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Vital Reactions as a Measure of Stress Levels in Bicycle Riders According to Degree of Task

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Synopsis

In this study, the amount of stress felt by bicycle riders is analyzed to obtain a method for measuring the relationship between the stress factors of the rider and the rider reaction to the environment, particularly while riding in bike lanes. Several vital reaction indices are used in a variety of traffic environments with differing stress factors. This study examines individual differences to include the level of riding experience and complexity of bicycling tasks to better explicitly consider the differences in experience related to stress and the complexity of riding in each environment. We also compare the differences in the vital reaction by the influence of individual based on biking experience and complexity of biking tasks. Results indicated that during a ride in the bike lanes, multitasking induced higher values in all indices of vital reactions, compared with the responses recorded under single-task conditions. It was also found that the vital reactions in subjects who rode their bikes daily tended to be higher under all biking conditions compared with the reactions of those who rode bikes only occasionally.

KEYWORDS: Bicycle, Stress, Vital Reaction, RRI, Biking Task

1. Introduction

Bicycles have become a popular means of transportation owing to their excellent mobility, contribution to reducing the environmental load, and positive impact on rider health. There are various types of bicycle lanes on sidewalks and roadways that separate or share the space with other modes of traffic. Because of the variation in the biking skill of individual riders, the usage rate of bike lanes varies from one type of bicycle lane to another. How the rider evaluates the environment influences whether or not the rider feels comfortable riding their bicycle; thus, it is essential to consider the subjective and objective assessment of the rider when examining what makes a traffic lane desirable from the rider point of view. Previous studies have shown that safety, stress, and the level of comfort for bicycle riders affects their choice of lanes. Research has evaluated stress reactions in the traffic lane by measuring the heart rate variability interval (RRI), galvanic skin response (GSR), and electroencephalogram (EEG) when riding a bicycle, driving a car, or walking[2)], and there is also research using electromyogram (EMG) for stress measurement in the medical field[4)]. This research has provided established data of rider reaction during bicycle operation as a stress reaction using various indices.

However, cycling requires physical activity performed under complex task conditions. Previous studies have shown that personal attributes, such as gender and the presence or absence of knowledge regarding traffic rules, affect the selection of a traveling lane from the various types of bicycle traffic lanes[6)] available. Furthermore, when riding a bicycle, the person who rides the bike simultaneously processes many other tasks; requirements will change significantly depending on the road surface condition and road outline of the selected lane. It is expected that the biking task is closely related to the psychological load of the person when riding a bicycle; thus, there is a need to evaluate rider reaction comprehensively, including the degree of the biking task, the conscious ability of the rider, and riding confidence. However, few research examples capture the interaction between rider reaction, factors in the traffic environment, and rider knowledge.

In this study, to obtain essential knowledge regarding the method of measuring the relationship between stress factors and reactions related to bicycle use, RRI, EMG, and GSR are measured in multiple traffic situations with different biking tasks and stress factors. Then, by conducting a comparative analysis of the rider reaction during bicycle operation and the degree of riding skill required in each traffic situation, it was experimentally examined whether evaluation of the usage environment was possible using a vital reaction index.

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2. Definition

2.1 Definition of stress

Stress is generally defined as a “non-specific vital reaction caused by an external stimulus”. At present, the positive aspects of stress are also of interest, as moderate stress has the effect of increasing energy, increasing clarity, and helping the person under stress to understand the situation more accurately[7]. In this study, we defined all vital reactions caused by physical and psychological loads during bicycle operation as stress reactions, considered the influence of the biking environment on riders as external stimuli, and examined the relationship between them.

2.2 Definition of biking task

Bicycle riders handle many tasks when traveling in a bicycle lane. When the traffic lane changes, the types and number of functions required for the bicycle rider differ, and it is expected that they will appear as a vital reaction on the load on the rider.

Therefore, in this study, we defined a biking task as the workload required to travel in each lane when riding a bicycle. The workload is the total amount of external conditions and demands that act to change the physiological and psychological state of a person[8]. In the experiment, the degree of a biking task was expressed as an experimental factor that characterized the complexity of the task. For instance, in a closed space, simple tasks can be performed without the effect of external factors; however, tasks performed on actual roads, where there are various external factors, require greater complexity.

