

# Stress of Kindergarten Bus Drivers: How we reduced un-safe driving of Kindergarten Bus by using a small and wearable ECG and acceleration measuring device

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## ARTICLE INFO

## ABSTRACT

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To decrease un-safe cut in of kindergarten bus to the traffic, we evaluated stress during driving and other mental and physical factors which adversely influences driver's driving performance, cognition and decision making etc. by the 24 hour's measurement with M-BIT. For bus drivers, the most stressful situation was turning to move to the standby position in narrow and crowded kindergarten's parking lot, in this case. And this stress caused "un safe cut in" of kindergarten bus. To reduce these, structured parking in the parking lot and effective cooperation of bus drivers and attendant teachers had started. These efforts may decrease drivers stress, and thus, improve the safety of kindergarten bus. Other risky-factors for driving, the occurrence of arrhythmia due to driving, and frequent occurrence of apnea during sleeping were also detected.

## Introduction:

Previously, we have developed a small wearable (size: 40×39×8mm, weight: 14g) ECG and acceleration measuring device (M-BIT) and data analysis software group, and performed 24 hours measurements of 4 years old children at Nazareth Kindergarten (Yokohama, Japan), and reported their physical activities and sleep behaviors [1,2]. Using hourly obtained VPA (vigorous physical activity) and MVPA (moderate-to-vigorous PA) percentages we have revealed the effect of specific educational event, importance of playing outside, and largeness of the influence of weather [1]. By the sleep measurements at their home, we could estimate NREM sleep areas and automatically detect sleep apnea [2]. Since then, we have been studying children's PA, sleep behaviors and activities of autonomic systems and their relationships

with kindergartens educational programs. In the course of our study at kindergartens, we have noticed there were several claims about un-safedriving of kindergarten bus. Most of them were "un-safe cut in" of kindergarten bus from kindergarten parking lot to running traffic in the road in front of parking lot. Since bus drivers are professional and experienced drivers, we thought there might be very large stress in bus drivers on the occasion which affect them adversely and cause such dangerous situation. Recent findings have shown that stress not only is tightly intertwined neurologically with the mechanisms responsible for cognition but plays a vital role in decision making, problem solving, and adaptation to unpredictable environments, such as driving [3], as well. Driver stress has been measured in two conventional ways –through the use of self-report questionnaires or the

use of physiological data. Data collected via self-report questionnaires are based on the drivers' self-indication of their feelings towards the questions, and there are three well used questionnaires, Driver Behaviour Inventory (driving performance) [4], Driver Behaviour Questionnaire (driving errors and road violations) [5], National Aeronautics Space Administration –Task Load Index (driver's mental effort) [6]. Physiological metrics of driver stress are collected using physiological sensors during driving tasks, and involuntary since these data respond to stress with no conscious control or subjective bias on behalf of the participants [7]. Previous research suggests that blood volume pressure, heart rate, heart rate variability, respiration rate and Galvanic Skin Response (GSR) of a driver's hand are the physiological data most closely correlated with driver stress level [8-10]. As an obstruction to drivers should be kept to the minimum necessary to ensure scientifically valid data, heart rate, heart rate variability and respiration rate (RR) have been most commonly adopted during real-world driving tasks [11]. Our 24 hour's measurement of day time activity, sleep behavior and activity of autonomic nervous system of drivers using M-BIT involves these stress measurement during driving. Acceleration data of M-BIT can provide simultaneous information about the movement of vehicles. Beside stress during driving, we can provide information about their sleep quality including sleep apnea occurrence and 24 hour's stress situations. In this study we evaluated stress during driving and other mental and physical factors which adversely influences driver's driving performance, cognition and decision making etc. by the 24 hour's measurement with M-BIT, and found very important factor which causes dangerous driving situation, and could start to improve it.

