JESK J Ergon Soc Korea 2015; 34(2): 191-198
http://dx.doi.org/10.5143/JESK.2015.34.2.191
http://jesk.or.kr eISSN:2093-8462

Sitting Posture-Based Lighting System to Enhance the Desired Mood

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Received : March 31, 2015
Revised : April 01, 2015
Accepted : April 03, 2015

Objective: As a cue for desired mood, we attempted to identify types of sitting postures when people are involved in various tasks during their working hours.

Background: Physical behaviors in reaction to user contexts were studied, such as automated posture analysis for detecting a subject's emotion. Sitting postures have high feasibility and can be detected robustly with a sensing chair, especially when it comes to an office.

Method: First, we attached seven sensors, including six pressure sensors and one distance sensor, to an office chair. In Part 1, we recorded participants' postures while they took part in four different tasks. From the seven sensors, we gathered five sets of data related to the head, the lumbar, the hip, thigh pressure and the distance between the backrest and the body. We classified them into four postures: leaning forward, upright, upright with the lumbar supporting, and leaning backward. In part 2, we requested the subjects to take suitable poses for the each of the four task types. In this way, we compared the matches between postures and tasks in a natural setting to those in a controlled situation.

Results: We derived four types of sitting postures that were mapped onto the different tasks. The comparison yielded no statistical significance between Parts 1 and 2. In addition, there was a significant association between the task types and the posture types.

Conclusion: The users' sitting postures were related to different types of tasks. This study demonstrates how human emotion can interact with lighting, as mediated through physical behavior.

Application: We developed a posture-based lighting system that manipulates the quality of office lighting and is operated by changes in one's posture. Facilitated by this system, color temperatures ranging between 3,000K and 7,000K and illuminations ranging between 300lx and 700lx were modulated.

Keywords: Sitting posture, Office environment, Office lighting, Desired mood

1. Introduction

As reportedly by Miller and Brown (2004), workers make sitting postures for an average of 4.9 hours per weekday. This occupies roughly 62.5% of their daily working hours; consequently, a considerable number of studies have paid attention to observing the shapes of sitting poses. Sitting posture is one of the strongest components of exposure to risk of musculoskeletal injury in the office (Dowell et al., 2001). Therefore, studies have mainly pointed out orthopedic problems and the consequences of health problems. For example, Babski-Reeves et al. (2005) showed that one common postural problem is cervical pain, which is becoming more prevalent because of the increasing use of computers. Office workers are exposed to awkward postures because prolonged static poses of the neck and body, whereas the upper limbs require dynamic working. Moreover, Moore (2004) and Caneiro et al. (2010) said that forward head posture while sitting can lead to muscular skeletal disease, such as upper-crossed syndrome. On the other hand, sitting postures can be detected robustly with a sensing chair and has high feasibility, and Dowell et al. (2001) show that sitting postures can be affected by task types (Mutlu et al., 2007). Moreover, as a cue of desired mood, physical behavior in reaction to user contexts or emotions has been studied, such as through automated posture analysis to detect the subject's interest level (Mota and Rosalind, 2003). In this regard, we aim to examine the feasibility of sitting postures as a cue of desired mood and ultimately develop an applied system to improve the quality of daily life.

In particular, we propose a posture-based lighting system focusing on office environments that provides optimal lighting quality for different user contexts. By extending the role of lighting, the lighting system-facilitated by LEDs (light emitting diodes) can easily control its illumination and color temperature, offering users a wide possibilities of desirable lighting environments. Thus, efforts are currently underway to investigate the optimal lighting environment to enhance task productivity and emotional satisfaction. For example, some studies have been conducted to determine the proper lighting for educational situations (Lee et al., 2013; Wessolowski, 2014). Previous studies have revealed and replicated that higher color temperatures serves attentive tasks better, such as matching quizzes, while lower color temperatures are better for social activities. In this regard, we intended to find an optimal match between the sitting posture and lighting to create a coherent mood, focusing specifically on an office environment.

2. Method

In order to obtain the quantitative data on people's different sitting postures during their working hours, we planned an empirical study by attaching sensors to an office chair. Differently from thorough studies on human ergonomics, we tried to reduce the number of sensors as much as possible while minimizing the loss of meaningful data. Moreover, we also intended to find a synergetic match between the types of posture and types of tasks. Finally we anticipated mapping out appropriate lighting content, as unconsciously modulated by one's sitting postures.