2.3 Overview of vital reaction index

(1) Autonomic nervous system

The autonomic nervous system controls functions essential for life support, such as blood circulation, respiration, and body temperature regulation, and is composed of a sympathetic nervous system and a parasympathetic nervous system. The sympathetic nervous system works to increase the activity level and athletic ability of the body, and functions mainly when it is active, nervous, and stressed. Reactions caused by sympathetic nerves include an increase in heart rate and blood pressure, increase in blood flow to muscles due to contraction of peripheral blood vessels, improvement in oxygen uptake capacity due to a rise in the respiratory rate, and increase in sweat on the palms and soles of the feet.

(2) Heart rate variability interval (RRI)

Heart rate variability represents the variation in the range between the R-waves of the electrocardiogram. When the RRI is reduced more than usual, stress is considered to be occurring.

(3) Electromyogram (EMG)

The electromyogram detects a slight change in potential difference occurring in the muscle, and the amplitude fluctuation of the myoelectric becomes more significant than usual during a stress reaction. The electromyogram waveform is composed of a positive waveform and a negative waveform with the baseline as the boundary; however, to facilitate understanding during analysis, RMS waveform processing is performed to reverse the negative waveform and display it as a positive waveform.

(4) Galvanic skin response (GSR)

The galvanic skin response is an electrical change that occurs temporarily on the skin due to sweating or similar due to a strong stimulus or mental activity. If the value increases, stress is considered to be occurring. In general, an electrode is often placed on the fingertip with the highest concentration of sweat glands to measure this response.

2.4 Overview of measuring equipment

As a measuring instrument, a biology sensor manufactured by S&ME (Fig. 1) was used to measure the RRI, EMG, and GSR of the subject while riding a bicycle. The heart rate sensor electrode was attached to the chest, and the sweat sensor electrode was attached to the index finger and ring fingertips. After a simple experiment to compare reaction due to exercise and stress reduction, the masseter muscle of the masticatory muscle was selected among five muscle candidates, and the electrode attachment of the myoelectric sensor was placed. The measurement interval of each sensor was measured at 0.5 s intervals for RRI and 0.001 s intervals for

EMG and GSR, and recorded in the data logger.

3. Experimental

3.1 Outline of biking experiment

A biking experiment was conducted to compare the electrode mounting positions and examine how the vital reaction index reacts to biking tasks. The subjects were five male students with different bicycle riding experiences (2 daily riders, 3 non-daily riders), and the experimental course was divided into two routes—simple path and complex path (real road). The experimental course (Fig. 2) used for the simple biking task was set up in a university without the influence of other traffic. The experimental course (Fig. 3) used for more complex biking was a 1.5km long course composed of a bicycle track and a shared-use path on an actual road, set in Sakai City, Osaka Prefecture. The width of each lane is 1.1m on the bicycle track and 1.35m on the shared use path with visual separation[9]. The biking experiment on the campus was conducted on January 16, 2018, and the experiment on the actual road was held on January 25, 2018. At the time of measurement, to set the vital reaction in the exercise state to a reasonable value, the resting state for 5 minutes and the bicycle running state for 3 minutes were measured for a specific time, then, the measurement was performed on the course.

3.2 Analysis method

This study demonstrates that by using individual differences in biking experience and complexity of biking tasks you can see how they relate to stress and the complexity of the task required for different environments. This study compared the differences in vital reactions by the influence of individual differences, such as biking experience and sophistication of biking tasks. A comparison was performed using the mean value and variance value of each vital reaction. Here, the variance represents the fluctuation range of the vital reaction.

