Measurements to Detect Mental Fatigue

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<u>Abstract</u>

Introduction

Mental fatigue is defined as a "state of reduced mental alertness that impairs performance" It affects nearly everyone in society at some point and has become one of the leading causes of workplace accidents [2]. Common symptoms of the condition include discomfort, tiredness, and reduced motivation [1]. Recently, there has been a significant push for the development of technology to detect mental fatigue and prevent related accidents. Through this project, I will review current detection methods and their results. I will then explore whether such a detection system is possible to create with current technology and whether it could feasibly be implemented in real world scenarios.

Review of Detection Methods

Several signals have been analyzed in their reliability of detecting the onset of mental fatigue. These are blink rate, heart rate variability, respiration, and brain activity. Since blink rate increases with fatigue, it can be analyzed using continuous recording and facial recognition techniques. Similarly, heart rate variability increases and respiration rate becomes more erratic. Both can be measured with physical sensors or physical sensors. Out of these, brain activity is the most accurate indicator of mental fatigue and has to be monitored with an EEG sensor.

Review of Results

Yamada and Kobayashi collected eye tracking data from subjects who watched video clips before to induce mental fatigue. They found that participants showed significant increases in blink rate and duration as they became more fatigued and a fatigue detection model was developed which was able to achieve 91% accuracy [6].

To investigate the effects of mental fatigue on heart rate variability and respiration, Huang and his team gave 35 participants a wearable ECG device known as "LaPatch," which was capable of recording ECG and respiration states. Four classifiers were created and out of these KNN was the most accurate with a 75% chance of correctly identifying mental fatigue [5].

Tanaka and others conducted a study to understand how mental fatigue affects cognitive performance. Magnetoencephalography data was recorded and analyzed.

They found that these tasks caused the alpha frequency band power, 8-13 Hz, to decrease, which suggests that mental fatigue causes over activation of the visual cortex [1]. Another approach by Shen and others used Electroencephalography data, which was then classified by a support vector machine algorithm. The results indicated a 90% accuracy in detecting lapses in cognitive performance [2].

Discussion

The main deterrent to developing a mental fatigue detection system with all four of these signals is that it would not necessarily be contactless. Including an EEG reading would significantly increase the accuracy of the system overall, but it is the only signal that requires a physical sensor. The most beneficial detection system would have to be entirely contactless in order to be applicable in multiple situations and this is not possible with the current technology. As such, currently there is no detection system for mental fatigue on the market.

Key words: mental fatigue, cognitive performance, blink rate, heart rate variability, respiration rate, brain activity

<u>Introduction</u>

Mental fatigue is characterized by a transient decrease in maximal cognitive performance due to prolonged periods of activity. Prolonged periods of fatigue can impair memory, judgement, decision making, emotional control, and in extreme cases lead to mental disorders such as anxiety and depression. If left untreated, it can even lead to health problems such as Cerebrovascular/Cardiovascular Disease (CCVC), diabetes, and cancer [3].

One notable example of mental fatigue is troops in combat situations. The combined performance of several demanding tasks is enough to induce fatigue. These conditions are unfortunately exaggerated by sleep deprivation and can lead to resistance in continuing tasks [7]. Similarly, endurance athletes face the impact of mental fatigue during training. In this case, athletes' decrease in drive to exercise can be contributed to two factors. Mental fatigue can activate the brain's inhibition center as well as deactivate its facilitative center. As a result, the athlete feels that the task requires an increased amount of effort and loses motivation to continue [8]. However, mental fatigue is an issue that affects everyone at some point in their lives. The most common people affected by mental fatigue are arguably those in office environments. Repetitive, monotonous tasks, such as working on a computer, are known to induce mental fatigue over time. People continuously working long shifts are more likely to have chronic fatigue as a result [9]. No matter the occupation, a person's safety is at risk because of higher accident levels, absenteeism, and reduced productivity [3].

Currently, mental fatigue is not used as an indicator in a person's health status. However, if left untreated, it can lead to serious consequences. An accurate detection system would not only lead to increased productivity, but also increased safety. Once someone

becomes aware that they are experiencing mental fatigue, they can take the necessary steps to alleviate the issue and improve their wellbeing. Through this project, I will review current detection methods of mental fatigue and their results. I will then explore whether such a detection system is possible to create with current technology and whether it could feasibly be implemented in real world scenarios.

Review of Detection Methods

There are various signals that can be affected by the onset of mental fatigue. One such signal is blink rate. As a person becomes more fatigued, their blink rate tends to increase due to eye strain from concentrating too long. Blink rate can be acquired fairly simply through computer vison techniques. One common method is by using a webcam and facial recognition. Once the eyes are isolated, light intensity can be analyzed over time. For instance, a shift from dark to light pixels would indicate the eyes going from closed to open [6].

