Microsleep Prediction Using an EKG Capable Heart Rate Monitor

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***Abstract*—Microsleep is an involuntary episode of sleep which lasts for a fraction of a second or up to one minute where an individual fails to respond to their environment and becomes unconscious. Because of the lapsed time, microsleep can create dangerous situations, for example when a user is driving a car, any microsleep can result in unsafe situations or even death. In this paper, we design a system that detects and predicts microsleep using data gathered from an EKG capable heart rate monitor. The results of our study show that we detect microsleep correctly 96% of the time and we can predict the time period in which the next microsleep will occur 83% of the time. These predictions occur between 15 seconds and 5 minutes before the next microsleep. After a microsleep is detected or predicted, the system alerts the subject, allowing the shortening of current and prevention of future microsleeps.**

I. Introduction

Drowsiness is a major cause of automobile accidents and is the cause of approximately 40,000 injuries and 1,500 deaths in the US each year [1]. Nearly 55% of drivers have driven while drowsy and 23% have fallen asleep while at the wheel [2]. Microsleep is period of sleep which may last for a fraction of a second or up to 1 minute where an individual involuntarily lapses into unconsiousness and fails to respond to sensory input [3]. During the microsleep the individual may fail to respond to sensory input, have no memory of the lapse in time due to sleep, or be able to respond to you but have no idea what is happening around them.

Microsleep can be caused by a variety of sources including but not limited to sleep deprivation, diseases, disorders, pharmaceuticals, sickness, and just plain tiredness [4], [5], [6]. The symptoms of microsleep can be subtle and difficult to detect. Symptoms include nodding of the head, drooping or closed eyelids, staring off into space, and lack of or difficulty concentrating [7]. It is common for individual who is experiencing microsleep to not be aware of the event [8]. It can be just as difficult, if not sometimes more difficult to realize if someone is microsleeping around you as they may seem fully awake, responsive, or be able to snap right out of their daze. Prevention of microsleep can be difficult when individuals do not always realize they are experiencing microsleep.

The goal of this study is to accurately detect and predict an occurrence of microsleep. This will allow us to not only alert the individual that a microsleep has occurred but also prevent the microsleep all together. To achieve this goal, we performed a study with 10 participants (IRB approved with PHSC protocol number 10683) in which each participant was asked to wear an electrocardiogram capable heart rate monitor while in a situation that could lead to microsleep. The results of this study show that the participants heart beat is highly correlated with occurrences of microsleeps. This paper makes the following contribution: it presents a method to detect and predict microsleep using only an electrocardiogram capable heart rate monitor.

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II. System Design and Evaluation

Figure 1 displays the overview of our system for Microsleep Prediction. It begins with a wearable electrocardiogram devices, extracts the heart beat, runs a low pass filter to remove the noise, and finally extract the features to detect and predict microsleep.

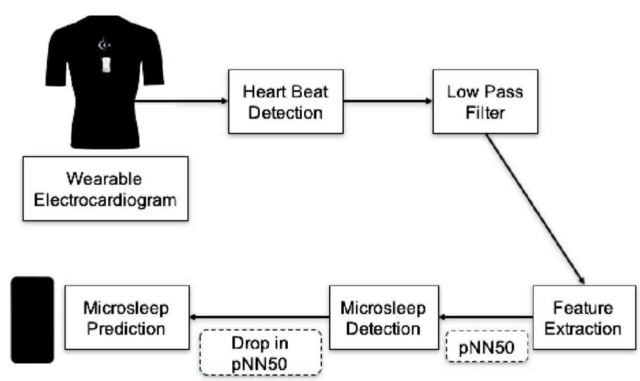

Fig. 1: Overview of the System for Microsleep Prediction.

A. Heart Beat Detection

The cardiovascular system is influenced by the sympathetic and parasympathetic pathways of the autonomic nervous system [9]. HRV analysis quantifies the autonomic nervous system and can be used to it can be used to differentiate between a stress response and a resting response [10].

B. Data Normalization

Biometric data is known to be noisy [11]. To remove this noise, we remove any data in which the heart rate is zero or the RR interval is negative. Next, we use a low pass filter that removes the RR interval if it is more than twenty percent

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different from the previous RR interval. This removes the noise from motion that affects the computation of pNN50, which we will introduce in the next subsection [10].

C. Feature Extraction

pNN50 is the number of pairs of consecutive normal intervals (NN) with a difference greater than 50 milliseconds [12]. We will calculate the difference between the normal intervals as follows:

$$NN_k - NN_{k-1} \tag{1}$$

Then, we designate NN50 to be the number of normal intervals for which we have a difference greater than 50 milliseconds [13]. Now we can compute the final pNN50 score as follows:

$$pNN50 = \frac{NN50}{n} * 100 \tag{2}$$

pNN50 scores range from 0 to 63 as a percentile range. Low pNN50 scores indicate a stressed response and high pNN50 scores indicate a rest response.

D. Microsleep Detection

To detect if a microsleep has occurred, we evaluate the pNN50 scores for a rest response. If the scores are above 20, the participant is drowsy and we perform peak detection with slope pattern analysis to detect whether a microsleep has occurred. We detect microsleep correctly 96% of the time and have a false positive rate of 1.6%.

E. Microsleep Prediction

Once we know a microsleep has occurred we predict when the next microsleep will occur using the change in pNN50 score after the last microsleep. For each participant we created an empirical cumulative distribution function using the change in pNN50 score and the time from the previous microsleep to the current microsleep. We predict 30 second window at which the next microsleep will occur 83% of the time. The false positive rate is 12% due to the participant leaving the situation that is causing their microsleeps. These prediction occur up to 5 minutes before the next microsleep.

III. Related Work

A fair amount of work has been done working to combat drowsy driving [14], [15], [16]. Work has also been done using biometrics to detect microsleep events using EEG sensors, eye tracking technologies, and heart rate variability methods [17], [18], [19]. These works include many different disciplines and many technologies but, to the best of my knowledge, there has not been a solution that is noninvasive and accurate, which we aim to provide.

IV. Conclusion

To prevent microsleep in unsafe conditions, it is necessary that we learn to track and alert users before a microsleep occurs. The results of our study suggest that HRV analysis on EKG data can be used to accurately determine when someone microsleeps and predicts when they will microsleep. Our predictions will occur from 15 seconds to 5 minutes before the next microsleep. This will give the user time to mitigate the consequences of a microsleep in a dangerous situation.

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