Study on the Effect of the Ambient Temperature toward the Quality of Sleep

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Article Info	ABSTRACT
	Getting enough sleep at the right times can help in improving quality of life and protect mental and physical health. This study proposes a portable sleep monitoring device to determine the relationship between the ambient temperature and quality of sleep. Body condition parameter such as heart rate, body temperature and body movement was used to determine quality of sleep. All readings will be log into database so that users can review back and hence analyze quality of sleep. The functionality of the overall system is designed for a better experience with a very minimal intervention to the user. The simple test on the body condition (body temperature and heart rate) while asleep with several different ambient temperatures are varied and the result shows that someone has a better sleep for the temperature range of 23 to 28 degree Celsius. This can prove by lower body temperature and lower heart rate.

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1.   INTRODUCTION

Sleep is a type of "brain activity" that help to recover from brain fatigue [1]. Good sleep quality can contribute in many positive outcomes that helping a person to go through their day time activity [2]. When someone asleep, some of the measurable body condition such as heartrate, temperature, body movement and respiration rate are varied [3]. This parameter can also be used to determine some of the sleep abnormality including sleep apnea [3], [4]. The duration of without interrupt periods of sleep can be used to investigate the sleep continuity. To measure the movement of body during sleep stage, movement time (MT) and movement events (ME) are two important parameters to be measured.

Nowadays, there are many existing procedures and methods to measure the quality of sleep that use several different types of sensor and measurement to indicate the sleep stages. Polysomnography (PSG) for an example is used to measure the physiological variables including brain electrical activity, muscle movement respiratory effort and oxygen saturation [6]. Through this technique, researchers can identify sleep-onset and wake-up time [7]. A device must be worn on the wrist of user during sleep to measure their activity. The device must be placed on the user's wrist because it is believed that there is a strong connection between wrist movement and sleep status of the user [8]. The other method that is available is the use of video and audio recording together with Passive Infra-Red (PIR) sensor to detect the user sleep status [9]. The study in [10] presented a research on ambient sleep monitoring which using sensors that are installed

inside living apartments. The type of sensors that had been used in this study include passive infrared (PIR) sensors as motion detection, contact sensors that had been attached to the windows and doors, temperature sensors to detect room temperature and sensors that can detect heat application usage and electricity.

In this study, our focus is to illustrate the relationship between temperature and sleep quality and for that purpose, the use of PC instead of smartphone is preferable because while we are in sleep, we did not require too much of mobility ergo PC with higher processing capability is more suitable than smartphone that allowing user to do a lot of processing and video recording. The developed sleep monitoring system is a combination of sensors and BLUNO microcontroller board to monitor and record the ambient parameters and body condition while user is sleeping. Our goal is to develop a sleep monitoring system that can be used at home and can do the monitoring in more than one night. Other than that, this monitoring system can help to determine the relationship of room ambient and quality of sleep.

2.   RESEARCH METHOD

Figure 1(a) shows the overview of monitoring system which is consist of room ambient system and body condition system. Ambient monitoring system equips with, thermistor, LDR and DHT22 sensors to measure room temperature, light intensity and humidity respectively while portable body monitoring system equips with thermistor, accelerometer and heart pulse sensor. The ambient sensors and body condition sensors are connected to BLUNO and BLUNO NANO respectively to capture the input data and the data will display on the Window Application interface as shown in Figure 1(b). In this system, the room temperature, light intensity and humidity is the input for ambient sensor hence to measure heart rate, the pulse sensor is simply attach anywhere near to the blood vessel. The audio video recording is also capable by the system as it can be used to monitor the behavior of user during sleep. The development of the sleep monitoring system and the validation of each of the sensor use has been describe in [5].

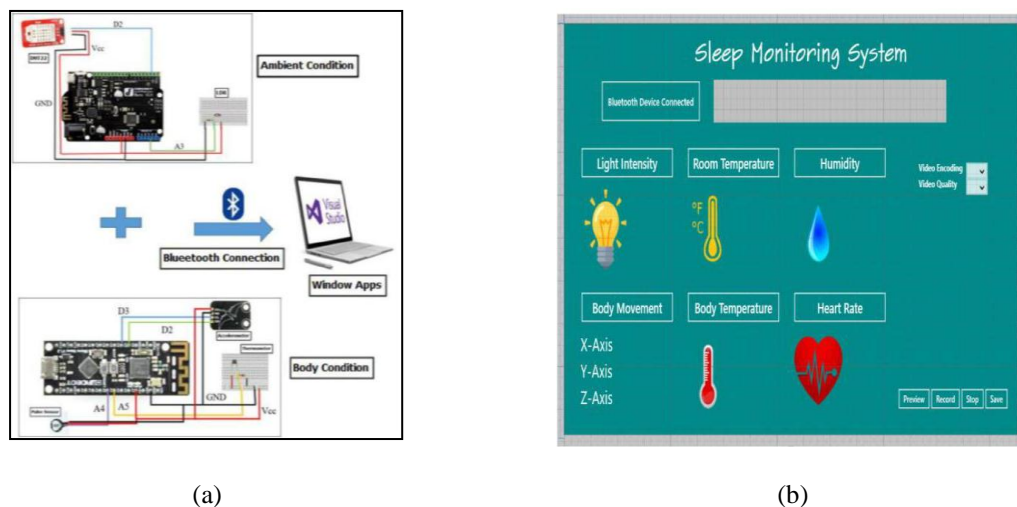(a)   (b)

