

Toward Good Circadian Rhythm through a valuate of Stress Condition

Ryo Takano[†], Sho Kajihara[†], Satoshi Hasegawa[†], Eiki Kitajima[†], Keiki Takadama[†],
Toru Shimuta[‡], Toru Yabe[†] and Hideo Matsumoto[‡]

[†]Graduate School of Informatics, The University of Electro-Communications, Tokyo, Japan

[‡]Murata Manufacturing Company, Ltd.

takano@cas.hc.uec.ac.jp, kajihara@cas.lab.uec.ac.jp, hasegawa@cas.lab.uec.ac.jp, kitajima@cas.lab.uec.ac.jp, keiki@inf.uec.ac.jp
t-yabe@murata.com, shimuta@murata.com, hmatsumoto@murata.com

Abstract

The final goal of this study is to implement a recommendation system for promoting health which judges the degree of stress and the degree of the health with less measurement and presents actions that will bring about appropriate health condition. To implement such a system, authors tried to find the knowledge on the relationship between circadian rhythm and stress. For this purpose, this paper proposes the method employing two indices ccvTP and LF/HF to evaluate the degree of stress. To combine of LF / HF and ccvTP can implement that not only the degree of stress but also the condition of stress is evaluated. In addition, the index showing the goodness of the circadian rhythm is employed the magnitude of the increase and decrease in the basal body temperature of each time zone. Such an index which evaluates the totally trend for each time zone can reduce the influence of the unexpected value such as noise. In order to verify the practicality of these indexes, this paper analyzes the data obtained by subject experiments by 4 adults. As a result, by comparing two types of data of ten-odd days in parallel, we obtained the finding that severe stress adversely affects the circadian rhythm after a few days.

Introduction

In this study, the final goal is to establish a recommendation system for promoting health. In order to achieve this goal, the authors have tried to reveal the relationship between a quality of sleep, a degree of stress, and a goodness of circadian rhythm [Takano, 2018]. As a result of this trial, the relationship between these data is becoming some apparent as the follows: (1) Three indices (the degree of stress, the quality of sleep, and the goodness of circadian rhythm) have been moving with a similar trend in units of

days; (2) the trends of these indices coincide details from the simple diary written by the subject. However, this is not enough that to realize the recommendation system and further analysis is indispensable. Because these indices representing the degree of stress and the goodness of circadian rhythm are insufficient. In this analysis, LF/HF was employed to express the degree of stress. In addition, the standard deviation of basal body temperature was employed as an index for evaluating the goodness of the circadian rhythm. These indicators may take unexpected values such as noise and cannot always be evaluated appropriately as the degree of stress and the goodness of circadian rhythm.

In this paper, in order to tackle the problem, the evaluation of the stress condition and the evaluation of goodness of circadian rhythm are improved for more detailed analysis. This paper employs the autonomic nervous activity level (ccvTP) as an additional index to evaluate the degree of stress. To combine of LF / HF and ccvTP can implement that not only the degree of stress but also the condition of stress is evaluated. In addition, the index showing the goodness of the circadian rhythm is employed the magnitude of the increase and decrease in the basal body temperature of each time zone, not the standard deviation of the basal body temperature. Such an index which evaluates the totally trend for each time zone can reduce the influence of the unexpected value such as noise. Furthermore, in order to verify the practicality of these indexes, this paper analyzes the data obtained by subject experiments. This data is consisted on numerical values (ccvTP, LF/HF and basic body temperature) and simple diaries in about 2 weeks for 4 adults. The degree of stress and condition, goodness of circadian rhythm is evaluated from these data and are analyzed these two relationships. Finally, the analysis

