Estimation of Thinking States in Cyberspace Using Multiple Physiological Parameters

Hiromu Miyashita* Ryo Segawa† Ken-ichi Okada‡
Graduate School of Science and Technology
Keio University

Abstract

Thinking states are very important factors in the evaluation of and interaction with virtual spaces. Physiological information is often used to estimate thinking states objectively. However, it is difficult to estimate complex feelings numerically from limited physiological information. In this paper, we propose a method for the evaluation of thinking states in cyberspace using multiple physiological parameters. We developed a mapping matrix that converted physiological data into a composite of thinking states. In experiments, we found that with one mapping matrix the thinking states of different subjects for the same task could be derived. In addition, we investigated the similarities and differences between six estimated thinking states by using the mapping matrix.

CR Categories: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

Keywords: Psychology, Presence, Feelings

1 Introduction

Thinking states are subjective feelings that include information regarding a person's mood, emotions, and thoughts. In this study, we focus on describing feelings numerically in the context of virtual reality, which will be applied to evaluations of and interactions with cyberspace. In efforts to construct indexes of thinking states, physiological information has received considerable attention. However, many previous studies have estimated only a narrow range of feelings, deriving feelings not as numerical values but rough vectors.
Therefore, we hypothesized that a precise estimation of a wide range of feelings could be achieved by measuring multiple physiological parameters and analyzing them compositely. For this proposed method, we developed a mapping matrix that defines the weighting coefficients of the physiological parameters for conversion to thinking states.

2 Estimation of Thinking States

In this research, we define physiological information as the biological response that occurs unconsciously in humans. Physiological information is an index of autonomic nervous system activity and is related to the states of the mind and body.

*e-mail: miyashita@mos.ics.keio.ac.jp
†e-mail: segawa@mos.ics.keio.ac.jp
‡e-mail: okada@mos.ics.keio.ac.jp

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Some research has been conducted that combines physiological information with thinking states. Wiederhold et al. analyzed reactions of fear and rest in a virtual space via measurements of heart rate, skin conductance and skin temperature [2002]. Meehan et al. investigated an index for estimating presence [2002]. Based on an evaluation of physiological information, they concluded that the most effective method is the measurement of heart rate.
However, existing technologies have two problems.
The first problem is that the thinking states were estimated from an isolated axis. However, people think and act in a complicated manner and do not experience a single feeling or thought. It is possible that many thinking states are related to each other in a more complicated manner.
The second problem is that the accuracy of the existing methods is not sufficiently high. Since physiological information has considerable noise, thinking states are difficult to calculate accurately. It is difficult to compute the strength of each thinking state by simple analysis of physiological information.

3 Proposed Mapping of Thinking States

In this paper, we propose a method of estimating of thinking states in cyberspace using multiple physiological parameters. In this approach, multiple physiological parameters are measured synchronously and feelings are estimated by matrix calculation using a mapping matrix (**MAP**) that relates the measured data to the states (Formula 1). The strength of the physiological parameters was expressed as five levels in the mapping matrix. The mapping matrix defines the weighting coefficients of the physiological information in the thinking states.

$$\begin{pmatrix} FeelingA \\ FeelingB \\ FeelingC \\ etc. \end{pmatrix} = \mathbf{MAP} \begin{pmatrix} Parameter1 \\ Parameter2 \\ Parameter3 \\ etc. \end{pmatrix} \quad (1)$$

In this study, we focused on four physiological parameters: Brain Activity (BA), Breathing Rate (BR), Heart Rate (HR), and Skin Conductance (SC). The brain activity was calculated from the 14-27 Hz EEG frequency band. Additionally, we chose anxiety, concentration, drowsiness, relaxation, repugnance and amusement as the thinking states to be estimated in this study. Therefore, **MAP** is expressed as follows.

$$\mathbf{MAP} = \begin{pmatrix} W_{Anx.} \\ W_{Con.} \\ W_{Dro.} \\ W_{Rel.} \\ W_{Rep.} \\ W_{Amu.} \end{pmatrix} E_6 \begin{pmatrix} A_{BA} & A_{BR} & A_{HR} & A_{SC} \\ B_{BA} & B_{BR} & B_{HR} & B_{SC} \\ C_{BA} & C_{BR} & C_{HR} & C_{SC} \\ D_{BA} & D_{BR} & D_{HR} & D_{SC} \\ E_{BA} & E_{BR} & E_{HR} & E_{SC} \\ F_{BA} & F_{BR} & F_{HR} & F_{SC} \end{pmatrix} \quad (2)$$

E_6 is a 6-by-6 identity matrix. A_{BA} to F_{SC} are importance factors of the physiological parameters for tasks (A to F) that elicit a feeling. These factors were based on the significant differences in physiological changes when subjects performed the tasks. $W_{Anx.}$

to $W_{Amu.}$ are adjustment weights to normalize the levels of the thinking states. We set W_n in experiment 1 such that all levels of feelings for the standard six tasks became 5.0.