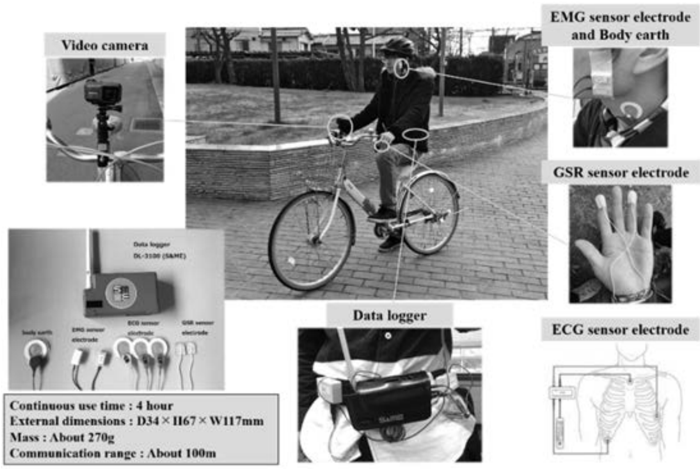


Figure 1. Measuring equipment

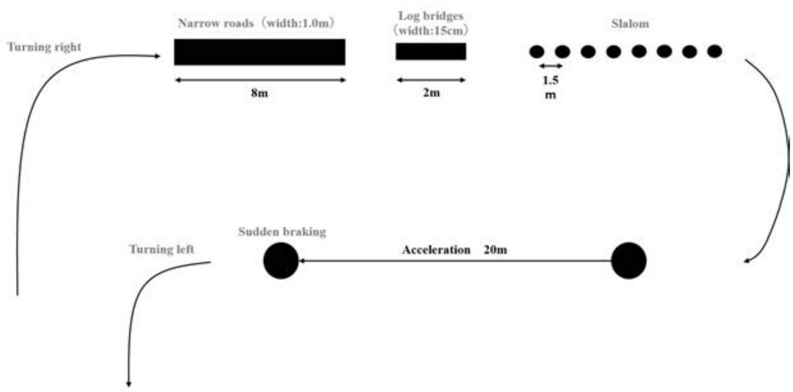
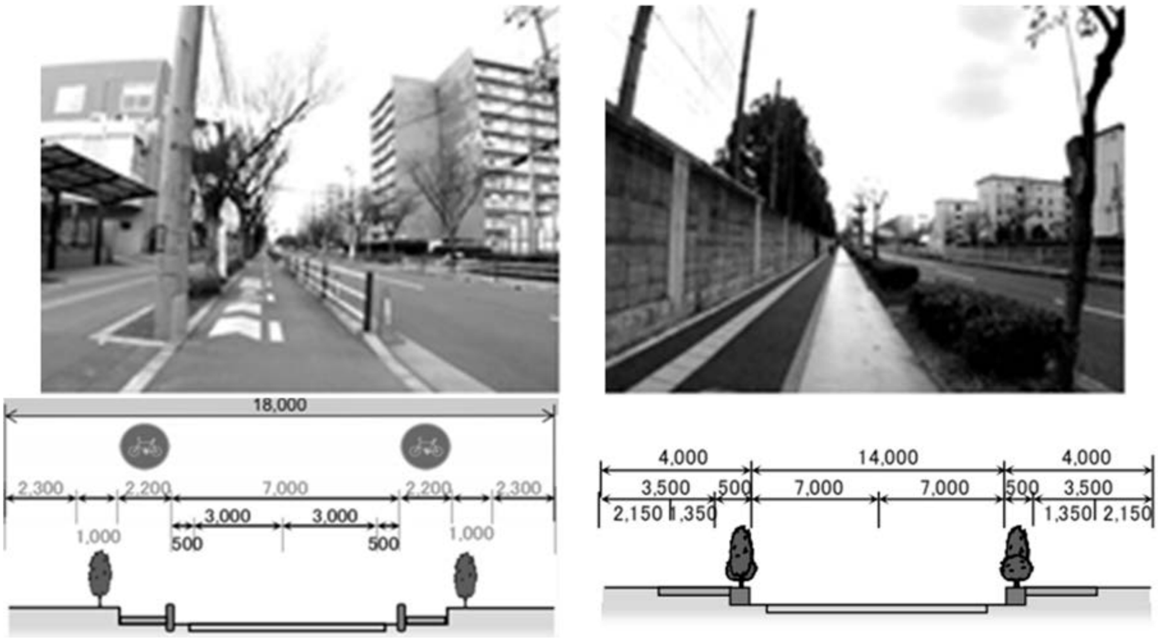