Figure 1. (a) The overview of hardware system and (b) is user interface of developed Window Application

Arduino IDE is programmed that consist of sensor algorithms to enable those sensors and to read the value that has been captured by each of room ambience system and body condition system. An application for PC was programed by Visual Studio to display the value of those parameters as can be seen in Figure 1(b). The sensor value is transferred between hardware part and software part via Bluetooth communication. The video recording using a webcam also included in this project. All the data that collected from two systems will be logged into MySQL database. This is enabling the user can view back the changes in body parameter during sleep stage. By this feature, user can console doctor to help them to analysis their sleep pattern.

The value of light intensity is obtained based on the digital value with a range between 0 and 1023. Based on the study done in [11], value of light intensity can be identified subjectively by five different level ranging from very dark (1 to 9) to very bright (501 to 1023). Value ranging from 10 to 20 is indicate dark

surrounding conditions, value 21 to 45 is indicated as dim condition and value ranges from 70 to 487 indicate bright surrounding.

The reading of room humidity was measured by using DHT22 sensor. The condition of room humidity can be subjectively separated into three category which are dry, medium or moist condition. The humidity reading for dry condition is ranging between 1 to 2% RH that indicates a dry condition during sunny day such as in the afternoon and in the evening. For the moderate condition, the measured reading is between 3 to 8% RH. The reading indicates medium humidity in several surrounding conditions, such as during raining. The reading of humidity is ranging between 13 and 32% RH which is referred to moist condition when there is raining for quite a long time and right after the raining when the temperature is low.

Temperature readings are divided into five different conditions which are very cold, cold, moderate, hot and very hot. Very cold conditions such as inside the room with air conditioner or during heavy rain in the midnight with the measured reading is recorded between 18 and 22 degrees Celsius. Cold condition has a range of temperature between 23 and 28 degrees Celsius. The reading for cold condition is obtained in early in the morning or right after a rain. The moderate condition has a range of temperature between 29 and 33 degrees Celsius. The reading is taken in the bedroom with a speed of fan 3 during the day or night. The temperature for very hot condition is between 37 and 40 degrees Celsius. The reading can be obtained outside the house in the afternoon or in the evening.

3.   RESULTS AND ANALYSIS

The experiment Set 1 and Set 2 had been done on 27th April 2017 and 28th April 2017 respectively. These two set of experiments are carried out to observe the effect of ambient temperature toward quality of sleep. Both experiments are carrying out in Bukit Beruang, Melaka, Malaysia. The weather Set 1 is good which with 31˚C room temperature and 7 %RH humidity which is in the moderate range. The lamp is turn off and just a little of light from outside is penetrated through the curtain that give the measure light intensity is in the dark range. Graph of the ambient parameters observation are shown as Figure 2 and Figure 3 for both set of experiments.
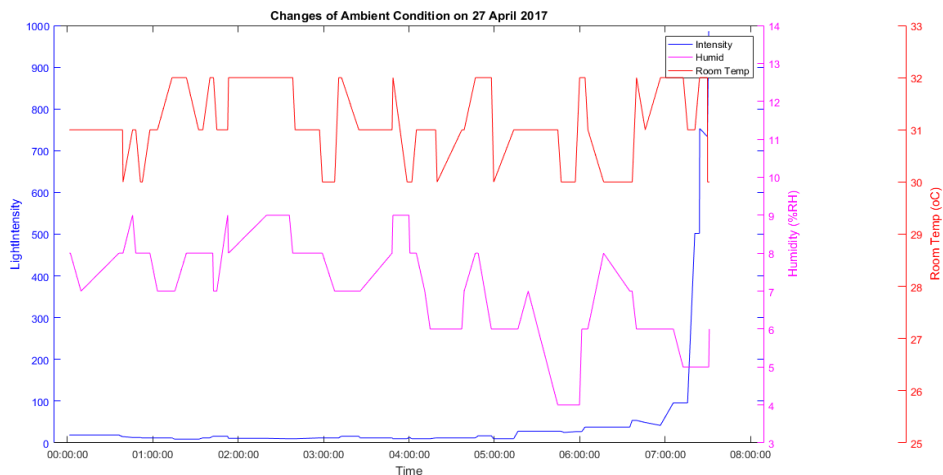

