P300 and Vigilance Level of University Student Under Hot and Humid Condition

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Abstract

The purpose of our study is to contrast the P300 and vigilance indicator in hot and humid condition. Sixteen participants performed this experiment. The participants are university students with nationality Japanese (eight participants) and Indonesia (eight participants). Indonesia participants conducted four experimental conditions: standing position and natural condition (without Air Conditioning and fan), standing position and used a fan, standing position and used Air Conditioning, and sitting position and used Air Conditioning. Japanese participants conducted only one experimental condition (standing position and natural condition (without Air Condition (without Air Conditioning and fan). P300 and vigilance indicators were measured before and after the given task. Event-Related Potential (ERP) P300 and Psychomotor Vigilance Task (PVT) were accommodated for P300 and vigilance indicators. According to the measurements, the task performances of the Indonesia participants among interaction between the subjects and the contrasting conditions were significantly different in ERP P300 latency (p<0.05), ERP P300 potential (p<0.05), and mean reaction time of PVT (p<0.05). On standing position and natural conditioning, P300 and PVT were not significantly different by nationality (Indonesia and Japanese students). Results showed that high temperature and humidity in the Japan summer season decreased P300 and vigilance, particularly for natural conditions.

1. Introduction

The summer season (June - September) in Japan is hot and humid. In summer 2019, Japan Meteorology Agency (Hamamatsu WMO Station ID:47654 Lat $34^{\circ}42.5$ 'N Lon $137^{\circ}43.1$ 'E) reported 25.6 ± 2.3 °C for average air temperature and 79 ± 5 % for average relative humidity (Japan Meteorology Agency, 2019). The highest temperature was 32.1° C in August 2019. For students who are from Indonesia with a comfortable temperature range $20 - 26^{\circ}$ C, and relative humidity maximum $60 \pm 5\%$ (SNI 6390:2011) (The National Standardization Body of Indonesia, 2011), the heat and humidity in Japan may be difficult to adapt and keep the performance. Still, with the use of Cooling Systems (Fan or Air Conditioning), it is possible to avoid heat and discomfort. The use of Air Conditioning in early hours sleep can protect sleep and thermoregulation (Okamoto-Mizuno 2004).

According to the previous studies (Roelofsen, 2002; Lan *et al.* 2010) have shown that human performance and productivity shows a significant relationship to thermal condition. Investigating the relationship between indoor thermal and human performance needs considering many factors: education, skills, genders, circadian cycle, emotional states, response bias, speed, accuracy, etc. (Lan and Lian 2009; Wickelgren 1977). Study on integrating speed and accuracy, Lan *et al.* (2010) mentioned the decrease of task performance due to thermal discomfort.

A few pieces of research have been done on changes such as human cognitive performance due to changes in sleep quality and the thermal environment. By examining the relationship between the sleep variables, thermal environment, and human cognitive performance, it will be useful for controlling the thermal environment, which is necessary for better cognitive performance (P300 and vigilance) in the next day. The aim of this study was to investigate P300 and vigilance levels with different cooling systems and positions.

2. Methods

2.1 Participants and Controlled Condition

Eight-man healthy volunteers with nationality Indonesia (age of 28 ± 4 years) participated in the experiment. Indonesia participants are students at Toyohashi University of Technology (2 undergraduate students, six graduate students). For analysis in a natural condition, eight-man healthy volunteers with nationality Japanese (age of 22 ± 1 years, two undergraduate and six graduate students) also participated in the experiment.

The participants did the experimental measurement in the building energy laboratory. The participants were presented with four different conditions:

- 1. Condition 1: Standing position, without Air Conditioning and fan
- 2. Condition 2: Standing position, with a fan
- 3. Condition 3: Standing position, with Air Conditioning
- 4. Condition 4: Sitting position, with Air Conditioning

For condition 3 and 4, participants set the Air Conditioning with a range of 20°C-26°C (Indonesian comfort standard).

2.2 Procedure

The day before the experimental day (part two), participants came to the laboratory, got a full explanation about the procedure experiment, and received a set device for the night before the experimental day (part one). In experimental steps (Figure 1), participants came to the laboratory and did the procedure of the experiment. Physiological measurements were made by measuring skin surface temperature and body weight. The skin surface temperature was measured by attaching probes for skin temperature measurement (LT ST0812 made by Gram Co., Ltd.) with surgical tape to the skin surface of the subject, and attaching the probe to a skin thermometer (LT 8A made by Gram Co., Ltd.). The skin temperature was measured with reference to Hardy Dubois's 7-point method (Figure 2 (a)): forehead, chest & back, upper arm and back of the non-dominant hand, thigh, lower leg and foot of non-dominant side (Ramanathan 1964). The body weight loss due to exercise from the measured weight. Cognitive measurements were examined by ERP P300 for decision-making level and 5 minutes PVT (Reaction Time Monitor PVT-192, CWE Inc.) for vigilance level. Participants did cognitive measurements before and after the task. For the main task (activity simulation), the respondent calculated the 30-Row Kraepelin test with a one-minute break in the middle (total = 31 minutes).





