A STUDY FOR DEVELOPMENT OF THE INDEX OF MENTAL WORKLOAD USING THE OXIDATIVE-STRESS MARKER

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Abstract: The aim of this study is to obtain the background knowledge of oxidative-stress maker as an index of mental workload. Many indexes of mental workload have been developed by many researchers. Almost indexes can evaluate the degree of mental workload correspond to the work at that time. However cumulative mental workload with time course cannot be measured by these indexes. Oxidative-stress maker may be possible to evaluate cumulative mental workload because it detects the product of stress response in the blood.

In this study, a computer based pattern-matching task that was designed to induce time pressure was used. NASA-TLX, subjective rating of fatigue, HR, blood volume pulse (BVP) from the tip of finger were measured as indexes of mental workload. Plasma NOx (nitrite/nitrate), plasma TBARS (thiobarbituric acid-reactive substances), Plasma SOD (superoxide dismutase) activity in blood and 8-isoprostane, NOx in the urine were measured as indexes of oxidative-stress maker.

1. INTRODUCTION

It should be discussed how to evaluate the impact of mental workload on worker’s health. The measurement of cumulative mental workload would be one of the indexes to estimate the effect of work operation on worker’s health at the workplace. The mental workload degree induced by work operations is not constant in the real work (not laboratory simulation). Almost indexes can evaluate the degree of mental workload correspond to the work at that time. Because continuous monitoring and recording the data with some restriction will be required to evaluate cumulative mental workload during work operation, it has much difficulty to apply the conventional way to workplace.

Oxidative stress is a general term used to describe the oxidative damage in a cell, tissue, or organ, caused by the reactive oxygen species (ROS). Reactive oxygen species, such as free radicals and peroxides, represent a class of molecules that are derived from the metabolism of oxygen and exist inherently in all aerobic organisms. Endothelial dysfunction may be caused by accelerated inactivation of NO by reactive oxygen species. This phenomenon has been implicated in many pathophysiological conditions, including hypercholesterolemia, atherosclerosis, cigarette smoking, hypertension, diabetes, and heart failure. (H. Cai and D. G. Harrison 2000). Recently, oxidative stress induced exercise load (Y. Jammes et al. 2005, G. Kennedy et al. 2005) and the effect of short-term stress including psychological stress on oxidative stress (M. L. Pall) are discussed. These studies would promise a possibility that oxidative stress can be used as an index of cumulative mental workload. Additionally, oxidative stress starts to garner attention as an index of oxidative damage in a cell which would be connected directly with health.

Time pressure is a component of mental workload. Time pressure is induced by time constraints. There are very few works without time constraints. In other words, almost workers should be performed their work under time pressure condition. So, time pressure is one of most important stressors in the workplace. In various industries, fixed time to perform one work unit is set for production control as standard operation time. Every worker should finish within standard operation time with time pressure.

The aim of this study is to investigate whether the indexes of oxidative stress can be used as an index of mental workload or not. The indexes of oxidative stress were compared between under the condition with time pressure and without time pressure in this study.
2. METHOD

2.1 Subject
Six healthy right-handed male college students with normal vision and no cardiac disease were used. Their average age was 21.83±0.75 years.

2.2 Task
An original task was prepared for this study. It was a kind of pattern recognition task which required one to search for and select a target from some given visual information on a computer display (Figure 1). On the left side of the screen, four cards with a Landolt ring at the center were shown (the question site). Each Landolt ring was placed in one of four directions (upward, downward, leftward or rightward), respectively, and each of them was randomly set for one question. On the right side of the screen (the response site), four cards with Landolt ring were also shown in the same way as the question site, but only one was placed in a different direction from that on the question site. Then subjects were requested to compare each card on each site, and to click with a computer mouse on the card placed in the different direction on the response site from the question site as soon and as accurately as possible. The pointer for the answer always appeared in the center circle on the response site when a new question appeared. One task consisted of ten questions and the accuracy was given feedback to the subjects to show the proceedings of the task and to avoid that they underestimate the results. Thus the ten white boxes (which mean the ten question) on the upper left of the screen changed one by one to blue if answer was correct, or to red if it was wrong. The time limit for one task was shown by the changing color of gauge at the bottom of the screen to impose time pressure visually. The gauge started to decrease from the right side when the first question appeared. When they finished a task within the time limit or could not do that, next new task appeared immediately and the gauge started to decrease again.

The first five tasks were self-paced, and gauge did not change. Next, the average processing time for a task was calculated using a computer program, and the first time limit was determined. Thus, subjects had to achieve the sixth task under the time limit (i.e., the gauge decreased so as to impose time pressure). The time limit fluctuated from the seventh task to the end, and subjects were imposed stricter time pressure gradually in order to measure the maximum processing speed for a task on which they could constantly (not by chance) achieve tasks at a certain level of success rate under time constraints. Thus if they succeeded in finishing the task within the time limit, that of the next task was reduced 5% (time pressure stricter), while if they failed to do so, that of the next task was extended 5% (time pressure became laxer).

2.2 Performance measures
The processing time for a task (time required to complete a task within a time limit) and the successful task rate (number of tasks completed within a time limit / number of submitted tasks) were measured as indexes of task performance to evaluate the effect of time constraints.