2.1 Participants

A total of 10 college students participated, with an average age of 21.50 years (SD = 1.78 years). Their average height was 167.30cm, and their average weight was 59.20kg; both genders were evenly recruited. In order to prevent abnormal sitting postures caused by poor eyesight, we acquired participants with eyesight scores higher than 0.7 by pre-investigation. Also, the participants had never received treatment for neck, shoulder, leg or arm pain.

2.2 Experimental setup

The experimental room was set up to resemble an office environment. Sitting postures on the office chair were observed while the participants were taking part in the given tasks presented on a computer monitor (Figure 1). To identify the postures, we attached six pressure sensors and one distance sensor to an office chair. To find relevant locations for the sensors, we referred to the related research (Park et al., 2012) and then covered the chair with cotton fabric (Figure 1). While a participant was sitting, we received signals from their head, lumbar and hip, as well as for thigh pressure and backrest-body distance at every 5Hz. We transformed the signals into manageable data by utilizing Arduino Processing. In addition, to measure the body angle, markers were attached on the participants' shoulder, hip and knee joints, and the side views were recorded. The monitor was set to the center of the participants, and the distance between the monitor and the eyes was 50cm. The chair's height was adjusted depending on the participant's height, in order to keep a 90-degree knee angle. To reduce the influence of lighting, the experiment was conducted under a constant illuminant (5,000K, 600lux).

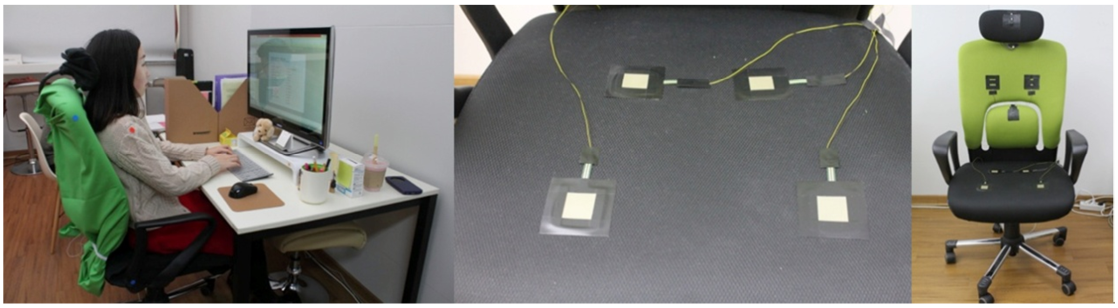

Figure 1. Experimental environment and sensor-equipped office chair

2.3 Experimental procedure

The empirical study involved two steps. In Part 1, we observed the participants' unconscious postures while they were working on the following four tasks: (1) memorizing words, (2) playing game-Tetris®, (3) reading magazine articles, and (4) relaxing. Memorizing words represented strong attention with high workload, while playing Tetris® was considered to require attention but low workload. Also, reading simple articles was associated with medium levels of concentration and workload. As reading material, we provided six articles that were not too informative. Finally, relaxing was expected to release the participants from any types of tasks, and the participants listened to meditation music. Each task took seven minutes until completion, and the tasks were given in random order (Figure 2). In Part 1, the participants were not informed that their posture was being recorded. In Part 2, on the other hand, the purpose of the experiment was revealed. The participants were asked to consciously take postures that best fit the given task type. They sat in different positions for approximately 10 seconds each, and the request was repeated three times in random order (Figure 2).

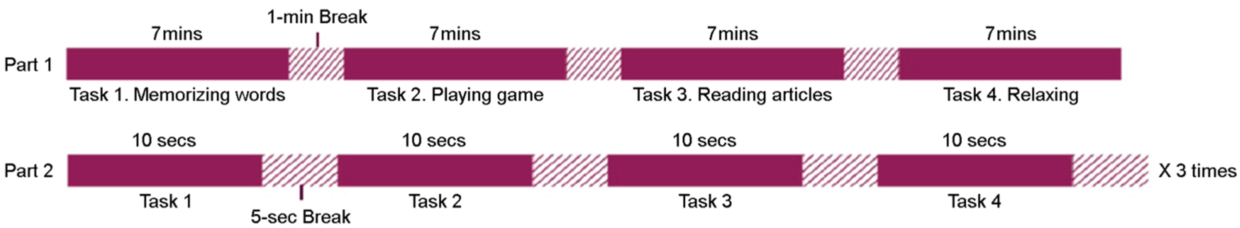

Figure 2. Experimental process of Parts 1 and 2

3. Results and Analysis

3.1 Data extraction

After having collected the data from both Parts 1 and 2, we focused on the replicated postures that appeared consistently. In Part

