Study of the Relationship between Heartbeat and Subjective Evaluation during the Performance of a Cognitive Task

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Objectives: The purpose of this study was to evaluate the relationship between heartbeat and subjective evaluation (POMS, SFF) when the cognitive task consisted of calculation problems. Methods: The subjects were five males and six females. The cognitive task was calculation problems (e.g., subtract a single-digit number from a two-digit number) displayed on the screen at regular intervals (2 sec and 4 sec). The R–R interval was measured for the subjects’ heartbeat during rest and during the task. The POMS Brief Form and the SFF new edition were used as the indices for subjective evaluation. Results: The R–R interval changed between the rest time and the calculation time. The correlation didn’t accept it between the changes in the score (POMS) and in the heartbeat. But it accepted between the changes in the score (SFF) and the heartbeat. Conclusion: We found that a task that carried a high cognitive burden did not affect an individual’s mood or emotional state, but was correlated with indices used to measure subjective degree of fatigue.

Keywords: Subjective Evaluation, Heartbeat, Correlation, Cognitive Task, Workload

1. Introduction

When measuring workload during the performance of a cognitive task, physiological reactions, such as heartbeat and brain waves, are evaluated together with subjective reactions. In many cases, the latter are obtained using various questionnaires. Heartbeat has been used to evaluate the burden of a cognitive task for many years (Yamaji, 1981). To measure mood and feelings of fatigue subjectively, questionnaires such as the Profile of Mood State (POMS; Curran, 1995) and Subjective Feelings of Fatigue (SFF; Sasaki, 2005) are often used. In a study where heartbeat and POMS were measured simultaneously, although no significant change was observed in the heart rate due to a calculation-task load, the score of each item in the POMS changed (Washino, 2011). In a study where heartbeat and SFF were measured simultaneously, the heart rate and scores of “feeling of drowsiness,” “feeling of uneasiness,” and “feeling of eyestrain,” tended to increase during the performance of a cognitive task (Tanahashi, 2004). Many previous studies, including these two, have analyzed changes in heart rate and subjective evaluation (POMS and SFF) separately; no studies have compared heart rate and subjective reactions and examined the correlation between them. To evaluate workload during the performance of a cognitive task accurately, the relationship between the changes in heart rate and those in subjective evaluation must be examined.

This study adopted calculations for the cognitive task and performed an experiment using POMS and SFF for subjective evaluation to examine the relationship between heartbeat and subjective evaluation.

2. Experiment

2.1 Subjects

The subjects were five males and six females 20.0 ± 0.8 years of age. Before the experiment, each subject’s heart, eyesight, and hearing were confirmed to be normal. The study was performed with approval from the ethics committee. The study rationale was explained to the subjects and their written consent was obtained.

2.2 Environment

The subjects were asked to lie in a semi-supine position; the distance between the display screen and the subject’s eyes was set at 60 cm (Figure 1). The curtain on a window in the room was closed and the room
illuminations was set at 300 lx. The room temperature was 26.3°C ± 0.45°C, the humidity was 46.47% ± 3.7%, and the background noise was 40.8 ± 0.9 dB. The subjects were asked to keep quiet and remain still during the experiment.

Figure 1. The scenery of the experiment.

Figure 2. The screen of the experiment.

2.3 Methods

The experiment used a 17-inch screen display. A set of calculations was adopted as the cognitive task. The task consisted of calculation problems (e.g., subtract a single-digit number from a two-digit number) displayed on the screen at regular intervals. The subjects were asked to solve each calculation problem mentally and to answer orally (Figure 2). The display intervals between problems were 2 and 4 seconds, and each task was performed for 10 minutes. The order of tasks was determined randomly. The R–R interval was measured for the subjects’ heartbeat during rest and during the task. The POMS Brief Form and the SFF new edition were used as the indices for subjective evaluation. The subjects were asked to fill out these two evaluations before and after the task. The POMS evaluates an individual's mood or emotional state, in which six items of “T-A: tension–anxiety,” “D: depression–dejection,” “A-H: anger–hostility,” “V: vigor,” “F: fatigue,” and “C: confusion” are evaluated using a five-point Likert scale (0–4 scores) ranging from “not at all” to “extremely.” Total mood disturbance (TMD) scores were calculated based on the six items in the POMS. The SFF evaluates the state of subjective fatigue, in which “I: feeling of drowsiness,” “II: feeling of instability,” “III: feeling of uneasiness,” “IV: feeling of dullness,” and “V: feeling of eyestrain,” are evaluated on a five-point Likert scale (1–5 scores) ranging from “disagree strongly” to “agree strongly.”

3. Results

3.1 Correct answer rate for the calculation task

Figure 3 shows the mean correct answer rate for the 11 subjects on the calculation task at each display interval. As shown in Figure 3, the correct answer rate was 91.9% (average) when the display interval was 4 seconds and 60.4% (average) when the interval was 2 seconds. A one-way analysis of variance using the factor of display intervals revealed that the effects observed in the display intervals were significantly different (F(1,20) = 23.59, p < 0.01).

3.2 R–R interval

Figure 4 shows the mean R–R interval for the 11 subjects during rest and during the calculation task at each display interval. As shown in Figure 4, the R–R interval during rest was approximately 92 sec/100 and that during the calculation task was approximately 84 sec/100. In particular, the change in the R–R interval
during rest and during the calculation task was greater when the display interval was 2, rather than 4 seconds. A two-way analysis of variance using the display intervals and the subjects’ condition (rest and performing the task) revealed that the differences between the subjects’ conditions were statistically significant ($F(1,40) = 4.48, p < 0.05$).