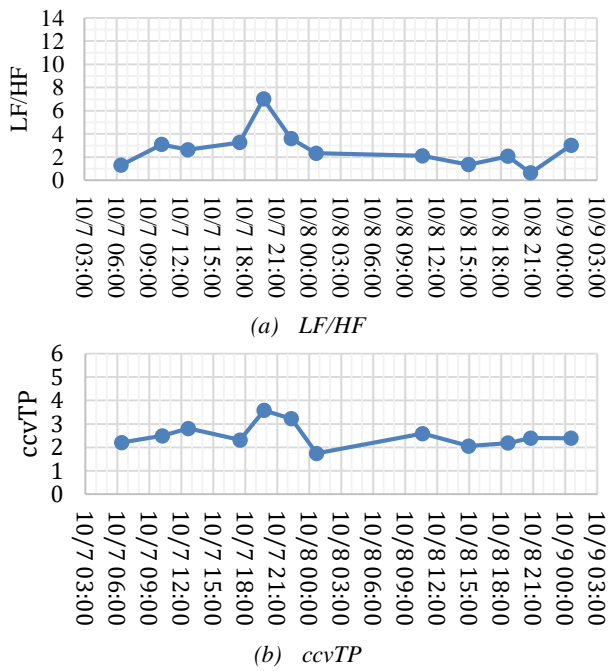


Figure.1 The transition stress in two days

results are checked whether it is consistent with the fact obtained from diaries.

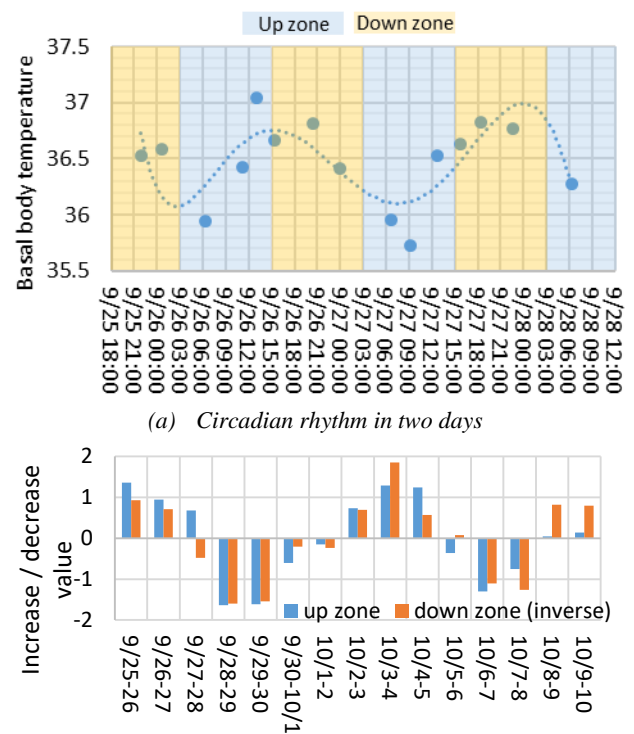
The remaining of this paper is organized as follows. First, second section will explain the indices for expressing the degree of stress and the goodness of circadian rhythm. Next, third section will describe the comprehensive analysis to interpret these indices. Fourth section shows the subject experiment and its result. Finally, the conclusion of this paper is given in the final section.

Analytical method

In this chapter, we explain how to calculate the indexes the degree of a stress and the goodness of a circadian rhythm. In this paper, the basal body temperature and the two types of values about the autonomic nervous system are employed to calculate these indices. These three values are measured every several hours in daytime.

Indies of the degree of the stress

To evaluate the condition of stress, we employed "LF / HF" and "ccvTP". First, "LF / HF" is the index showing the balance between the sympathetic nerve (LF) and the para-sympathetic nerve (HF), which means that the higher the value show that a person gets the higher the stress. Next, "ccvTP" is an index showing the magnitude of the entire autonomic nerve activity. The low value of ccvTP shows that autonomic nervousness is impaired due to fatigue and stress. Figure 2 (a-b) shows the transition of LF / HF and ccvTP measured every few hours for two days as



(b) Indies for circadian rhythm in two weeks

Figure.2 Index of goodness of circadian rhythm

the example. When the value of LF / HF is smaller than 2, the stress is small. On the other hand, when it is 2 or more, it indicates that the stress is high. Figure 1 (a) shows that the subject was relatively higher stressed and especially noticeably high in the evening on October 7. On the other hand, it shows that October 8 is the day the subject did not feel relatively stress. In addition, Figure 1 (b) shows that ccvTP continues to maintain a value of 2 to 3 over 2 days. This fact can be interpreted that the subject did not feel a fatigue or stress which impairs the activities of autonomic nerves. The average per day of these values are employed in order to analyze the stress of daily.