1, when the participants maintained a certain posture for longer than 30 seconds, it was considered as one posture. We cropped out a 15-second segment from the middle of the posture and then averaged segments for each sensor value. Finally, a total of 45 segments (observed postures that were maintained for longer than 30 seconds = 45) were collected from Part 1, which became the unconscious sitting postures (Figure 3). In Part 2, we applied an identical method but only observed the postures for 5 seconds each. Since we requested that the participants pose three times, we collected a total of 15 seconds in segments and then averaged them for each sensor value. Therefore, 40 segments (4 tasks × 10 participants) were collected from Part 2, which became the conscious sitting postures (Figure 4).

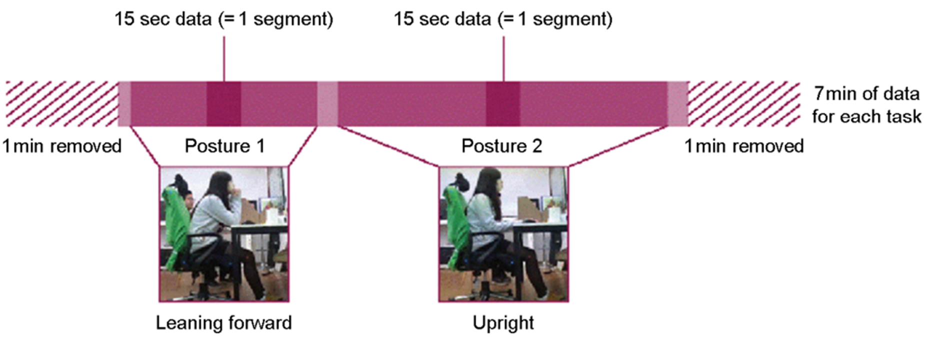

Figure 3. Process of extracting data from Part 1

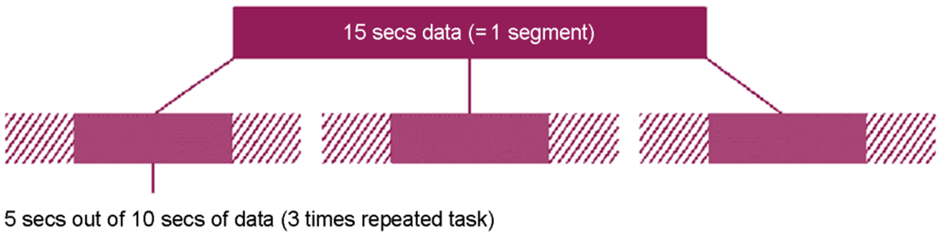

Figure 4. Process of extracting data from Part 2

3.2 Classification of sitting postures based on the sensor values

We classified the total of 85 extracted posture segments into four kinds of postures: (P1) leaning forward (under 85 degrees), (P2) upright (between 85 and 95 degrees), (P3) upright with the lumbar supporting, and (P4) leaning backward. We distinguished (P2) from (P3) because of different range of lumbar pressures. Furthermore, to confirm the statistical difference between the posture types, we used one-way independent ANOVA based on the sensor values of each posture. The analysis yielded statistical significance [$F(3,81) = 22.033$, $p < .05$], indicating that each posture can be profiled with noticeable differences. For example, the backrest-body distance was significantly greater than for the other postures while the participants were leaning forward. While upright with the lumbar supporting and leaning backward, the lumbar pressure was significantly higher than for the other postures. Subsequently, all 85 segments from the observed postures could be classified into four posture types (Figure 5).

In addition, Figure 6 illustrates the flow of the signal processing to sort out the sensor signals into the corresponding postures.