Figure 2. Experimental courses



Bicycle tracks Shared use paths with visual separation

Figure 3. Experimental courses in Sakai City

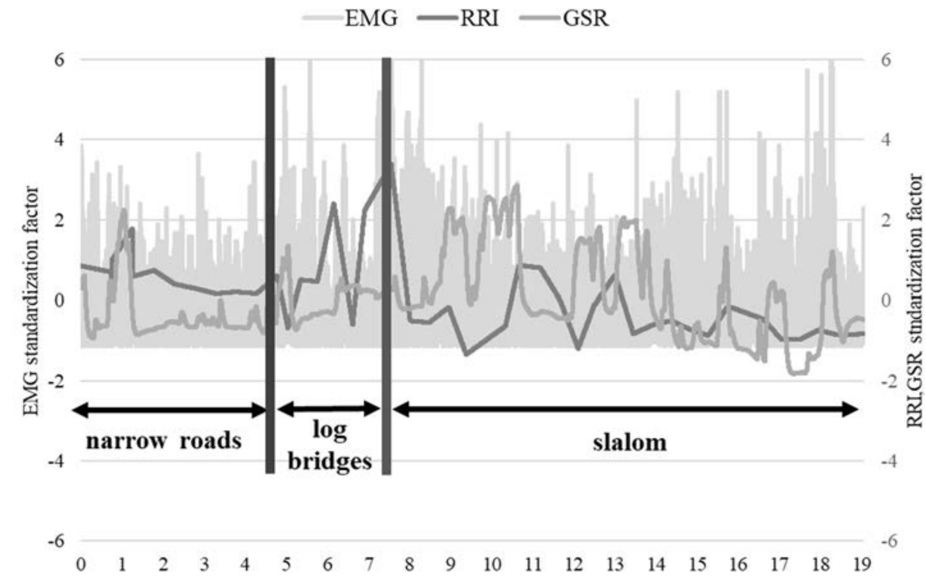


Figure 4. Reaction characteristics of vital reactions

4. Results

4.1 Vital reaction characteristics running on a simple course

A comparison of the reaction characteristics of vital reactions of each obstacle in the biking course (Fig. 4) revealed that RRI and GSR exhibited a gradual response for almost all subjects and continued for a certain period of time under conditions where biking loads, such as narrow roads and log bridges, continued. GSR and EMG also tended to react instantaneously to steering operations such as wobbling, slalom, turning right, turning left, and avoiding obstacles. There was no reaction to movements such as hand signals and left/right confirmation.

Regarding individual differences, a comparison of the changes in vital reactions due to the frequency of daily use of bicycles caused by activities such as going to school revealed an RRI with a greater tendency to decrease or increase than for students who did not use bicycles at school. In GSR, there was a tendency that the numerical fluctuation at the time of reaction was significant. In EMG, there was no difference in reaction depending on the frequency of bicycle use. Even for students with the same rate of use, RRI and GSR showed significant differences in the time to return to normal values after the values fluctuated.

4.2 Changes in vital reactions depending on degree of biking tasks

The five subjects were classified according to the difference in their biking experience, and vital reactions due to simple biking tasks in campus experiments and vital reactions due to complicated biking tasks in road experiments were compared by the average values of each group (Fig. 5).

Consequently, as tasks became more complex, RRI values tended to decrease, and EMG and GSR values tended to increase gradually. Therefore, it was found that the vital reactions increase as biking tasks become more complicated.

Regarding changes in vital reactions due to differences in biking experience, RRI decreased as tasks became more complicated for both regular and infrequent bikers. However, there was no significant difference in reaction between subjects who rode bicycles daily and those who did not. Moreover, in EMG and GSR, compared to subjects who ride bikes infrequently, the subjects who rode them regularly tended to have a more significant reaction under any biking task. A possible reason for the difference in biking experience is that EMG and GSR have a faster reaction rate to stressors than RRI. Perhaps in addition to the overt mental load, such as a collision or contact typically felt by a bicycle rider, regular riders are also subjected to greater potential psychological pressure from risk prediction. Therefore, it is reasoned that experienced riders were more responsive to stress.