Figure 2. Changes in ambient condition in experiment Set 1

Ambient temperature for Set 2 is within the cold range which is between 23 to 28°C. At the beginning, the room temperature is normal which is 32°C but there is a small rain at midnight which make the temperature decrease until 26°C. Raining make the average room temperature become 28°C. The humidity and light intensity are maintained within the same range as in Set 1 condition.

Figure 4 and Figure 5 shows the changes of body condition in two nights that can be distinguished into several sleep stages. By observing the pattern from plotted graph, the sleep stage of Non-Rapid Eye Movement (NREM) and Rapid Eye Movement (REM) can be been determined. There are more changes of body movement during the transition stage but the body temperature and heart rate do not change much

during this stage. Then, there are some changes in heart rate and body temperature in next stage which is light sleep stage. The body temperature and heart rate are slightly decreased in this stage. Someone is difficult to wake up at this stage so the body movement did not change more. Next sleep stage is called as deep sleep stage. At this stage, the heat rate and body temperature become increase as blood supply to muscle increase. Someone is more potential to the surrounding disturbance so that fewer changes in body movement in this deep sleep stage. Other than that, someone will feel disoriented for several minutes if woken during this stage. Final sleep stage in one cycle is called as dream sleep stage and it is REM where the dream is occurred. At this stage, body temperature and heart rate will increase and more changes in body movement. The duration spent for each sleep stage had been analysis and compare with the normal duration sleep cycle and based on the duration of each sleep stage, the quality of sleep can be determined.

The comparison on changes of ambient condition and changes of body condition in each sleep stage had been summarized into Table 1 and Table 2. From the summary of result for both set of experiment, it shows that the suitable ambient condition for people to sleep better is in a cold environment. This conclusion is made based on the time spent for transition stage for Set 2 is only 12 minutes which is a normal time for a person to fall asleep while sample takes longer time to fall asleep in experiment Set 1. Dream sleep stage is the stage where the dream happens and normally only takes 90 minutes to 120 minutes after fall asleep. In experiment Set 2, it shows that sample only spends 1 hour and 28 minutes which in the good range while 2 hours in experiment Set 1 which is also in the good range as well. This shows that sample can sleep better in environment Set 2 rather than Set 1. Besides that, the time to complete one sleep cycle in experiment Set 2 is shorter than experiment Set 1.
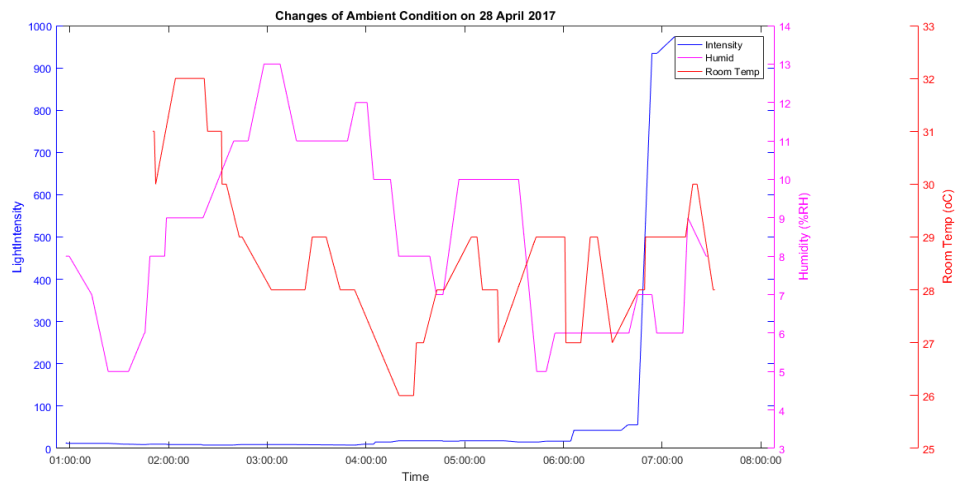