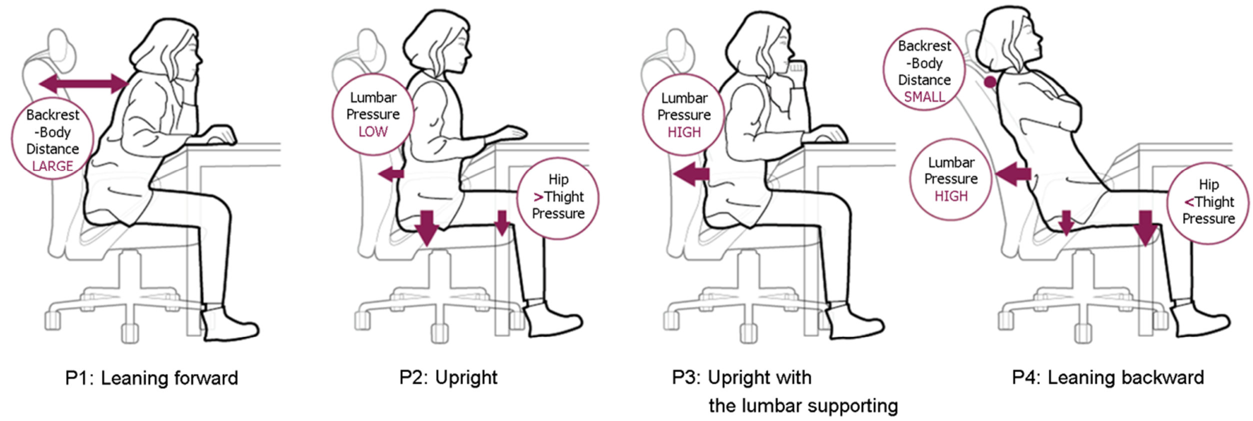

Figure 5. Posture classification process and criteria

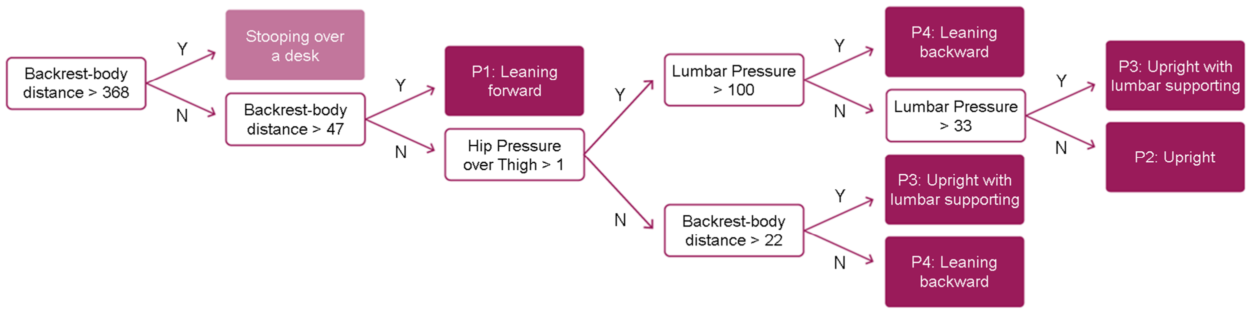

Figure 6. Process of signal to be corresponded to one of the four posture types

3.3 The relationship between postures and tasks

Next, we tried to explore whether the postures could represent the user's task. A chi-squared test was conducted to compare the frequency of observed posture types depending on unconscious or conscious tasks. Differently from anticipated, the difference between the unconscious postures in Part 1 and the conscious postures in Part 2 did not show a statistical significance at an alpha level of 0.05 in each task. Therefore, the sum of the posture frequencies from both parts was used for statistical analysis (Table 1).

Table 1. Posture frequency depending on task type

	P1	P2	P3	P4
(1) Memorizing words	11	6	3	3
(2) Playing Tetris®	7	7	5	2
(3) Reading articles	4	5	11	2
(4) Relaxing	0	0	2	20

The results indicate that postures are influenced by the task. There was a significant association between the task types and the posture types [χ^2 (9, N = 85) = 62.087, p < .05]. The leaning-forward posture was most frequently observed while the participants were memorizing words. While playing a game, the leaning-forward and upright postures were equally dominant, whereas the upright posture with the lumbar supporting was quite frequent when reading articles. In addition, while relaxing, the frequency of the leaning-backward posture was much higher than the other postures. That is, people unconsciously and consciously lean forward when working intensively, but lean backward while relaxing.

4. Discussion

4.1 General discussion

This empirical study showed that sitting postures could be classified in posture types based on signals. Also, the sitting postures appeared at different rates, related to the concentration level of the work. Since the postures reflect the users' states, they can be used in a novel lighting control interface. To some disappointment, there was weak similarity between the unconscious and conscious postures in memorizing words, out of the four task types. It could be assumed that intensive work caused some tiredness, which made the posture tendencies inconsistent. As such, accurate and stable sensor signals should be collected to make a more reliable posture-sorting algorithm. Also, more in-depth studies would be worthwhile to investigate the relationship between sitting postures and task types.

