Oculomotor Indicator Pattern for Measuring Fatigue in Long Duration of Driving: Case Study in Indonesian Road Safety

Maya A. Puspasari, Hardianto Iridiastadi, and Iftikar Z. Sutalaksana
Department of Industrial Engineering and Management, Bandung Institute of Technology, Bandung, Indonesia
Email: maya.arlini@yahoo.com, hiridias@vt.edu, siftikar@y7mail.com

***Abstract*—In Indonesia, the number of road accidents increase every year. One of major causal of road accident is fatigue and sleepiness. It is common in Indonesia that commercial drivers have long working hours (around 15-16 hours/day), thus it contributes to fatigue accumulation. However, there is still lack of research that focus on fatigue in long driving. One of the reliable fatigue measurement is oculomotor indicator, which consist of blink, saccade, and fixation of human eye. This study focuses on obtaining pattern of oculomotor indicator in long driving. Participants are asked to drive in simulated driving for three hours. It can be concluded that the blink and saccade parameters are affected significantly towards driving duration, unless the fixation parameter and pattern of fatigue is fluctuating throughout time.**

***Index Terms*—oculomotor indicator, pattern, fatigue, long driving**

I. Introduction

In Indonesia, the number of road accident increases every year, according to National Statistics Bureau. It was stated that number of accident exceeds 100.000 cases in 2013 with number of fatality surpassed 25.000 people [1]. Economic and social lost acquired from the fatality went above approximately 200 billion per year. One of major causal towards road accident is fatigue and sleepiness [2]. There are some studies that stated 20-30% of road accident caused by fatigue [3], [4]. Condition in Indonesia worsened the fact that commercial driver in Indonesia has long driving hours, which exceeds 15 hours/day. The condition of Indonesia contributes to fatigue accumulation. Therefore, there is an importance to study long driving hours towards fatigue in Indonesia.

Fatigue is defined as a biological drive that caused by circadian rhythm, homeostatic, and work related factor that affects decrement in performance and drive to rest [2] [5]. On the other hand, sleepiness is defined as a function of relative strength of sleep drive and wake drive, that caused by circadian rhythm and homeostatic process [6] [7], [8]. Based on Williamson *et al*. (2011), fatigue is a construct that linked its causes and effects [2]. The manifestation of fatigue is sleepiness, mental fatigue, physical fatigue, or muscular fatigue, depends on the causes [2]. It can be concluded that sleepiness is a part of fatigue. Therefore, this research is focused on fatigue when driving.

Based on the literature, the causes of fatigue can be characterized into two major causes, which are sleep related factors that associated with time of day and homeostatic factor, and task related factors that associated with job characteristics (work duration, workload, work environment, visibility and secondary task) [2], [9]. Time of day is related to circadian rhythm, that correlated to human biological clock, where human tends to feel sleepy during certain time (e.g.: in the morning, after lunch, at night, etc.) and homeostatic is defined as factor related to quality and quantity of sleep [2].

To mitigate fatigue, there are two common approaches. The first approach focuses on regulation, which manages work shift, resting time, and working time [10]. However, this approach has a limited control towards driver and environment. Consequently, second approach arises, which is mitigate fatigue through fatigue measurements [11].

Currently there are three main indicators to measure fatigue, which are physiological, performance, and subjective indicators [11]. Physiological indicator involves various human monitoring, such as: brain wave signal, oculomotor, heart rate variability, blood pressure, head nodding, and electrodermal activity. On the other hand, performance indicator measures the task related to work or secondary task, such as: reaction time, lane deviation, braking response, and number of incident. Furthermore, subjective indicator measures the psychological aspect with questionnaire, such as: Karolinska Sleepiness Scale (KSS) and Swedish Occupational Fatigue Index (SOFI) [2], [11], [12].