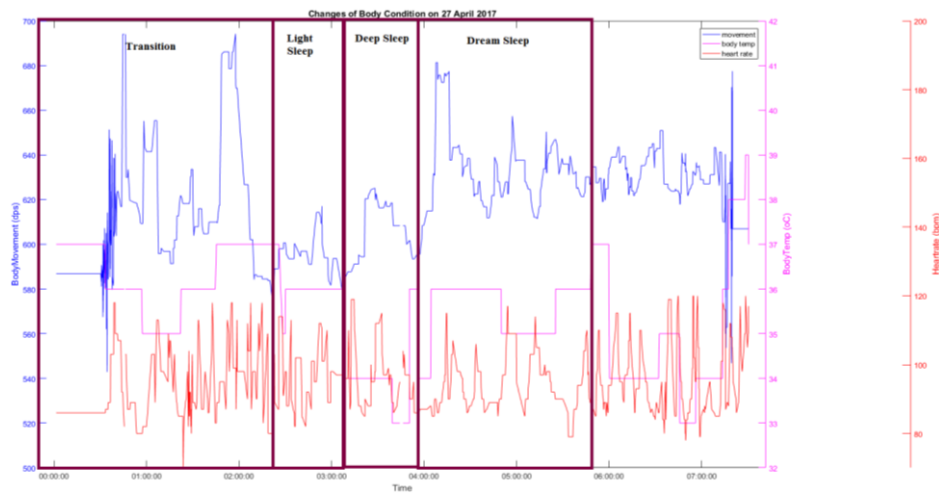Figure 3. Changes in ambient condition in experiment Set 2

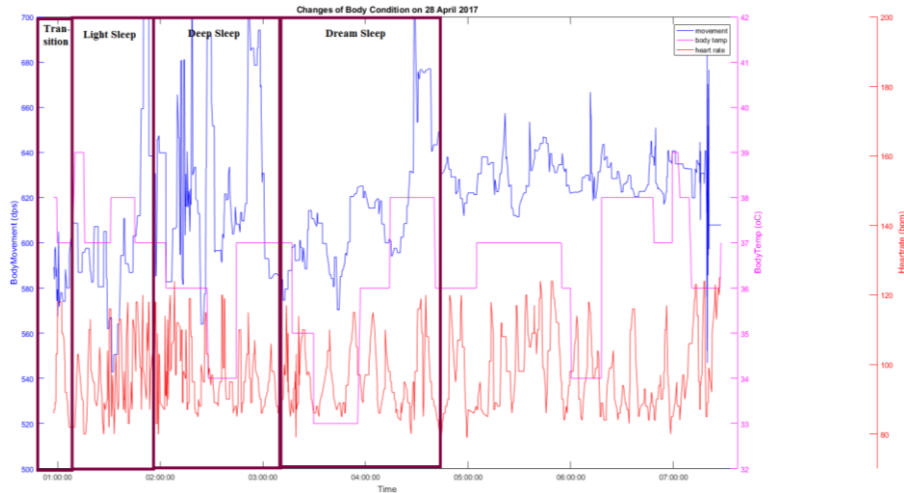Figure 4. Changes in body condition in experiment set 1

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Figure 5. Changes in body condition in experiment Set 2

Table 1. Summary of ambient condition data in experiment set 1 and 2

Parameter		Set 1	Set 2
Room Temperature	Maximum	32	31
(˚C)	Minimum	30	26
	Average	31	28
Humidity	Maximum	9	13
(%RH)	Minimum	4	5
	Average	7	8
Light	Maximum	986	974
Intensity	Minimum	9	8
	Average	153	188

Table 2. Summary of body condition data and analysis the sleep cycle in experiment set 1 and 2

Parameter		Set 1	Set 2
Body Temperature	Transition	35-37	37-39
(˚C)	Light Sleep	34-36	37-39
	Deep Sleep	33-36	34-36
	Dream Sleep	33-38	33-39
Heart Rate	Transition	91-114	82-118
(BPM)	Light Sleep	82-113	80-113
	Deep Sleep	85-119	85-124
	Dream Sleep	78-120	79-124
Body Movement	Transition	More	More
	Light Sleep	Less	Less
	Deep Sleep	More	More
	Dream Sleep	Less	Less
REM	Transition	0030-0228 (2 hours)	0057-0110 (12mins)
Sleep Cycle	Light Sleep	0230-0304 (44mins)	0110-0158 (48mins)
	Deep Sleep	0304-0353 (49mins)	0159-0312 (1hour 13mins)
	Dream Sleep	0353-0553 (2 hours)	0312-0440 (1hour 28mins)
Quality of Sleep		Bad	Good

4.   CONCLUSION

At the end of this project, a portable sleep monitoring system for ambience and body condition have been demonstrate. Based on the testing of the device toward the effect of the room temperature toward the quality of sleep shows that a person has a good quality of sleep in a cold condition range which is between 23 and 28 degrees Celsius. This showed that a person can easy fall asleep in a cold environment.

ACKNOWLEDGEMENTS

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