## Measurement and Analysis:

### A. Measurement:

Nazareth Kindergarten locates in a well-known high class bed town of Tokyo. The traffic of the road in this area considerably crowded in the morning commuting time zone. And kindergarten bus drive through the residential area near station in 7:50-10:00, most crowded time zone and area, to gather children. We tried to evaluate the bus driver's stress during driving in this most stressful morning services. Details of M-BIT were reported elsewhere. Electrode placement for ECG measurements made using M-BIT involves a monitoring lead, which is similar to II lead. Since M-BIT is small

and lightweight and body ground is unnecessary due to improvements in electronic circuit design, it can be worn to subject's thorax using two electrodes for ECG. This made the "one touch attachment" of M-BIT possible, and we could attach them to all the five drivers for morning driving in busy start ready time in the early morning around at 7:30. In the normal mode M-BIT allows 25 hour's measurement with sampling frequency of 128Hz (ECG) and 1Hz (3-axes acceleration). We performed bus drivers' measurements twice. First time was the survey of their stress situation of during driving, and measurements were during driving only. For the sensitive measurement of the movement of bus or its vibration, and driver's body movements, we used "high frequency sampling mode" of M-BIT, which samples all the ECG and three axes acceleration with sampling frequency of 128Hz, and allows about 9 hours measurement. Second time was the confirmation of reproducibility of stress situation during driving, and the survey of their sleep behavior, sleep apnea occurrence. Drivers information were summarized with their SASI values in the second measurement.

### Table I Drivers and Services:

\*n.d.: no data

### B. RR interval detection:

We detected time locations of the R wave on the ECG signal based on a robust real time QRS detection algorithm currently in broad use worldwide. In this algorithm, ECG signals undergo band pass filtering using a frequency band of 5 to 11 Hz, where most components of QRS peaks exit, and are then differentiated. Absolute values are determined and averaged over an 80 millisecond window, resulting in conversion to hill like waveforms. The R wave is located at points where the waveform exceeds a certain defined threshold level [12]. Normal analysis may be implemented by performing frequency analysis of R-R interval time series data that comprise the amount of time between successive R waves, and then calculate high frequency (HF, 0.15Hz-0.40Hz) and low frequency (LF, 0.04Hz-0.15Hz) components as the area below the spectrum of these frequency bands. Para-sympathetic and sympathetic nervous system activity can then be taken as HF and LF/HF, respectively. Inferior quality ECG signal areas due to body movement or deterioration of contact between the skin surface and electrode, or the superimposition of power line alternating-current

noise, however, may generate a fake RR interval and affect the results of the RR interval frequency analysis. We have been classifying and removing false RR intervals by considering the distribution behavior of the RR intervals [12].

**C. Time frequency analysis:**

Since RR intervals form an unequal interval time series, they had to be converted to an equal interval time series for frequency analysis. How to convert the data determines the upper limit frequency used for frequency analysis. In this study, we resampled RR interval time series using a re-sampling frequency of 2 Hz, and performed time frequency analysis up to a level of 1 Hz. We set analysis epoch as 512 seconds, and for each epoch we performed a time frequency analysis of RR intervals using the SPWV (Smoothed Pseudo Wigner-Ville) method, obtaining time frequency MAPs. Details have been reported previously [12]. In time frequency analysis, it is impossible to have simultaneous large time and

duration in M-BIT measurement, we automatically detected SA only from RRIV based on CVHR. Our accuracy was 75.6%. Details are publicly available [15]. We judged apnea or normal epoch by epoch, and defined sleep apnea safety index (SASI) as the proportion of normal epochs to the total epochs. Previously we reported SASIs about university students (age 21.6±3.2), whose sleep and respiration during sleep were judged normal by PSG examination, calculated by sleep PSG ECG data as 0.81±0.08 [16]. Hence, the level of SASI below which considerable amount of SA exist was thought to be 0.73[2].

