states and stress markers before and after he or she played. The authors examined the differences between the various games, the players' skills, and the information to play the game.

Author Keywords
psychophysiological effect, ergonomics, human factors

1. INTRODUCTION
Video games made their first appearance more than thirty years ago. Today, they are a popular form of entertainment. Although the effects of video games on users can be interpreted in many ways, they are often discussed against the background of social incidents, with special attention being paid to their negative effects. Some reports have suggested a relationship between video games and violence [4], while others have suggested that they cause a reduction in visual acuity [1], deterioration in brain functioning [10], etc. In Japan, such negative-effect theories tend to appear periodically; however, some of them are not sufficiently supported by scientific evidence [11]. Meanwhile, some recent studies have been considering the positive uses of video games. Educational video games that offer chances to solve social problems are called "serious games" and are subjects for scientific study. An increasing number of reports are examining the positive influences of video games, such as the educational effects of serious games [12], improvements in visual selective attention through game play [6], and temporary increases in spatial cognition after the playing of puzzle games [8].

The authors carried out a preliminary examination focusing on the possibility that the short-term playing of video games can improve a gamer's mood [7]. In this study, the authors conducted an experiment to evaluate the psycho-physiological effects of portable video games. The purpose was to specify which aspects of game content, players' skills, and experience can improve players' moods.

2. METHODS
In the experiment, the authors used psychophysiological indices to evaluate changes in the subjects' moods before, during, and after they played video games, and on considering the polarization between game play styles (concentrated type for a long playing time and recreational type for a short playing time), the authors chose a portable game machine (PlayStation Portable: PSP, Sony Computer Entertainment), which allows gamers to play at an easy, short pace. The subjects played the selected stage of the software for fifteen minutes. The results of the experiment suggested the possibility that a player's mood became more positive as his/her degree of mastery increased during game play [7]. The experiment was conducted in two stages. The

Situated Play, Proceedings of DiGRA 2007 Conference

first stage was conducted when the subjects had little experience in playing the selected game. The subjects continued playing the game until they reached a certain score and level to indicate mastery; then, the second stage of the experiment was conducted.

2.1 Measurements

The physiological indexes used were electrodermal activity (EDA) and amylase in saliva. A subject's emotional state, cognitive activity, information processing process, etc., can be evaluated by measuring changes in the electrical activity on the skin of the palm, caused by sweat gland activity, which is controlled by the sympathetic nervous system [2] (Figure 1). Amylase is a digestive enzyme in the saliva that is thought to promote toxin degradation in the digestive tract when stress stimuli excite the sympathetic nervous system. Amylase is used as a marker for stress evaluations [5]. The psychological index used was the Profile of Mood States (POMS), which was one of the questionnaires used to evaluate the subjects' moods or feelings. The POMS can measure the temporal mood state, which varies with the conditions under which the subject is put. The factor items of the POMS are "Tension Anxiety" (T-A), "Depression-Dejection" (D), "Anger-Hostility" (A-H), "Vigor" (V), "Fatigue" (F), and "Confusion" (C) [3]. In this study, EDA was used to examine the awakening state, the emotional changes, and concentrated level produced by game play, while the POMS and amylase were used to evaluate the mood and stress states before and after game play.

2.2 Stimuli

As experiment stimuli, we chose five PSP video games belonging to four genres (racing, music, action, and puzzles).

(1) RIDGE RACERS

RIDGE RACERS is a 3D racing game that features various tracks that wind through different landscapes such as cities, beaches, woods, and mountains.

Figure 1: RIDGE RACERS © NBGI

(2) TAIKO DRUM MASTER PORTABLE

TAIKO DRUM MASTER PORTABLE is a drumming game, wherein a drum simulating the taiko is played in time with music.

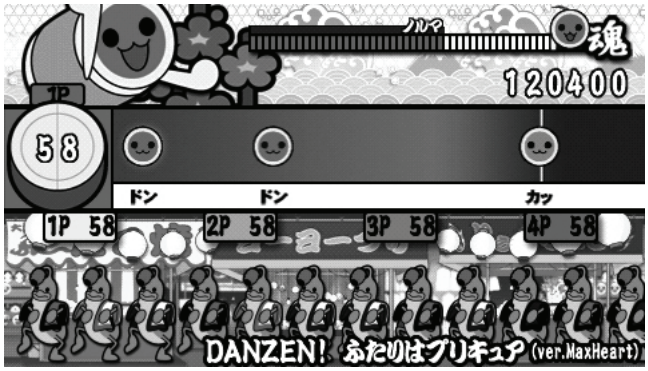

Figure 2: TAIKO DRUM MASTER PORTABLE © NBGI

(3) DIGDUG

DIGDUG is a classic action game produced in the early 1980s. The player character digs underground tunnels and uses an air pump to inflate and blow up enemies.