Oculomotor response is one of the reliable physiological indicators to measure fatigue and sleepiness. Oculomotor is a term of neuron connected with Central Nervous System to control human eye movement. In general, oculomotor indicator consists of eye blink (duration, velocity, frequency, interval), saccade (velocity, duration), and pupil (duration of pupil dilation and pupil constriction) [12]. Literature has shown that oculomotor response often used as indicator of sleepiness; however, there is still limited research that uses oculomotor

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response as an indicator for measuring fatigue [13]-[15]. Furthermore, oculomotor indicator is a voluntary indicator that measures eye blink, saccade, and pupil movement unconsciously and difficult to be controlled by human [12]. Therefore, the measurement result of this indicator will be objective. Moreover, there is a need to develop oculomotor indicator to measure fatigue.

One of fatigue causal is work duration, extracted from task related factors. There are some research questions still unanswered regarding long duration, of driving where most of previous researches study shorter driving duration (under 2 hours) [12], [14]. On the other hand, in Indonesia, it is common for commercial drivers to have long working hours (exceed 15 hours/day), so it is outdoing requirements of driving hours of WHO, which is 8 hours/day maximum [16]. There is also limited study that focus on oculomotor indicator to measure long driving fatigue. For that reason, this research is purposed to obtaining pattern of oculomotor indicator that measuring fatigue in long driving.

II. Method

This research covers the preliminary study of the actual research. Five male participants, aged 25-35 years, have profession as commercial driver, are willingly to participate in this study.

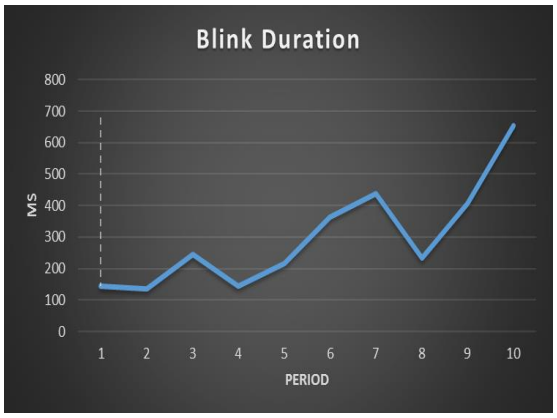
Participants are assigned in a three hours driving task in a medium fidelity driving simulator. Researcher controlled their sleep duration the day before, which is 7 hours, with Fitbit Charge HR. Participants also restricted in consuming caffeine and smoke, and only consumed meals provided by researcher.

Figure 1. Instruments of this research

Oculomotor indicator is measured by EyeLink II eye tracker. The driving simulator consists of Logitech G27 92 series with three pedals, software City Car Driving Simulator version 1.4, 32 inch HD screen and sound system and computer with i7 processor. The instruments used in this research can be viewed in Fig. 1.

III. Results and Discussion

The result of oculomotor indicator pattern that measure long duration of driving can be viewed in Fig. 2, Fig. 3, and Fig. 4.



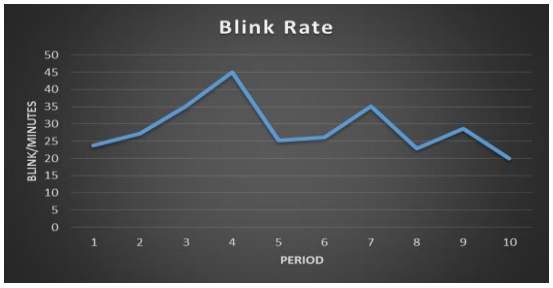
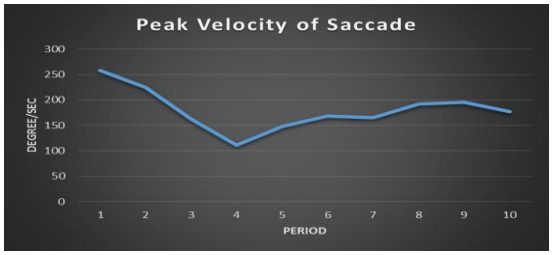