4.2 Application of posture based lighting system

Finally, we developed a posture-based lighting system that manipulates the quality of office LED lighting based on changes in one's posture (Figure 7). Previous studies have revealed there are optimal combinations of color temperatures and correlated illuminations that can enhance people's affective experience. They demonstrated that higher color temperature (7,500K versus 3,000K) is more activating for mental level (Deguchi and Sato, 1992), while low-color-temperature lighting lowers central nervous system activity (Noguchi and Sakaguchi, 1999). In addition, the efficiency of learning increases under high color temperature and high illuminance lighting, whereas the lighting of low color temperature and low illuminance was proper for relaxing (Lee et al.,

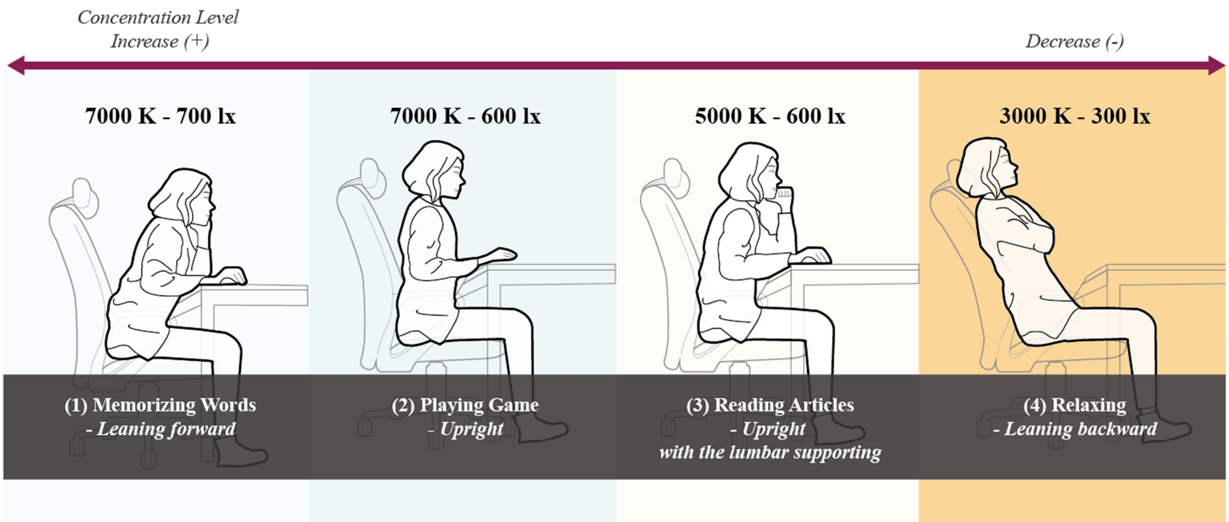

Figure 7. Four scenarios for a posture-based lighting system

2013; Wessolowski, 2014). Consequently, users need a high color temperature, high illuminance lighting condition for activities requiring concentration; on the other hand, low color temperature, low illuminance lighting is suggested for relaxation.

From previous studies and a real demonstration using a high-rendering LED in a room with ambient lighting, the modified illumination ranges between 300lx and 700lx, while the correlated color temperatures range between 3,000K and 7,000K. After real-time posture classification by Arduino Processing, color temperature and illuminance of LED lighting can be adjusted to offer the desired mood for users. Thus, optimal lighting presets for each task can be produced by one's posture. Four representative lighting scenarios were generated as follows: (1) for strong attention with a leaning-forward posture, 7,000K - 700lx lighting will apply; (2) for the attentive tasks, such as playing a game, with upright posture, 7,000K - 600lx lighting will apply; (3) for a medium level of concentration in daily life, like reading, 5,000K - 600lx will apply; and (4) for relaxation, 3,000K - 300lx lighting will apply. Ultimately, this system might increase the intuitiveness and unobtrusiveness of lighting control interfaces for office environments. Furthermore, a more accurate posture classification algorithm should be developed with a larger number of participants. Also the verification experiment will be conducted in these posture-based lighting scenarios.

5. Conclusion

This study investigates the feasibility of posture classification based on a simple sensor-equipped chair. The experiment showed that users' postures are related to the different concentration levels of tasks. Also, there was no significant difference between unconscious and conscious sitting postures during identical tasks. A wide range of possible automated indoor lighting systems to provide a desired mood using sitting postures was explored. The empirical findings of this research can be utilized for interactions between human emotion and lighting, mediated through physical behavior.

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