4.3 Evaluation of each traffic lanes

The comparison of the traffic lane for each single road section and intersection (Fig. 6), in the individual road section, shows that the stress value was higher in the bicycle track for EMG and GSR. In addition, at the intersection, the stress value was higher in the shared use path for RRI and EMG. It was assumed that the bicycle track would be more comfortable to travel than the shared use path, however, it appeared that road conditions, such as the width of the traffic lane and curve, and traffic conditions, such as the distance between the opposing bicycles, impacted the original assumption. As for the width of the traffic lane, the bicycle track with a diameter of 1.3 m feels more squeezed than the shared use path with a width of 3.5 m (lane coloring section 1.35 m) where the travel position cannot be specified. Therefore, a more significant response was demonstrated during passing in the bicycle track for EMG and GSR. In addition, because the RRI and EMG responded more significantly to the curves existing in the bicycle track, it became clear that the lane outline was also a factor affecting the vital reaction.

From these results, it is expected that RRI is suitable as an index for evaluating the entire section, and EMG and GSR are suitable as an index for assessing the degree of each stressor. In particular, EMG and GSR have different reaction rates, such that aptitude may differ depending on the duration of the bike ride. Therefore, EMG is suitable for stressors with low biking loads such as avoiding pedestrians, bicycles and obstacles. Furthermore, GSR may be ideal for stressors with continuous biking loads, such as the width of the traffic lane, fences, and curves.