Figure 2. Result of blink parameters



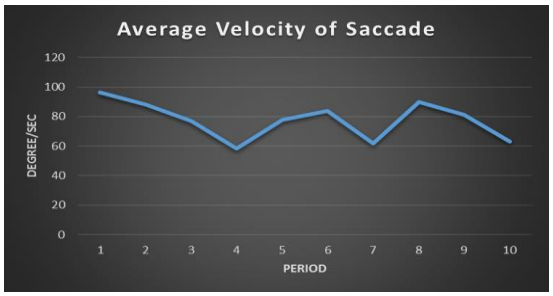


Figure 3. Result of saccade parameters

Result of blink parameter shown that there is an increase in blink duration that begins before one-hour driving. The blink duration worsened towards the end of

the session (three-hours driving). On the other hand, the blink rate has significant increment before one-hour driving. It marks the beginning of fatigue, according to Schleicher *et al*. (2008) and Di Stasi *et al*. (2012) [12], [14]. After three hours driving, the blink rate is slightly decrease, as the blink duration increase significantly, therefore it indicates heavier fatigue, according to Schleicher *et al*. (2008) [12].

The result of saccade parameter shows the average and peak velocity have the same pattern. Somewhere after one hour driving the velocity of saccade decrease dramatically, and after that become leveling. The velocity of saccade decrease to almost 40% of prior speed at the end of the session (three hours driving). Thus, there is a significant decrease of average and peak velocity of saccade that shows an increase in fatigue [14].

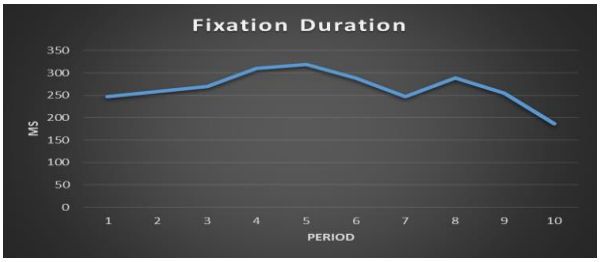


Figure 4. Result of fixation parameters

Fig. 4 shows the fixation duration towards time. There is slight significant difference between beginning and the end of the session. It shows that fatigue slightly affect the decrement of fixation duration.

IV. Conclusion

It can be concluded that the pattern of oculomotor indicator generated from this study is differed, depends on the parameters. The blink and saccade parameters are affected significantly towards driving duration, unless the fixation parameter. It also can be resolved that fatigue can be fluctuating throughout time.

Acknowledgment

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Maya A. Puspasari was born in Jakarta, Indonesia on March 22th 1988. She obtained her bachelor degree in Industrial Engineering from University of Indonesia on 2009, followed by master degree from NTUST and University of Indonesia on 2011. Currently she is pursuing doctoral degree of Industrial Engineering and Management from Bandung Institute of Technology.
She has been an academic staff of University of Indonesia for 6 years. Her research interests including ergonomics and transportation safety. She is also a part of Indonesian Ergonomics Society (Perhimpunan Ergonomi Indonesia).

Hardianto Iridiastadi was born in Indonesia on February 3rd 1966. He finished his master's and PhD in Industrial Engineering from Louisiana State University (LSU) and Virginia Polytechnic Institute and State University (VT), respectively.
He is the past president of Indonesian Ergonomics Society (PEI), and is currently a member of Institute of Industrial and Systems Engineers (IISE). Currently, he is an associate professor at Bandung Institute of Technology.
Dr. Iridiastadi has research interest in the area of industrial ergonomics, human error, and fatigue in the transportation sector. He is the co-author of "Ergonomi – Suatu Pengantar", an Indonesian ergonomic book for university-level students. He can be reached at hiridias@vt.edu.

Iftikar Z. Sutalaksana was born in Cimahi, Indonesia on April 19th 1954, He was graduated from Katholieke Universiteit Leuven, Belgium.

He is an associate professor of Department of Industrial Engineering and Management, Faculty of Industrial Technology, Bandung Institute of Technology. His current research interests are macroergonomics, physiology study, and road safety.

Dr. Sutalaksana is the principal author of "Methods of Engineering", an Indonesian ergonomic book for work system design subject. Currently, he is a prominent member od Indonesian Ergonomics Society and advisor of several private universities in Indonesia