Index of the goodness of the circadian rhythm

As an index showing "the goodness of a circadian rhythm", we employed the s transition of basal body temperature. It is known that basal body temperature goes up and down according to circadian rhythm and a basal body temperature rises from 3 a.m. to 3 p.m. due to the influence of circadian rhythm and falls from 3 pm to 3 am. Based on this knowledge, this paper sets that these time zones are Up zone and Down zone (blue and orange in Figure 2 (a)), respectively. In these zones, the sum from each previous value is calculated as an index showing "goodness of circadian rhythm". These calculation results are shown in Figure 2 (b). Figure 2 (b) is calculated from the basal body temperature measured for the same timing as in Figure 1.

Furthermore, in order to improve visibility, the numerical value of down zone is inverse. In addition, the numerical standardization is carried out in order to improve the ease of visual analysis. The numerical standardization is calculated as that the values subtracted each numerical value by the own average and divided by the own standard deviation. As a result, the average value and the standard deviation of the data set is 0 and 1, respectively. And the closer the value in the data is 0, the closer it is to the mean value.

Comprehensive analysis

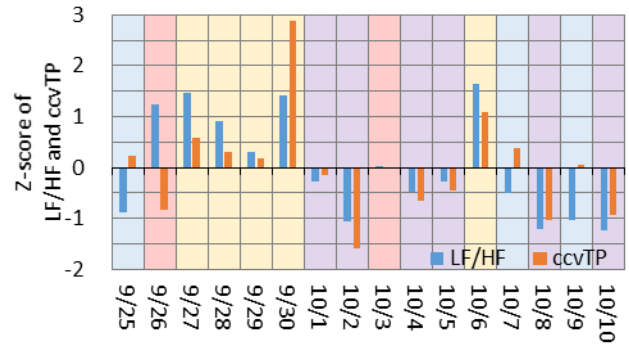
Estimating the condition of the stress

In this paper, we assumed that "LF / HF" responded to mental stress and "ccvTP" responded to body fatigue, and classified the stress condition into 4 types using these two indicators. First type of them is "LF / HF" is small and "ccvTP" is large. this indicates the state without mental stress and body fatigue. Second type of them is "LF / HF" is large and "ccvTP" is small. This indicates the state that a subject has mental stress and body fatigue. Third type of them is "LF / HF" is large and "ccvTP" is large. This indicates the state that a subject gets only mental stress, and body condition is fine. Fourth type of them is "LF / HF" is small and "ccvTP" is small. This indicates the state that a subject gets only body fatigue, and mental condition is fine. In this paper, we evaluate the stress condition from the above types and the numerical values of "LF / HF" "ccvTP".

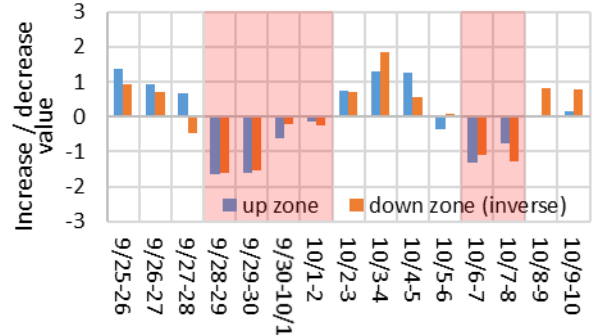
Figure 3 (a) shows the transition of LF / HF and ccvTP measured every few hours for two weeks as the example. The numerical standardization is calculated as that the values in per 1 day subtracted each value by the own average and divided by the own standard deviation. As a result, the average value and the standard deviation of the data set is 0 and 1, respectively. And the closer the value in the data is 0, the closer it is to the mean value. On the other hand, large value in the data is as characteristic data. The coloring of four colors shows each of the four types of stress conditions in Figure 3.