The correlation between the $R$-$R$ interval during the calculation task and the correct answer rate for the task was also examined. The correlation coefficients were 0.493 and 0.238 when the display intervals were 2 and 4 seconds, respectively. Therefore, the correlation was weak at both display intervals (Figure 5).

![Figure 3](image1.png)

Figure 3. The comparison of the correct answer rate of the issue of calculation.

![Figure 4](image2.png)

Figure 4. The comparison of resting period and the R-R interval at the time of the problem.
Figure 5. The relations with R-R interval and the correct answer rate.

3.2 Relationship between heartbeat and subjective evaluation

Table 1 shows the correlation coefficients between the changes in the score (POMS) and in the heartbeat. Here, the change in the score represented the difference in the score of each item before and after the calculation task, while the change in the heartbeat represented the difference in the average R-R interval before and after the calculation task. As shown in Table 1, the correlations were weak for all items, including “tension-anxiety,” TMD mood, and TMD emotional state.

Table 2 shows the correlation coefficients between the changes in the score (SFF) and that in the heartbeat. Here, the “total” of scores represented the change in the total number of points on all items. The change in the score and that in the heartbeat were the same as those mentioned above. As shown in Table 2, a correlation was observed between the change in heartbeat and “I: feeling of drowsiness,” “II: feeling of instability,” “III: feeling of uneasiness,” “V: feeling of eyestrain,” or “total” when the display interval was 2
seconds. In particular, a strong positive correlation was observed between the change in the heartbeat and “III: feeling of uneasiness,” “V: feeling of eyestrain,” or “total” at a significance level of 1%. In other words, the score increased as the R–R interval decreased (the heart rate increased).

Table 1. The correlation coefficient of POMS and heartbeat.

<table>
<thead>
<tr>
<th></th>
<th>T-A</th>
<th>D</th>
<th>A-H</th>
<th>V</th>
<th>F</th>
<th>C</th>
<th>TMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 sec.</td>
<td>-0.436</td>
<td>-0.219</td>
<td>0.027</td>
<td>-0.169</td>
<td>0.062</td>
<td>-0.243</td>
<td>-0.151</td>
</tr>
<tr>
<td>2 sec.</td>
<td>-0.458</td>
<td>0.277</td>
<td>0.489</td>
<td>0.301</td>
<td>0.127</td>
<td>0.015</td>
<td>-0.090</td>
</tr>
</tbody>
</table>

Table 2. The correlation coefficient of SFF and heartbeat. (*: p<0.05, **: p<0.01)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 sec.</td>
<td>0.445</td>
<td>-0.018</td>
<td>0.152</td>
<td>0.113</td>
<td>0.226</td>
<td>0.266</td>
</tr>
<tr>
<td>2 sec.</td>
<td>0.723*</td>
<td>-0.665*</td>
<td>0.749**</td>
<td>0.250</td>
<td>0.883**</td>
<td>0.875**</td>
</tr>
</tbody>
</table>

4. Discussion
The difficulty of the calculation task was controlled by setting the intervals between the problems at 2 versus 4 seconds. The correct answer rate was lower and the change in the R–R interval between rest and the cognitive task was larger when the display interval was 2 seconds than when it was 4 seconds. The heart rate is said to increase by 4–10 heartbeats/minute over the resting rate during a calculation task (Zwaga, 1973). Therefore, the difficulty of the calculation task could be controlled by changing the display interval between the problems, such that the cognitive burden was greater when the display interval was 2 rather than 4 seconds.

To examine the relationship between heartbeat and subjective evaluation during the performance of a cognitive task, POMS and SFF were adopted for subjective evaluation.

In this experiment, no correlation was observed between the changes in the POMS scores and the changes in heartbeat. When the display interval was 2 seconds, a correlation was observed between the changes in the SFF scores (five items) and the changes in heartbeat. In particular, a strong correlation was observed between the change in heartbeat and “III: feeling of uneasiness,” “V: feeling of eyestrain,” or “total.” However, no correlation was observed between the changes in the SFF scores and the changes in heartbeat when the display interval was 4 seconds. Because the SFF scores increase when the difficulty of a task increases, the scores can be used to measure differences in subjective fatigue (Fukuda, 2006). This means that the heart rate, an index of workload, increases as the burden of a cognitive task increases, resulting in increased subjective symptoms. The subjective symptoms included: “I feel heavy in the head, my head aches, and I am absentminded,” which are evaluated as “feeling of uneasiness,” and “my eyes get tired, are sore, and are dim,” which are evaluated as “feeling of eyestrain.” Thus, when the heart rate does not increase because of a small cognitive burden, the SFF scores also do not increase. However, when the heart rate increases because of a large cognitive burden, the SFF scores also increase.

5. Conclusion
To examine the relationship between heartbeat and subjective evaluation during the performance of a cognitive task, an experiment was performed in which a calculation task was adopted as the cognitive task and POMS and SFF were used for subjective evaluation. The experimental results can be summarized as follows: (1) changes in the POMS scores were correlated weakly with changes in heartbeat; (2) when the display interval was 2 seconds and the cognitive burden of solving a calculation problem was high, the changes in the SFF scores for three items (“feeling of uneasiness,” “feeling of eyestrain,” and “total”) were correlated strongly with the change in heart rate, and (3) when the display interval was 4 seconds and the cognitive burden of the calculation problem was low, no correlation was observed between the changes in the SFF scores and the changes in heartbeat.
Overall, we found that a task that carried a high cognitive burden did not affect an individual’s mood or emotional state, but was correlated with indices used to measure subjective degree of fatigue.

References