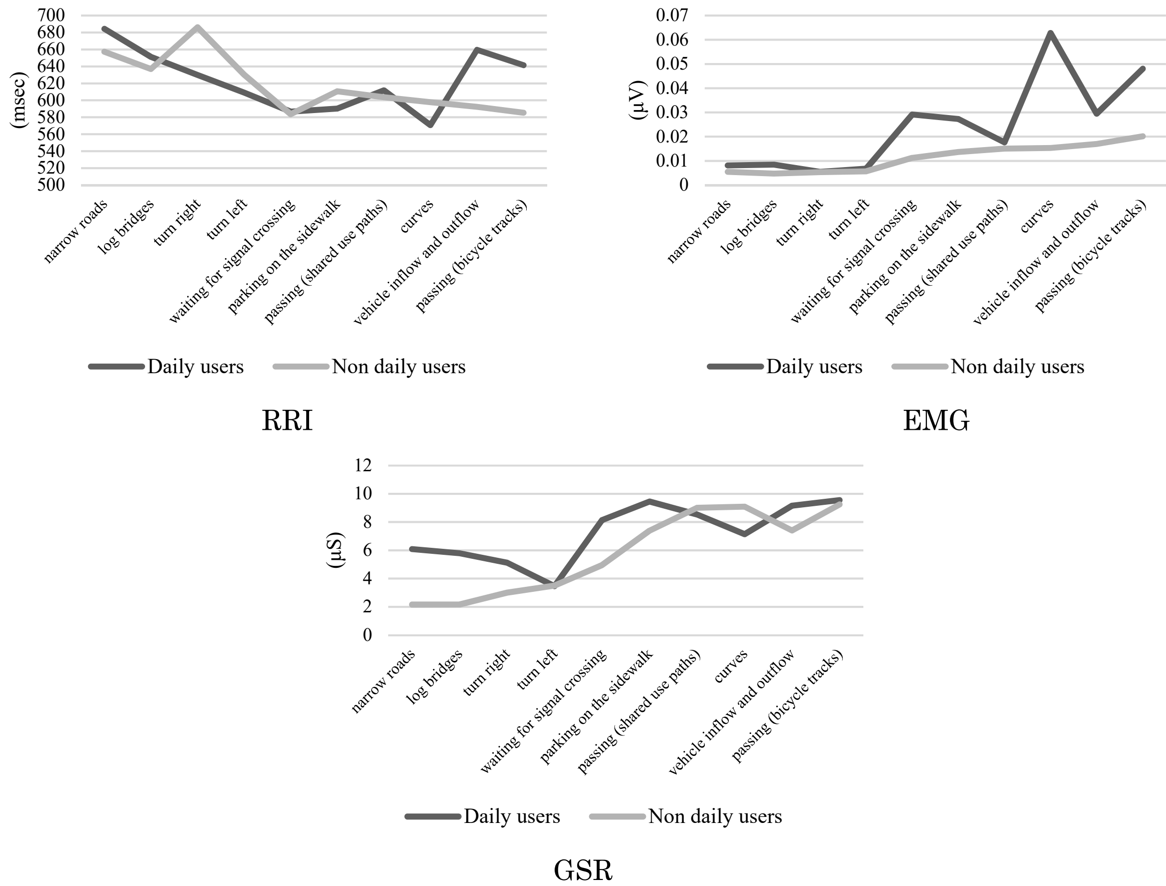


Fig 5. Vital reactions depending on degree of driving tasks

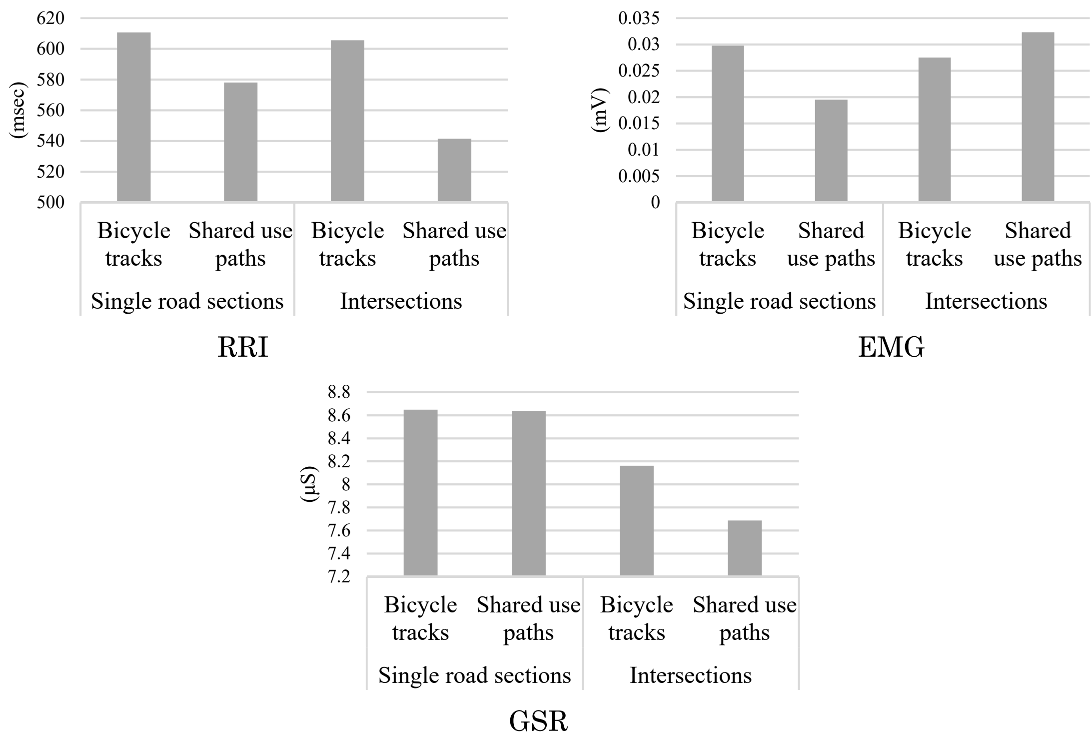


Fig 6. Evaluation of each traffic lanes

5. Conclusion

From the results of this experiment, RRI and GSR showed reactions that gradually started and continued when biking loads were maintained. In addition, EMG tended to respond to steering operation instantaneously.

A comparison of the changes in vital reactions depending on the degree of difficulty biking tasks, it was found that the essential reaction increased as biking duties become more complicated for all vital reaction indices. Regarding changes in vital reactions in EMG and GSR due to individual differences such as biking experience, compared to subjects who did not ride bicycles daily, experienced bike riders tended to have a more significant reaction under any biking task.

Thus, it is clear that the vital reactions of bicycle riders are greatly influenced by the degree of difficulty biking tasks required for traveling in each lane, the biking experience of riders, and their physical ability.

Furthermore, as a result of evaluation of traffic lanes, it became clear that even lanes separated from cars and pedestrians, such as bicycle-only lanes, can become a stress factor by route design, such as the width of traffic lanes and curves. These factors need to be considered in the design of future traffic lanes.

Prior to future development, it is necessary to classify in detail all biking tasks required for traveling in each traffic lane by measuring vehicle behavior and analyzing the relationship between the rider vital reactions and biking tasks.

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