Analysis between the stress and circadian rhythm

In this section, we describe the comprehensive analysis using two type of data. In order to understand each cause and effect relation, two types of data are classified according to good or bad, respectively. Regarding the index of the degree of the stress, as described in the previous section, standardized values for LF / HF and ccvTP are calculated from the average value per 1 day for 2 weeks. Further, the data is classified according to the above-mentioned four conditions. On the other hand, as the index of the goodness of the circadian rhythm, as described in the previous



(a) transition of stress in two weeks



(b) transition of circadian rhythm in two weeks

Figure.3 Analysis result (of Subject 1)

chapter, the data every two days in each time zone are standardized for 2 weeks. Next, this data is classified whether both up zone and down zone are minus values or not, and the day which the values is minus is colored in red as shown in Fig. 3 (b). This day which the values is a day when the circadian rhythm is damaged. The colored figure as shown in Fig. 3 (a - b) enables to judge which a condition of the four types of stresses are disturbing the circadian rhythm.

Human subject experiment

This chapter investigates the practicality of the analysis described in the previous section, using data obtained by subject experiments by four adults.

Details of usage data

In this human subject experiment, the stress measurement sensor was employed VM 302 of Fatigue Science Laboratory Inc. for measuring LF / HF and ccvTP. On the other hand, the commercially available basic thermometer was employed for measurement of basal body temperature. LF/HF, ccvTP and basal body temperature were measured every few hours in a day. After the end of the measurement, the value of each indexes is calculated according to the method described in the previous chapter. Four subjects carried out measurements every three to four hours for

Table.1 Short diary by the subject1

9/25	No description
9/26	Business meeting Exercise at the gym
9/27	Not have lunch
9/28	Leave the office regularly
9/29	Business seminar Drinking party
9/30	Business trip Important negotiation
10/1	[Holiday] Wander around Kanazawa
10/2	[Holiday] Chat with a friend
10/3	Desk work in all day
10/4	Long meeting Exercise at the gym
10/5	Go home early
10/6	Exercise at the gym
10/7	Busy day
10/8	[Holiday] Relaxing at home
10/9	[Holiday] Shopping

Table.2 Short diary by the subject2

1/16	Participate in the training at library
1/17	Working at midnight (11-12 p.m.)
1/18	Especially nothing
1/19	Especially nothing
1/20	Especially nothing
1/21	[Holiday] Watching the son's kendo match
1/22	[Holiday] Lunch party preparation at my son's school
1/23	Taking daughter to the hospital
1/24	Returning home temporarily due to my daughter's nursing
1/25	Working overtime until 7 p.m.
1/26	Stopping by to the library during the return home
1/27	Son did not go home late and staying up late
1/28	[Holiday] Taking naps
1/29	[Holiday] Going to bed twice after breakfast and shopping
1/16	Participate in the training at library

about 2 weeks in 2016 or 2017. Also, they wrote the simple diary every day for verification of analysis. Four subjects live as usual except for regular measurements. Their measurement period is as follows: The measurement period of Subject 1 is from September 25 to October 9 in 2016; The measurement period of Subject 2 is from January 16 to January 16 in 2017; The measurement period of Subject 3

Table.3 Short diary by the subject3

9/15	Oversleep
9/16	Especially nothing
9/17	[Holiday] Taking care of the nephew
9/18	[Holiday] Taking care of the nephew
9/19	[Holiday] Immerse in making piercings
9/20	Getting a strained back
9/21	Low back pain
9/22	[Holiday] Low back pain Going to a concert with a friend
9/23	Low back pain
9/24	[Holiday] Dinner with friends
9/25	[Holiday] Taking care of the nephew
9/26	Always feeling sick
9/27	Low back pain
9/28	Feeling dullness
9/29	Irritating at work