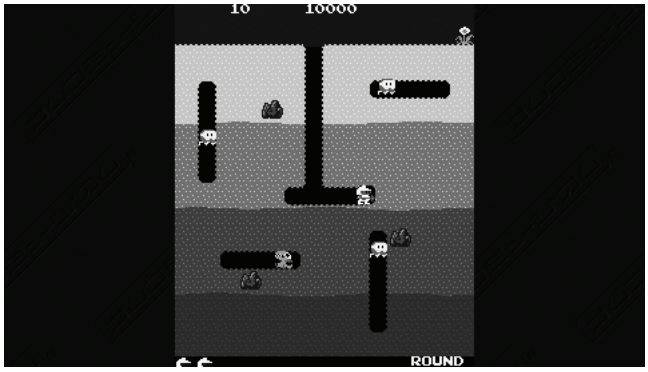

Figure 3: DIGDUG © NBGI

(4) MOJIPITTAN DAIJITEN

MOJIPITTAN DAIJITEN is a Japanese word puzzle game, which is similar to the word game "SCRABBLE."

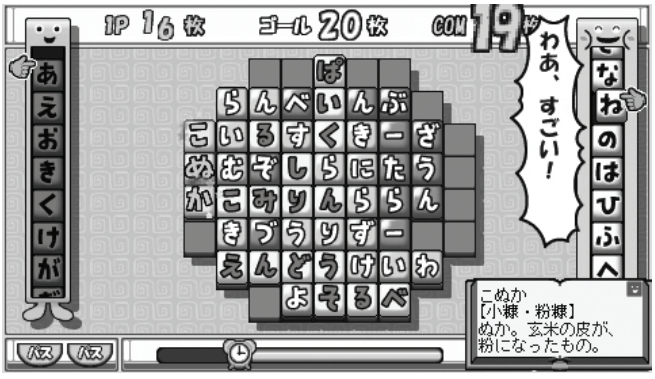

Figure 4: MOJIPITTAN DAIJITEN © NBGI

(5) LUMINES

LUMINES is a block-dropping puzzle game similar to "COLUMNS" or "TETRIS"; however, in this game, the music and visuals are more important.

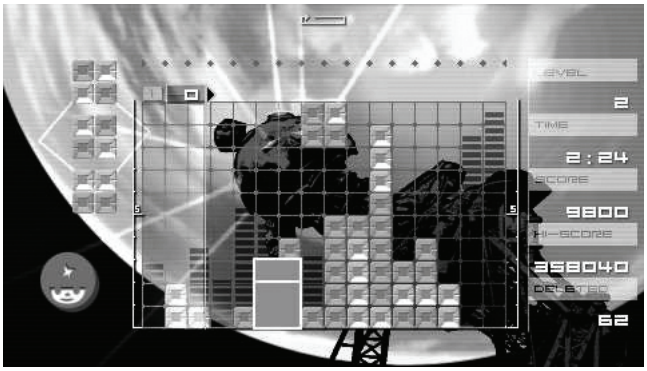

Figure 5: LUMINES © Q ENTERTAINMENT

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2.3 Subjects

The ten subjects were healthy graduate students (average age: 24.5 years) who had never played the five video games. The layout of the experiment is shown in Figure 6.

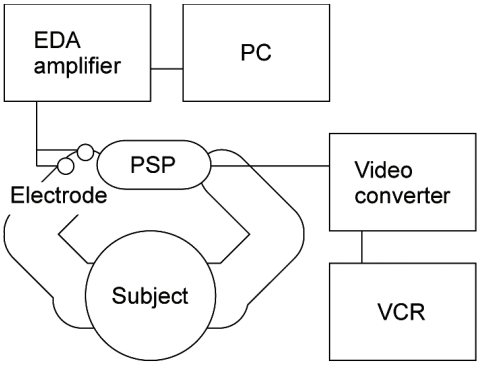

Figure 6: Layout of the experiment

2.4 Procedures

Each subject underwent the following steps of the experiment.

(1) Evaluation using the POMS

(2) Instruction based on the games' operation manuals

(3) Measurement of amylase activity

(4) Wearing of electrode and game practice for five minutes

(5) Playing of the game for 15 minutes and measurement of EDA

(6) Measurement of amylase activity

(7) Evaluation using the POMS

(8) Measurement of amylase activity (three minutes after playing)

(9) Introspection report

3. RESULTS

The EDA data collected during game play was quantified as emotional reaction frequency (ERF), emotional reaction amplitude (ERA), and skin potential level (SPL). The ERF was the average number of notable changes per minute in the SPL. The ERA was the average range of the size of notable changes in the SPL, which showed the emotional arousal level [9].