Another viable signal is heart rate variability, which is the time interval between heartbeats. Similar to blink rate, heart rate variability increases as an individual experiences mental fatigue. It is possible to detect heart rate variability through an entirely contactless method, but the output is not reliable. Therefore, it would be better to use a physical ECG sensor, even though it might make the system inoperable in all situations. One possible solution to this though, is using a wearable ECG, such as a smart watch, as they are more accessible to the general public [5].

Mental fatigue also affects respiration rate. While it is not clear exactly how, fatigue does cause respiration to become more erratic. Respiration can be derived from video-photoplethysmography (video-PPG) data. From this, pulse rate variability, pulse width variability, and pulse amplitude variability are calculated and used to create an expression for overall respiration. It is also possible to find respiration through airflow-based methods, which are more commonly used in clinical settings [4].

However, changes in brain activity would be the most accurate indication of mental fatigue. Electroencephalography (EEG) measurements have previously shown that theta and alpha wave activity increases as a person becomes more fatigued. Unfortunately, EEG data is not usable in most real-world scenarios. This is because it cannot be measured contactlessly with current technology, as it requires multiple sensors on the subject's head [6]. Although, it may be acceptable to implement an EEG recording system into soldiers' helmets. As long as it does not interfere with their other equipment, the EEG could be wirelessly transmitted to a team at the base who would continuously monitor it for anomalies.

Review of Results

In their study, Yamada and Kobayashi collected eye tracking data from subjects who watched video clips before and after performing cognitive tasks to induce mental fatigue. Throughout these tasks, their eyes were recorded. The data was then analyzed for blink rate.

They found that participants showed significant increases in blink rate and duration as they became more fatigued. This corresponded with them self-reporting the onset of fatigue in questionnaires. Afterwards, a fatigue detection model was developed which was able to achieve 91% accuracy [6].

To investigate the effects of mental fatigue on heart rate variability and respiration, Huang and his team gave 35 participants a wearable ECG device known as "LaPatch," which was capable of recording ECG and respiration states. Data was recorded for about 60-80 minutes, which was before, during, and after the participants took a quiz intended to induce fatigue. This data was used to create several classifiers: support vector machines, k nearest neighbor, naive bayes, and logistic regression. Of these, KNN was the most accurate with a 75% chance of correctly identifying mental fatigue [5].

Finally, in hopes to understand exactly how mental fatigue impairs cognitive performance, Tanaka and others conducted a study with 13 volunteers who performed fatigue inducing tasks. Magnetoencephalography data, which measures magnetic fields produced by brain activity, was recorded and analyzed. They found that these tasks caused the alpha frequency band power, 8-13 Hz, to decrease, which suggests that mental fatigue causes over activation of the visual cortex [1]. Another approach by Shen and others used Electroencephalography data from 10 volunteers who went through sleep deprivation experiments. They also had to complete a vigilance task in that state. The goal of this study was to classify mental fatigue into five levels using probabilistic based multi class support vector machines. The results indicated a roughly 90% accuracy in detecting lapses in cognitive performance [2].

Discussion

Mental fatigue is a serious health issue that is being overlooked. It causes reduced motivation, tiredness, and impaired judgement, among other symptoms. Loss of productivity not only negatively affects soldiers, athletes, and workers, but also businesses and institutions alike. Being able to reduce the number of accidents that occur due to mental fatigue would be beneficial to all.

Thus, the need for a reliable mental fatigue detection system arises. Four signals affected by fatigue are blink rate, heart rate variability, respiration, and brain activity. All of the mentioned studies reflect the potential of developing such a detection system. As shown in the previous section, each signal can be accurately recorded and analyzed to detect the onset of mental fatigue. In the case of blink rate and brain activity, it is possible to have a 90% accuracy with the use of classifiers. Heart rate variability and respiration rate can be used to classify a user's mental fatigue with 75% accuracy. Compared to the other signals, this is not reliable and further development has to be done on a sensor or technique for these signals to be acquired before it can be used in a real-world scenario.

The main deterrent to developing a mental fatigue detection system with all four of these signals is that it would not necessarily be contactless. Including an EEG reading would significantly increase the accuracy of the system overall, but it is the only signal that requires a physical sensor. For soldiers, this would not be an issue because the sensors could be built into their helmets or other equipment. However, for an athlete or someone working a desk job, these would hinder their performance. The most beneficial detection system would have to be entirely contactless in order to be applicable in multiple situations and this is not possible with the current technology. However, a completely camera-based system may be more costly and also raise ethics issues over continuous recording. These factors could turn away potential businesses from developing the technology. As such, currently there is no detection system for mental fatigue on the market.

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