Table.4 Short diary by the subject4

8/16	[Holiday] Spending one day with daughter
8/17	Working outdoors and getting annoyed
8/18	Busy day
8/19	Drinking party
8/20	[Holiday] Getting hangover
8/21	[Holiday] Playing with the children in the park
8/22	Working overtime
8/23	Surgery with dentistry and feeling uncomfortable with anesthesia
8/24	Progressing work well Getting to snooze at evening
8/25	Working overtime
8/26	Getting to snooze at evening
8/27	[Holiday] Getting hangover and snooze at afternoon
8/28	[Holiday] Playing with the children in the outdoor
8/29	Progressing work well
8/30	Busy day

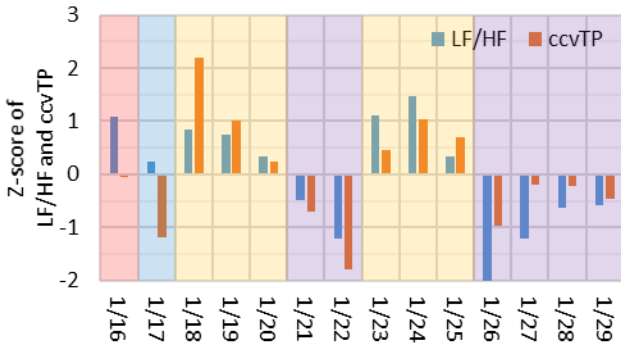
is from September 15 to September 29 in 2016; The measurement period of Subject 4 is from August 16 to August 28 in 2016. In addition, the summary of the contents of the diaries is shown in Table 1-4.

Result of measurement

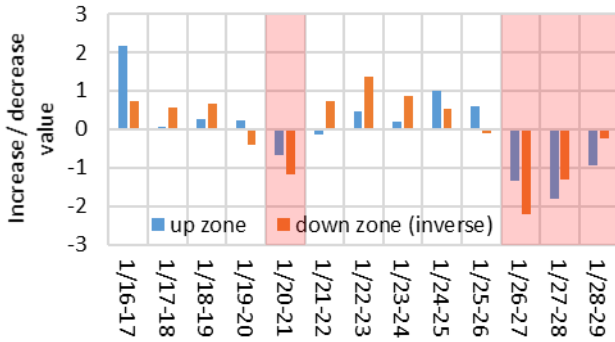
First, the measurement results of each subject are shown in Figures 3 to 6. In these figures, (a) in the upper row shows the result of the index of the degree of stress, (b) in the lower row shows the index of goodness of the circadian rhythm. In these figures, the color coding of stress is as follows. Blue area indicates the state without mental stress and body fatigue ("LF / HF" is smaller than 0 and "ccvTP" is larger than 0). Red area indicates the state that a subject has mental stress and body fatigue ("LF / HF" is larger than 0 and "ccvTP" is smaller than 0). Yellow area indicates the state that a subject gets only mental stress, and body condition is fine ("LF / HF" is larger than 0 and "ccvTP" is larger than 0). Purple area indicates the state that a subject gets only body fatigue, and mental condition is fine ("LF / HF" is smaller than 0 and "ccvTP" is smaller than 0). On the other hand, regarding the indicator of the goodness of the circadian rhythm, the days when both up zone and down zone are negative are colored in red.

Analysis

In this section, as described in the previous chapter, we analyze the relationship stress and circadian rhythm to judge which a condition of four types of stresses are disturbing the circadian rhythm. First, as a first step in the analysis, a common trend from the data of four subjects is found. This common trend is that the circadian rhythm