4 Experiments

4.1 Experimental Purpose and Method

Experiment 1 was performed to establish the mapping matrix. The subjects were given six tasks: watching a horror movie (Anxiety), taking a Kraepelin test (Concentration), performing simple clicking tasks (Drowsiness), viewing a calm VR beach (Relaxation), listening to the sounds of a scraped chalkboard (Repugnance), and watching a comedy video (Amusement). We developed the mapping matrix by observing the physiological responses of subjects during these tasks. This experiment involved five male participants (mean age 23 years). Each task required about 5 min, and the subjects performed the tasks in random order.

In experiment 2, we verified that the mapping matrix is usable for other subjects. We obtained numerical values corresponding to thinking states by using the mapping matrix made in experiment 1. This experiment involved five male participants (mean age 23 years) that did not participate in experiment 1. The tasks were the same as those in experiment 1.

In experiment 3, we offered other tasks: playing a horror video game (Anxiety), doing addition continuously (Concentration), viewing a movie of a fireplace (Drowsiness), listening to classical music (Relaxation), listening to the sounds of mosquitoes (Repugnance), and watching a different comedy video (Amusement). These tasks were assumed to provide similar feelings for the subjects. We examined the versatility of the mapping matrix by comparing the results with those of experiments 1 and 2.

4.2 Results

We set the weighting factors (A_{BA} – F_{SC}) to 3 or 2 or 1 in reference to the results of a Wilcoxon matched-pairs signed-ranks test comparing each task and no task (Formula 3). However, weights were set as minus values in cases in which the measured physiological level was minus. In addition, we calculated W_n such that the values of the thinking states in experiment 1 were 5.0.

$$\mathbf{MAP} = \begin{pmatrix} 0.77 \\ 0.71 \\ 1.41 \\ 1.21 \\ 0.70 \\ 1.84 \end{pmatrix} E_6 \begin{pmatrix} -3 & 2 & 3 & 2 \\ 3 & 3 & 3 & 1 \\ -2 & -2 & -3 & 2 \\ -2 & -3 & -2 & 2 \\ -3 & 2 & 2 & 3 \\ -2 & 1 & 2 & 2 \end{pmatrix} \qquad (3)$$

We produced radar charts of the six thinking states from three experiments, as shown in Figure 1.

Compared with the shapes of all graphs, the results of experiments 1 and 2 are similar. We interpreted this result to mean that for the same task, the mapping matrix can be used for different subjects. However, the result of experiment 3 suggests that the mapping matrix lacked versatility in this study.

Figure 1 indicates that the tasks for drowsiness and relaxation evoked a parallel physiological response and that the physiological indexes that were measured in this study did not isolate them. In contrast, since the radar charts of tasks involving concentration are different from the others, it is thought that mental concentration is detected easily.

In addition, anxiety and relaxation were equally likely to be evoked in the task for amusement. It was found that these feelings were not a one-dimensional mental change.

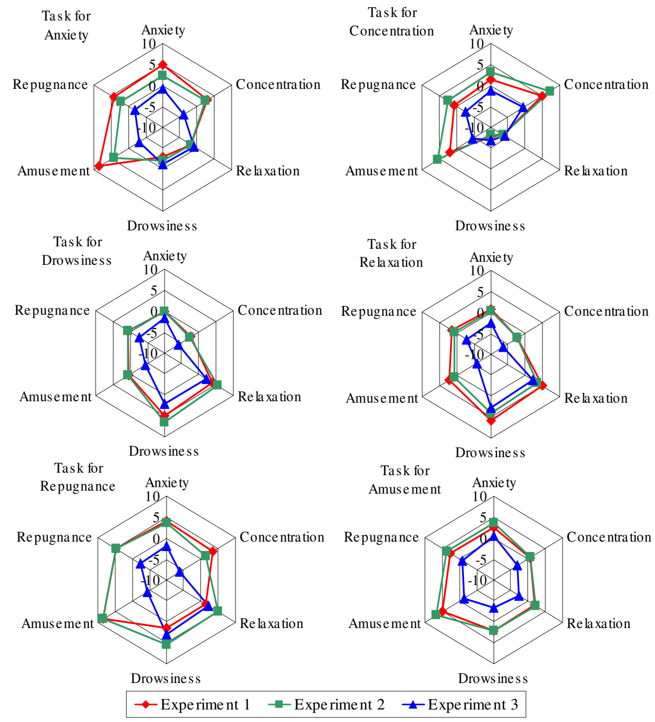

Figure 1: *Estimated thinking states in experiments*

5 Conclusion

Physiological information is related to the thinking states of humans and is widely used to derive information on thinking states objectively. However, thinking states have been estimated previously only from an isolated axis.

In this paper, we proposed a method for evaluating thinking states in cyberspace using multiple physiological parameters. This method uses a mapping matrix based on the significant differences in the changes of physiological information.

In our experiments, we developed the mapping matrix and compared the strengths of the thinking states between different subjects and tasks. As a result, we found that one mapping matrix was able to derive the thinking states of different subjects for the same task. In addition, we investigated the balance of estimated thinking states that were evoked by various tasks.

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