**Results And Discussion:**

**A. Time frequency map of the most stressful situation:**

An example of time frequency MAP for 512 seconds was shown in Fig. 1. The horizontal axis was time with 1 minute’s grid and labeled as the form of hours and minutes. The vertical axis was frequency and HF, LF and VLF zones were indicated. Colors indicated absolute values of intensity, as White corresponded to minimum, and as the increase of the value, color changed in the order of Red, Orange, Yellow, Green, Blue and Black. In Fig.1, equal interval converted RR interval time series used the calculation of the MAP, respiration frequency (Resp. Freq.), para-sympathetic and sympathetic nervous systems activity (PSNS act. and SNS act.) and VLF together with their scale range and lower and upper base lines were also plotted. Furthermore, above these plots, accelerations of up-down, right-left, back-forth directions were plotted. Here, since acceleration only indicated the existence of bus moving or posture change of the driver, their scales were not plotted. As shown in Fig.1, acceleration data indicated the bus was stationary state until 8:56. At this time, RR intervals were longer and fluctuated frequently, PSNS act was larger and SNS act was smaller. A little before 8:56, the frequent change of RR interval disappears, then accelerations started vibration and RR interval starts a monotonous and big reduction. PSNS act decreases rapidly and a large peak of VLF appeared. This situation was the same as those of we observed in a subject at 33th floor of tower residential building at the large earthquake [17] or subjects taking thrill drive [18]. This large decrease of RR interval meant large decrease of PSNS act which usually keeps RR intervals longer values, and beyond the concept of ANSA assessment based on RRIV. And we did not

Subject	Age	1st		2nd	
		services	note	services	SASI
1	40	○		○	0.57
2	72	○		○	n.d.
3	72	○	arrhythmia	○	0.85
4	68	○		n.d.	n.d.
5	33	○		○	0.88
6	73			○	0.90

frequency resolution. In our previous studies, we tuned our analysis to provide a large time resolution [13] or frequency resolution [12]. In this study, we tuned as both the time and frequency resolutions were moderate. We calculated very low (-0.04Hz), low (0.04Hz-0.15Hz) and high(0.15Hz-0.40Hz) frequency components (VLF, LF and HF) as the sum of the absolute values of the time frequency map of corresponding frequency bands along the frequency axis for each 0.5 second. As instantaneous central frequency (CFR) from 0.15 Hz (lower limit of high frequency band) to 1.0Hz, we calculated respiration frequency. We set HF and LF/HF as indexes of para-sympathetic and sympathetic nervous systems activity.

**D. Sleep apnea:**

Usually, for automatic sleep apnea detections, both of RRIV and ECG derived respiration which based on the variation of R wave heights, and detection of Cyclic Variation of Heart Rate (CVHR) were used and high accuracy of 83.0%-89.4% were achieved [14]. However, since R wave height is not always quantitatively reliable over the sleep



expect that such a situation occurred during daily driving of professional drivers.

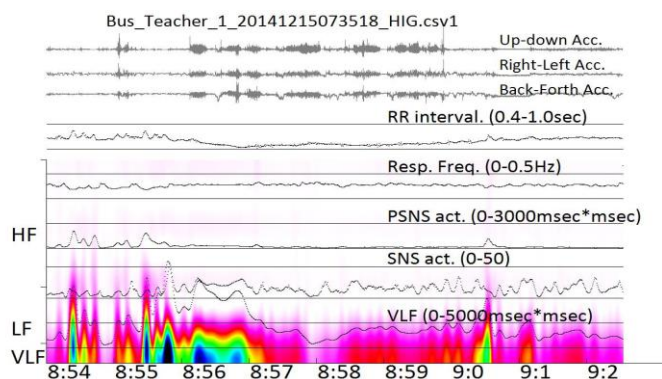


Figure 1 A example of time frequency map. (Subject1, the most stressful situation)

B. RR interval variation throughout morning services

Although, we calculated time frequency map for all the morning service data of all the subjects, their stress levels of most stressful situations were beyond the assessment of ANSA by RRIV, and could be detected easily by RR interval data itself. Figure 1 shows the RR intervals of subject 1 during morning services. The existence of large decrease of RR interval, i.e. the most stressful situation, existed at 530-550 minutes (8:50-9:10). The results of all the 5 drivers showed similar decrease of RR intervals (DECREASE) at almost the same time. In the morning, they had two services. The time position of DECREASE corresponded to the time zone from returning time from the first service to start time to the second service. And, here, at the time of second service start, “un-safe cut in” were reported. Hence, the DECREASE might cause “un-safe cut in”. Thus, the most stressful point of morning services existed within Nazareth Kindergarten area.

