ISASE 2020

Changes in Respiration Pattern Preceding Drowsiness During Driving

– Ambulatory Respiration Monitoring by Smart Shirts Sensors –

Emi YUDA*, Yutaka YOSHIDA ** and Junichiro HAYANO ***

** Tohoku University Graduate School of Engineering, 6-6-05 Aoba Aramaki, Aoba-ku, Sendai, 980-8759, Japan*
yuda@ieee.org
** Nagoya City University Graduate School of Design and Architecture*, 2-1-10, Kita Chikusa, Chikusa-ku, Nagoya 464-0083, Japan*
yoshida@sda.nagoya-cu.ac.jp
**** Nagoya City University Graduate School of Medical Sciences, 1 Kawasumi Mizuho-cho, Mizuho-ku, Nagoya 467-8602, Japan*
hayano@acm.org

Abstract: Although many attempts have been made to detect driver's drowsiness by ECG and pulse wave signals, it is not easy to record stable bio-signals while driving. In this study, we examined whether the driver's drowsiness can be detected from the respiration signal that can be acquired relatively easily with wearable clothing sensor. In 7 healthy subjects (five males and two females; age, 45 ± 9 y), respiration, ECG, and acceleration signals were recoded for a total of 2,359 min (137-468 min per subject) of driving with a smart shirt biometric sensor (Hexoskin). Minute-to-minute respiration amplitude and frequency and their variability were analyzed by complex demodulation between 0.05 and 0.45 Hz. The changes in the respiration parameters were analyzed in relation to the Dip & Waves, which are known to be a characteristic ECG R-R interval pattern associated with driver's drowsiness. Neither respiratory amplitude nor frequency showed significant changes with Dip & Wave, but respiratory frequency variability increased progressively from 4 minutes before, peaked at Dip & Waves, and then decreased shortly thereafter. Our observations suggest the possibility that respiration signal obtained by wearable garment sensor may be used to detect driver's drowsiness.
Keywords: *Driver, Drowsiness, Respiration, Wearable sensor, Clothing*

1. INTRODUCTION

Many attempts have been made to develop technologies for detecting driver's drowsiness by biometric sensors [1-4]. It is not easy to record stable bio-signals unconsciously while driving. In this study, we examined whether the driver's drowsiness can be detected from the respiration signal that can be acquired relatively easily with wearable clothing sensor.

2. METHODS

We studied 7 healthy subjects (five males and two females; age, 45 ± 9 y). Respiration, ECG, and acceleration signals during driving were recoded with a smart shirt biometric sensor (Hexoskin, Carre Technologies Inc., Montreal, Quebec, Canada). Hexoskin was composed of a smart shirt and a data logger in a shirt pocket. The shirt was made of smart garment sensors by which respiratory movements were measured. On the back of the shirt, ECG electrodes were placed. Collected bio-signals were stored on the logger, uploaded to the cloud, and analyzed by custom software (VitalRecorder2, Kissei Comtec, Matsumoto, Nagano, Japan). ECG, respiration, and 3-axial acceleration signals were sampled at 256, 128, and 64 Hz, respectively. Simultaneous recording on the Holter ECG recorder was performed as a backup to ensure stable monitoring of the ECG and acceleration signals.

Drowsiness during driving was estimated from a characteristic heart rate pattern. Drowsiness during driving is characterized by the state of fighting with sleepiness, which causes physiological conditions different from those observed during natural processes followed by sleep in daily life. In previous studies, we reported that drowsiness during driving is accompanied by typical heart rate pattern named Dip & Waves [5]. In contrast to conventional indices of heart rate variability which reflect stationary state characteristics of heart rate fluctuation, Dip & waves is a feature of wave form appearing transiently with individual episode of drowsiness.