With regard to amylase activity, the stress values measured immediately after the participants played and three minutes after they played were converted into change rates, using the values measured before they began playing as the baseline. Since amylase secretions are delayed by one to several minutes, the secretions were measured twice—immediately after the participants finished playing and three minutes after they had finished playing. In the case of the POMS, the T score of each feeling was examined before and after the participants played the games. The T score is the score converted from the original POMS scores for the purpose of standardization.

The authors defined "improved mood" when the T scores of (T-A), (D), (A-H), (F), (C), and amylase activity decreased, or the T score of (V) increased.

3.1 RIDGE RACERS

In the first stage of the experiment, the subjects remarked that they found the game exciting since they could not guess the driving course, etc., and many of them were tense while playing. In the second stage of the experiment, the subjects commented that they were comfortable playing the game since they could control the game satisfactorily, that it felt good to drift, and so on. Many of the subjects showed a sense of composure. The EDA, ERF, ERA, and SPL values tended to be lower during the second stage; however, a one-way ANOVA did not reveal any significant differences in values between the two stages. Typical emotional reactions were elicited by (1) overtaking, (2) crashing, (3) drifting through turns, and (4) turning the final corner alongside another car. Amylase activity tended to decrease three minutes after play in the first stage, and also tended to decrease in the second stage. A one-way ANOVA showed that the POMS scores for vigor increased significantly after the first stage ($F = 10.61$, $p < 0.05$) and reduced fatigue after the second stage ($F = 6.21$ $p < 0.05$) (Figure 7).

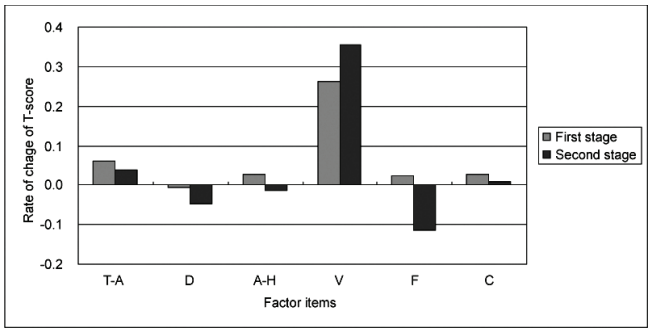

Figure 7: Rate of change in T-score

3.2 TAIKO DRUM MASTER PORTABLE

In the first stage of the experiment, the subjects tended to choose easy game levels; however, on gaining experience, many subjects chose more difficult levels, changed button configurations, aimed for higher scores, etc. The ERF, ERA, and SPL values of EDA increased after the second stage of the experiment (ERA: $F = 4.04$, $p < 0.10$, SPL: $F = 4.05$, $p < 0.10$) (Figure 8). It was observed that typical emotional reactions were elicited by (1) playing very difficult levels and (2) playing without mistakes for long periods.

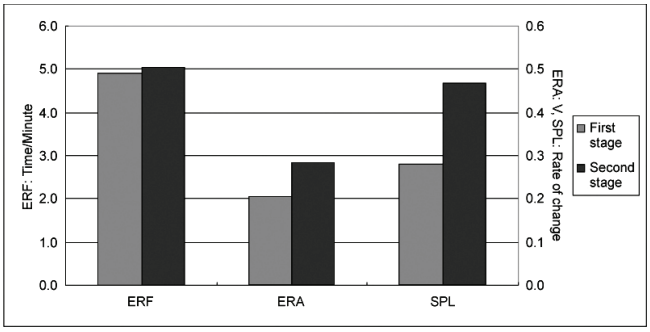

Figure 8: ERF, ERA, and SPL values of EDA

3.3 DIGDUG

A video game in the 1980s, DIGDUG, differs from recent video games in terms of its operating style. After the second stage of the experiment, some subjects commented that it was hard to control. The EDA, ERF, ERA, and SPL values tended to be lower after the second stage. In addition, amylase activity tended to be higher after the participants played in the second stage; however, it returned to its original level three minutes later. Although the POMS scores showed an increase in feelings of vigor after the first stage ($F = 7.44$, $p < 0.05$), they became slightly negative after the second stage. The subjects' introspection reports revealed that there were notable individual differences in the preference for characters or sounds (Figure 9).

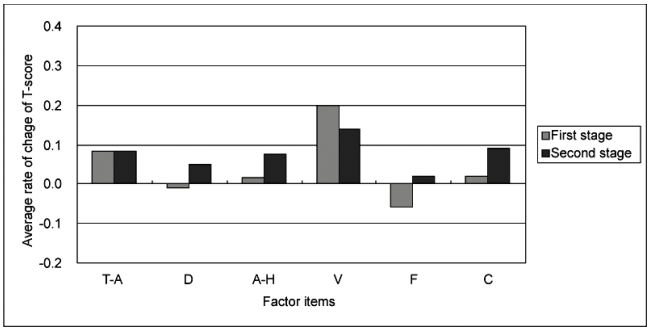

Figure 9: Rate of change in T-score

3.4 MOJIPITTAN DAIJITEN

As with TAIKO DRUM MASTER PORTABLE, a change in the subjects' attitudes was seen after the first stage of playing MOJIPITTAN DAIJITEN. The EDA and SPL values tended to be higher after the first stage. An example of a subject's SPL during play is shown in Figure 10. Although amylase activity increased after the subjects played this game in both stages, the level returned to normal three minutes after they finished playing. No notable changes were observed in the POMS scores.