2.2.1 ERP P300

The electroencephalogram (EEG) of ERP was measured using a micro DAQ terminal (intercross 413, manufactured by Intercross). The measurement points were at three scalps location (Frontal Zero: FZ, Central Zero: CZ, and Parietal Zero: PZ) according to the international 10-20 system method (Figure 2 (b)). Psychological aspects of P300 were described clearly in previous research. Attention, Perception, Prediction, and Reaction are cognitive aspects that possible measures with ERP P300 (Picton 1992). In order to recognize the P300 wave, the minimum recording

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montage would therefore involve at least three scalp locations (Fz, Cz, and Pz) (Picton 1992; Alvarado-González et al. 2016).

The EEG was measured with a dry electrode, the earlobe was used as a reference electrode, and the Conductive and Adhesives Ten20 (Weaver and Company) was used as a ground electrode. The measured EEG was sent to a personal computer via a Bluetooth line at the micro DAQ terminal and recorded using the EEG measurement software "DAQ Master." The sampling frequency for EEG measurement is 1000 Hz. The brain wave was recorded with the filter set to 0.5 Hz and the low-pass filter set to 40 Hz. For the measurement of P300, a sound stimulus generator (intercross 511) was used. The sound stimulus generator and the micro DAQ terminal were connected with a cord, and the trigger of the sound stimulus was measured. At the time of P300 measurement, the earphone was connected to the sound stimulus generator, and the subject listened to the sound. Hardy Dubois' 7-point method and 10-20 system positioning are explained in Figure 2.



Figure 2. Hardy dubois' 7-point method (a), 10-20 system positioning (b).

P300 is one of the most studied ERP components for a level of decision-making measurement (Martín 2012), and it usually emerges in the late period after the stimuli onset (300 - 600 ms). In the relevancy of task, the amplitude of P300 is generally considered memory load representation (Polich 2007). The amplitude of the P300 wave becomes smaller, and the P300 latency becomes longer when the task of discriminating the target stimulus from the standard stimulus becomes difficult (Picton 1992). P300 is one of the event-related potentials generated in EEG. The eventrelated potential is a phenomenon in which the potential of the brain changes over time due to an external or internal event. P300 is named because the change of EEG occurs after 300 ms. In this study, we performed an oddball paradigm task using a sound stimulus to induce P300. The non-target stimulus was 1 kHz, and the target stimulus was 2 kHz. The appearance frequency was set to 70% for the non-target stimulus and 30% for the target stimulus. The appearance interval of the sound stimulus was 1.5 s, and the task was terminated when the sound stimulus appeared 100 times. The subject was instructed to press the button of the sound stimulus generator as soon as the target stimulus sounded then focused on the task. In addition, during the assignment, the subject was stared at the cross point installed on the wall so that the noise of the eye movement less appears on the EEG. From the measured brain waves, event-related potential extraction software (DAQ Analyzer Intercross) was used to extract and analyze only the brain waves at the timing of presenting the target stimulus. The extraction time is a section of -0.1s - 0.7s of the target sound stimulus, and the analysis used data of 0.1s - 0.5s.

2.2.2 PVT

PVT is generally used measure of behavioral alertness due to a combination of sleep deprivation and psychometric advantages compared to other cognitive tests (Lim and Dinges 2008). PVT is a test to measure the simple reaction time (RT) on a stimulus that appears at random inter-stimulus intervals (ISI). The stimulus on PVT-192 is a red number on the screen. In many applications, the ISI varies randomly from 2 to 10 seconds. The standard test time is 10 minutes. However, the 5-minute test can also be an alternative with the same performance results (Loh *et al.* 2004). In this test,

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participants are asked to respond to the stimulus rapidly. Button presses when the counter is not displayed on the screen are counted as false starts.

2.3 Statistical Analysis

This study uses two main tools to answer the research objectives. ERP P300 produces data output Latency (ms) and Amplitude (μ V). PVT produces output time-reaction (ms) average data and slope of reciprocal reaction-time across the test. For Indonesia nationality, the results of ERP P300 and PVT were subjected to analysis of variance (ANOVA) [Before/After (2) x Controlled Condition (4)]. For Indonesia and Japanese nationality, the results were subjected to t-test analysis.