2.3 Indexes of mental workload
2.3.1 Subjective evaluation
Subjective rating of fatigue and NASA-TLX was used as a subjective evaluation of workload. The adapted weighted workload (AWWL) was calculated from six dimension rate scales related to mental workload. The AWWL was calculated by using the simplified method of NASA-TLX proposed by Miyake et al. (Miyake S. 1993)

2.3.2 Psycho-physiological index
HR, blood volume pulse (BVP) from the tip of finger were measured as indexes of mental workload.

2.3.3 Oxidative-stress maker
Plasma TBARS (thiobarbituric acid-reactive substances), plasma NOx (nitrite/nitrate), plasma SOD (superoxide dismutase) activity in blood and 8-isoporostane, NOx in the urine were measured as indexes of oxidative-stress maker.

2.4 Experimental Procedure
Informed consent was obtained from all subjects in written from after the experimental procedures had been fully explained. Subject required performing four 15 minutes task blocks after 5 minutes rest. Total task time was 60min. Subject required to attend a control experiment which included same procedure as load condition expect for the task replaced by watching the animation. NASA-TLX and subjective rating of fatigue were required after pre and post rest and each task.
Blood samples were collected after pre rest and each task for analysis of oxidative stress marker. Urine samples were collected before and after all tasks.

2.5 Statistical analysis
The test block differences in all indexes were tested by one-way repeated measures analysis of variance (ANOVA). Indexes of task performance data and subjective evaluation data were standardized within each subject by converting the z-score. Indexes of psycho-physiological mental workload data and oxidative stress data were standardized within each subject by rate of change from the pre rest values.

3. RESULT AND DISCUSSION

In this study, statistical significances are found in the processing time for a task (time required to complete a task with in a time limit), the subjective ratings of fatigue, HR, blood volume pulse (BVP) from the tip of finger, Plasma NOx, plasma TBARS in the blood.

3.1 The processing time for a task
The variation of processing time for a task (time required to complete a task with in a time limit) is shown in figure 2. Processing to time for a task significantly decreased between block 1 and 2, and stay constant after block 2. This change between block 1 and 2 might be affected by the learning effect. This result shows that learning process finished in the first block. It indicates that the task demand balanced with the subject capacity after test block 2. The constant time pressure could be loaded to subjects by use of this original task in this study.

3.2 The indexes of mental workload
The changes of AWWL score of NASA-TLX is shown in figure 3. The change of AWWL score of NASA-TLX is not significant, but it can be shown the increasing trends until test block 3 in control condition. Figure 4 shows the change of subjective rating of fatigue. The change of subjective rating of fatigue in load condition is higher than control condition after test block 2 significantly.

Figure 5 shows variations of average instantaneous HR. Average instantaneous HR during the task show significantly higher values in the load condition. Interaction effect between test blocks and test condition is observed. Figure 6 shows the variations of blood volume pulse (BVP) from the tip of finger. Significant difference between the load condition and the control condition was observed. The downward trend (not significantly) would be observed in the both conditions. It would be the effect of stress caused by restriction of experimental procedure and measurements.

These indexes of mental workload are indicated that the mental workload loading by time pressure would be successful in this study.
Figure 2. The changes of processing to time for a task

Figure 3. The changes of AWWL score of NASA-TLX

Figure 4. The changes of subjective rating of fatigue
3.2 The indexes of oxidative stress

Figure 7 shows the variations of plasma TBARS. Interaction effect between the test blocks and the test conditions is observed in the Plasma TBARS. Downward trend was observed in the load condition compared to the control condition. Figure 8 shows the variations of plasma NOx. Plasma NOx in the load condition was higher than in the control condition significantly.

These results mean that the task with time pressure induced the decreasing of plasma TBARS and the increasing of plasma NOx. Plasma TBARS is an index of oxidative damage, in the other hand plasma NOx is index of NO$^+$ activity. In the oxidative stress model proposed by H. Cai and D. G. Harrison (2000), oxidative stress effect will be determined by the balance between the production of reactive oxygen species (ROS) and activity of NO$^+$. The result in this study would be indicated that oxidative stress enhancement by mental workload could be controlled by the activation of NO$^+$ caused by time pressure (mental workload). The activation of NO$^+$ is considered to be a protective response from oxidative damage.

The degree of mental workload in this study might be not so severe estimated from NASA-TLX result. Short-term mild mental workload would activate a protective response against oxidative damage.
The indexes of oxidative stress were compared between under the condition with time pressure and without time pressure to investigate whether the indexes of oxidative stress can be used as an index of mental workload or not. The mental workload loading by time pressure would be successful in this study. The task with time pressure induced the decreasing of the plasma TBARS and the increasing of plasma NOx. In the short-term mild mental workload, oxidative stress enhancement by mental workload could be controlled by the activation of NO as a human protective response from oxidative damage.

These results indicate that there is higher possibility to use oxidative stress as an index of mental workload. However, it should be considered the balance between the production of reactive oxygen species (ROS) and activation of NO as a human protective response from oxidative damage.

4. CONCLUSION
5. REFERENCES