The respiration signal obtained by the shirt sensor was analyzed by complex demodulation, by which respiratory amplitude and frequency within 0.05-0.45 Hz band were demodulated continuously as functions of time. Obtained

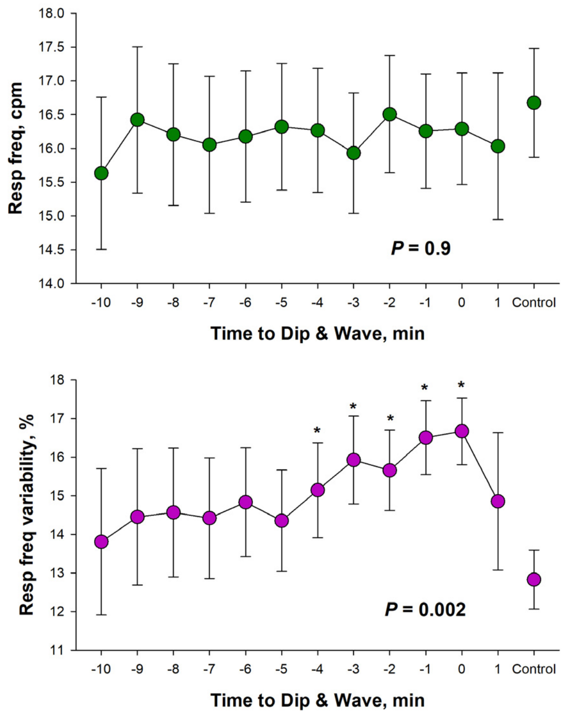

Figure 1. Changes in respiratory frequency and its variability preceding Dip & Waves of ECG R-R interval
The *x* axes represent time (minutes) to Dip & Waves (time 0 is the point where Dip & Waves occurred).
P values are the overall significance of the effect of time. *P <0.05 against control value (>10 min before Dip & Waves).

respiratory amplitude and frequency were averaged every minute. Additionally, respiratory amplitude and frequency variabilities were assessed as the deviation from 5-point (5 min) moving average of each parameter.

3. RESULTS

A total of 2,359 min (137-468 min per subject) of signals during driving were obtained. Respiratory amplitude and frequency showed no significant changes with Dip & Wave (Figure 1). Respiratory frequency variability, however, increased progressively from 4 minutes before Dip & Waves. It peaked at Dip & Waves and then decreased shortly thereafter.

4. DISCUSSIONS

We analyzed the changes in respiration patterns accompanying Dip & Waves. We found that a progressive increase in respiratory frequency variability preceded the episodes of Dip & Waves during driving.

In this study, we used Dip & Waves as a surrogate maker of driver's drowsiness, but its accuracy has not been established. Thus, it is unclear whether the increase in respiratory frequency variability is associated with driver's drowsiness or merely with the Dip & Waves themselves. In this study, only one subject reported a strong drowsiness episode while driving. The episode was preceded by a progressive increase in respiratory frequency variability.

4. CONCLUSIONS

Our observations suggest that respiratory signals obtained by wearable clothing sensors may be used to detect driver drowsiness. Further researches are needed to directly examine the relationship between changes in breathing patterns and driver drowsiness.

REFFERENCES

[1] M. Awais, N. Badruddin, and M. Drieberg; A Hybrid Approach to Detect Driver Drowsiness Utilizing Physiological Signals to Improve System Performance and Wearability, *Sensors,* vol. 17, no. 9, Aug 31 2017.
[2] R. Buendia, F. Forcolin, J. Karlsson, B. Arne Sjoqvist, A. Anund, and S. Candefjord; Deriving heart rate variability indices from cardiac monitoring-An indicator of driver sleepiness, *Traffic Inj Prev,* pp. 1-6, Apr 12 2019.
[3] T. P. Corey, M. L. Shoup-Knox, E. B. Gordis, and G. G. Gallup, Jr.; Changes in Physiology before, during, and after Yawning, *Frontiers in evolutionary neuroscience,* vol. 3, p. 7, 2011.
[4] F. Forcolin, R. Buendia, S. Candefjord, J. Karlsson, B. A. Sjoqvist, and A. Anund; Comparison of outlier heartbeat identification and spectral transformation strategies for deriving heart rate variability indices for drivers at different stages of sleepiness, *Traffic Inj Prev,* vol. 19, no. sup1, pp. S112-S119, Feb 28 2018.
[5] E. Yuda, Y. Yoshida, H. Kawashima, H. Yamamoto, H. Tanaka, and J. Hayano; Hear Rate Dynamics Related to Drowsiness, in *International Behavioral Neuroscience Society (IBNS)*, Cairns, Australia, 2019.