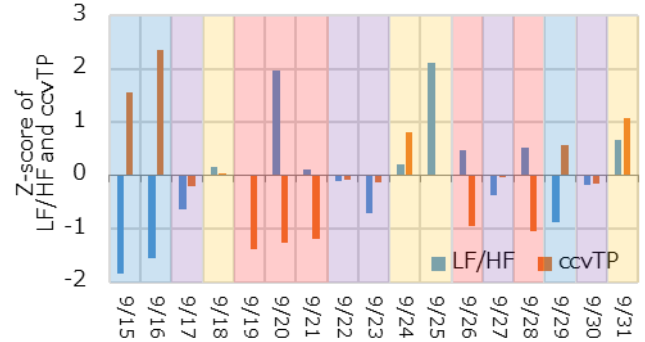


(a) transition of stress in two weeks

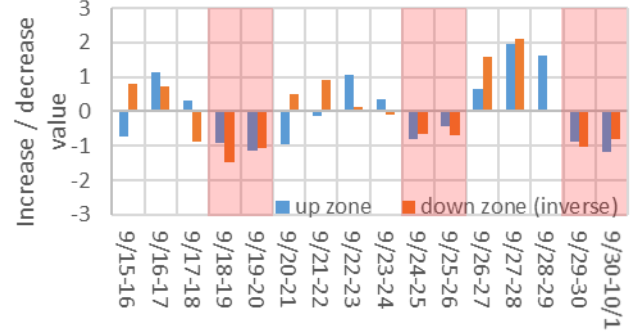


(b) transition of circadian rhythm in two weeks

Figure.4 Analysis result of Subject 2

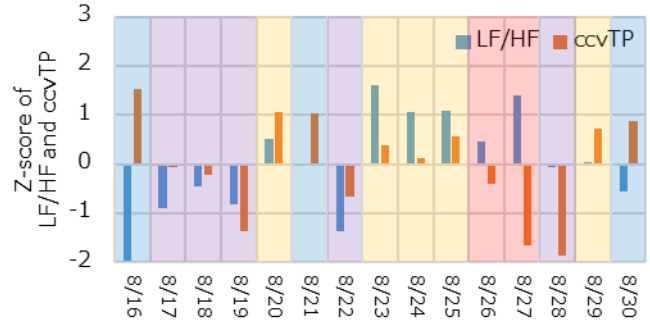


(a) transition of stress in two weeks

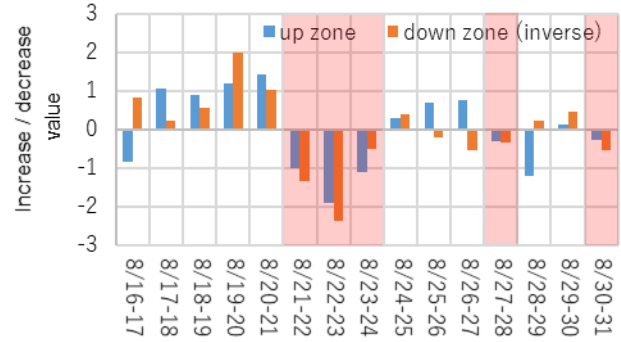


(b) transition of circadian rhythm in two weeks

Figure.5 Analysis result of Subject 3



(a) transition of stress in two weeks



(b) transition of circadian rhythm in two weeks

Figure.6 Analysis result of Subject 4

in the lower row as Figure (b) is worse 2 to 4 days after the stress condition shown in the upper part Figure (a) become red. In other words, if the subject suffers from bad stress, the adverse effect on circadian rhythm occurs several days later. Next, there was a statement in the diaries that the subjects got bad stresses in their bodies or minds when subjects suffer bad stress presented in the red area in most of days. From these results of analysis, when the subject receives stress both mentally and physically, it turns out that the circadian rhythm will be affected several days later.

Conclusion

The final goal of this study is to establish a recommendation system for promoting health. For this purpose, we attempt to evaluate the stress condition and the goodness of circadian rhythm and to clarify the relationship of them. The stress conditions are indicated by classifying four conditions from measurements of two autonomic nervous systems, "LF / HF" and "ccvTP". On the other hand, the goodness of the circadian rhythm is calculated from the up and down of the basal body temperature by two time zones.

In order to verify the effectiveness of this point of view, we conducted experiments by four subjects for about 2 weeks. In this experiment, the subject's basal body temperature, LF / HF and ccvTP were measured during the period. By comprehensively analyzing these two indices, we ob-

tained the following findings: (1) when the subject receives stress both mentally and physically, it turns out that the circadian rhythm will be affected several days later; (2) those trends coincide details from the simple diary written by the subject. As a result, by comparing two types of data of 2 weeks in parallel, these data were related to each other. As a future task, we try to analyze the impact on stress conditions not analyzed still yet.

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