3. Results and Discussion

3.1 Thermal Condition

In an experimental room, four controlled conditions reached different statuses, both for Temperature (T) and Relative Humidity (RH). Temperature, Relative Humidity, and Mean Skin Temperature for every condition were $31.4 \degree C \pm 0.2 \degree C$; $64 \% \pm 0.8 \%$; $34.5 \degree C \pm 0.5 \degree C$ (Condition 1), $31.8 \degree C \pm 0.1 \degree C$; $59.2 \% \pm 0.6 \%$; $34.6 \degree C \pm 0.5 \degree C$ (Condition 2), $24.6 \degree C \pm 0.2 \degree C$; $53.0 \% \pm 0.3 \%$; $33.4 \degree C \pm 0.4 \degree C$ (Condition 3), and $24.6 \degree C \pm 0.1 \degree C$; $56.8 \% \pm 1 \%$; $33.3 \degree C \pm 1.3 \degree C$ (Condition 4). Temperature between conditions 1, 2 (without Air Conditioning), and conditions 3, 4 (Air Conditioning) was significantly different (see Figure 3).



Figure 3. Average temperature and relative humidity experimental room.

3.2 ERP P300

The average of components P300 (Fz, Cz, Pz) was analyzed. The average of components P300 wave evoked at approximately 395 ± 32 ms for latency and $23 \pm 5 \,\mu$ V for potential after stimulus appears. Figure 4 and Figure 5 shows the average transition of a participant P300 measurement points obtained by EEG measurement.

As a change due to task (before and after measurement), there was no difference in brain waveform (potential and latency) before and after the task was observed at four conditions. On the other hand, at condition 1 (standing position and without Air Conditioning and fan), the brain waveform after the task had an overall (Fz, Cz, and Pz) smaller than that prior to the task for potential and taking longer time prior to task for latency. The potential and latency are smaller and later, respectively, when the task was becoming more difficult. Moreover, there is no difference between the two nationalities (Indonesia and Japanese) in condition 1.

Based on ANOVA results, the interaction between subjects (eight participants) and different condition (four conditions) were significant for both potential (F (7.3) = 4.96, p<0.05) and latency (F (7.3) = 2.97, p<0.05). The possibility of this condition, the participant performed the task in hot condition (without Air Conditioning and fan) that felt hard to concentrate. In older adults and under specific condition groups, heat-stress may have effects harmful on cognitive function (Trezza et a; 2015). Furthermore, Wang *et al.* (2015) reported that P300 latency and amplitude evoked latter and smaller in ambiguity conditions than risky conditions. The results showed that participants met

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higher working memory under ambiguity. Figure 4 shows Grand Average of Latency and Potential P300, while Figure 5 shows P300 Latency and P300 Potential.



Figure 4. Grand average of latency (a), potential P300 (b).



Figure 5. P300 latency (a), P300 potential (b).

3.3 PVT

The 5 minutes PVT was measured before and after the task. From the previous study, the 5 minutes PVT may provide an alternative for the 10 minutes PVT (Loh *et al.* 2004). The results of PVT represent differences in the sleepiness level. The interaction between subjects (eight participants) and condition (four conditions) (F(7.3) = 2.68, p<0.05), between subjects (eight participants) and time (before and after) (F(7.1) = 6.95, p<0.05), and between condition (four conditions) and time (before and after) (F(3.1) = 4.54, p<0.05) were significant. Figure 6 shows factorial plot of Indonesian students PVT interaction and plot of Indonesian and Japanese students PVT.



Figure 6. Factorial plot of indonesian students PVT interaction (a), plot of indonesian and japanese students PVT (b).

4. Conclusion

Based on the P300 and vigilance level, the present research shows that in condition 1 (without Air Conditioning, there is no difference in two nationalities (Indonesia and Japanese). Furthermore, ERP P300 latency (p<0.05), ERP P300 potential (p<0.05), and reaction time of PVT (p<0.05) were significantly different in interacting between different subject and the contrasting conditions for Indonesia students. The oddball auditory of the P300 wave recorded from a peak is smaller and later in discomfort condition (condition 1, standing position, without Air Conditioning and fan). The reaction time (vigilance indicator) of the PVT showed later in more comfort conditions (condition 3 and 4). Further research is needed to explore the variety condition for Japanese nationality and the relationship of sleep quality and performance for both nationalities.

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