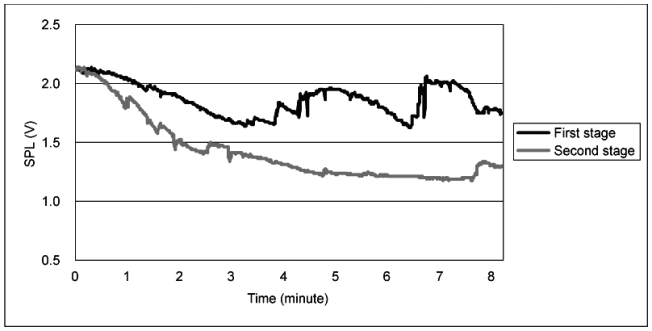

Figure 10: Example of a subject's SPL

3.5 LUMINES

Before and after the first stage, the subjects often commented that they were comfortable playing the game or that they were able to concentrate on playing it Although the EDA, ERF, and SPL values tended to be lower in the second stage, the arousal levels appeared to remain constant. Typical emotional reactions were elicited by (1) the blocks being stacked and the stacks nearing the top of the screen, (2) using special blocks to eliminate large quantities of blocks, and (3) placing a block in an unintended location, etc. Amylase activity tended to be lower in both stages, especially three minutes after the game had ended (Figure 11). The POMS scores tended to indicate increased vigor, and decreased fatigue and depression.

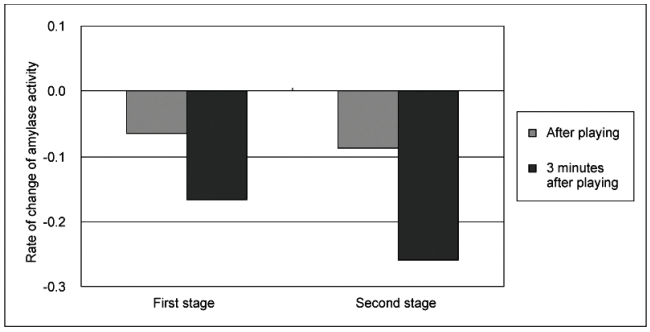

Figure 11: Rate of change in amylase activity

4. DISCUSSION

The results of the experiment show that the psycho-physiological changes elicited by video games vary among the video games as well as before and after game play. In the case of RIDGE RACERS, the subjects' feelings, especially increased vigor, changed constantly both before and after game play, even in the case of the subjects who could not play the game well. This suggests that the effects of this game are not easily influenced by skill level or content. In the case of TAIKO DRUM MASTER, higher levels of emotional reactions, arousal, and vigor were

observed when a subject cleared a favorite stage or a difficult level. Therefore, the effects of this game may be influenced by the game content. Many subjects felt stressed by the characteristic method of control in DIGDUG; however, the differences were likely due, in large part, to individual preferences. In MOJIPITTAN DAIJITEN, as in RIDGE RACERS, vigor increased and fatigue decreased; however, amylase activity increased after the participants had played the game. The subjects may not have been satisfied merely just by completing the easy levels and so chose more difficult levels with the result that many subjects became stressed by the time limit or the level of difficulty. In LUMINES, vigor increased and fatigue decreased; however, unlike the case of RIDGE RACERS, amylase activity was low both immediately after and three minutes after the participants finished playing. In addition, since the emotional reactions during play were low, many subjects may have remained relaxed from start to finish.

5. CONCLUSIONS

In this study, the authors focused on improved mood as a positive effect of video games and examined factors such as the characteristics of the games and playing experience. From the results of the experiment, which involved the use of five video games for portable players, the following conclusions can be drawn:

(1) Video games can produce psychophysiological changes in the gamers.

(2) The direction of these changes varies with the game software.

(3) Although the change also varies according to the players' skill levels (novice or mastery), the change in the mastery tended to be positive in many cases.

(4) Playing content and personal preferences cause characteristic changes.

The authors consider the reproducible changes in mood and the direction or degree of the mood changes as a positive effect of video game play. In the future, the authors will attempt to construct a new evaluation approach and optimum playing conditions for video games, by enrolling more subjects in the study, developing more experimental conditions, and measuring more aspects. Furthermore, the findings will be applied to game design for the purpose of inducing specific psychological effects.

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