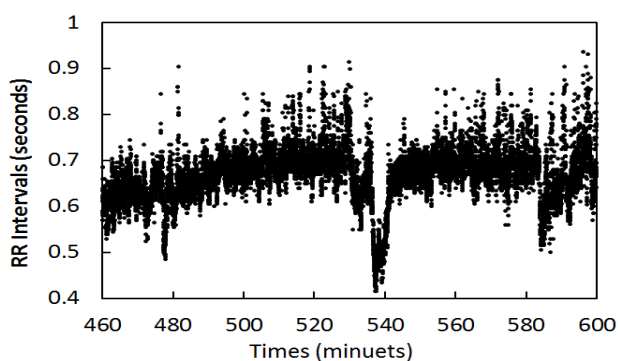


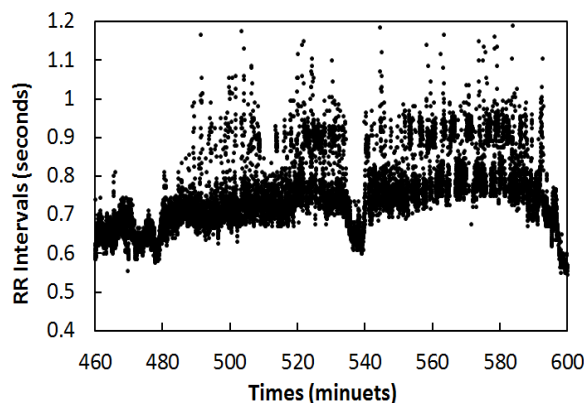
Figure 2 RR intervals during morning service. (Subject1)

C. The most stressful situation and un-safe cut in

Besides the confirmation of reproducibility, we observed the behavior of buses when they were within kindergarten area. We confirmed the reproducibility of DECREASE at the same position. Around 8:50, the first services returned with children and made children get off from the bus in the garden of kindergarten. Then they moved to adjoining parking lot. Parking lot was not so large, and many cars of teachers and parents who brought their children were parked in disorder. Furthermore, several cars and persons were moving within the parking lot. Buses entered parking lot, repeated the turn by the back and moved to the standby position. In some cases there was no backward confirmation and instruction by attendant teachers, in some cases did not well functioned. This was the time that drivers felt large stress and the DECREASE occurred. Within several minutes, they started for the second service. The traffic of road were increased in this time, and due to the existence of the adjoining structure, visual confirmation of the traffic situation of the road at the time of coming out from the parking lot was rather difficult. “Un-safe cut in” occurred here. DECREASE still adversely influenced driver’s driving performance, cognition and decision making at this time. We proposed that structured parking in the lot and cooperation of driver and attendant teacher will decrease the occurrence of stress, shortening of RR interval and thus “un-safe cut in”. These two were performed immediately.

D. Occurrence of arrhythmia during driving

Although the subject 3 did not have recognition that he has arrhythmia, arrhythmia occurred frequently at the time of morning service as shown in Fig.3 at the first measurement. Since the frequent occurrence of arrhythmia started a little after the start of first service and ended after the service, there is strong possibility that driving causes arrhythmia. In the second measurement, this arrhythmia was not observed.



**Figure 3 RR intervals during morning service. (Subject3)**

**E. Sleep apnea**

Subject 1 had sleep apnea as shown in TABLE I. Now we are confirming whether it was just temporary or habitually or always.

**Conclusion:**

For Nazareth Kindergarten bus drivers, the most stressful situation was turning to move to the standby position in narrow and crowded kindergarten's parking lot, in this case. And stress occurred here caused "un safe cut in" of kindergarten bus. To reduce these stresses, structured parking in the parking lot and effective cooperation of bus drivers and attendant teachers had started in Nazareth Kindergarten. These efforts may decrease drivers stress, and thus, improve the safety of bus. Other risky-factors for driving, the occurrence of arrhythmia due to driving, and frequent occurrence of apnea during sleeping were also detected in some drivers. Now, we are confirming whether they were just temporary or habitually or always.

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