Predicting Fatigue Impairment for Industry

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INTRODUCTION

Human performance can be critically impacted by fatigue resulting from inadequate sleep. In a technological society, the consequences of fatigue-related inattention and impaired response time are greater than ever. Industries such as aviation, rail, trucking, and medicine are mandated to have a Fatigue Management System (FMS) in place to ensure their personnel are ready for duty.

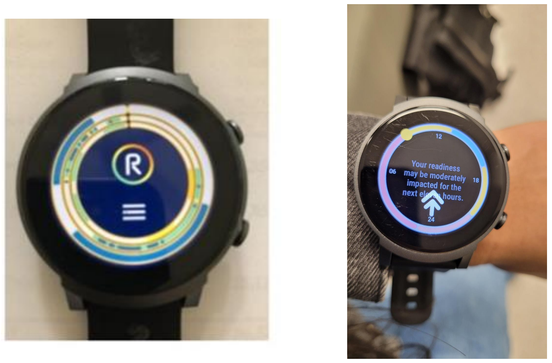

Figure 1. COTS smartwatch with app shows real time fatigue information at a glance based on sleep quality history

A biomathematical model of fatigue was created from cognitive test data collected during a 72 hour sleep deprivation study. A single prediction curve was generated from linear (hours awake) and cosinor (circadian) curve fits to the data.

OBJECTIVES

- Compare the similarity between the clinically-approved actigraph measures of sleep movement, and sleep quality with those of the COTS watch application.
- Compare the similarity between subjective fatigue measures and the fatigue score estimated from the biomathematical model used in the COTS watch.

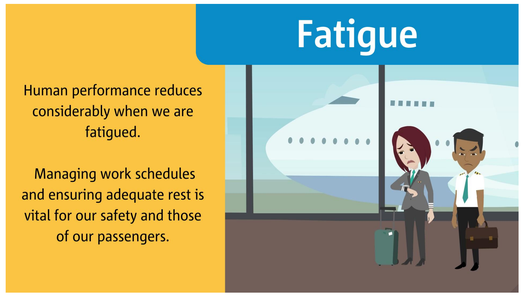

Figure 2. Efficient management of fatigue is essential for safety in many industries, perhaps especially in aviation.

It has been estimated that the costs from the national sleep debt is more costly than the national debt (Pelayo, 2020), considering lost hours of work, injuries on the job and spreading illness to a workforce impaired by sleep deprivation. Work by Arnedt (2005) and Dawson (1997) and others have shown that after just 20 hours of sleep deprivation, young adults are as impaired as if they had a BAC of greater than 0.1 %. Clearly fatigue management is ever more important to safe society.

METHODOLOGY

A COTS watch and a military-grade actigraph were used to collect sleep and fatigue data from college students. The data from the actigraph generated the duration and restlessness of sleep. The COTS watch collected similar data, and also collected data on sleep quality to be used in the model that estimated fatigue.

Participants were given both watches to wear to sleep for at least four consecutive nights. They were instructed to maintain their normal sleep habits. They entered a number on the watch to indicate fatigue throughout the day.

After their data was recorded, participants returned the watches to the researchers for data analysis.

RESULTS

The results comparing the sleep movements and duration from the actigraph with the watch app are shown in Figure 3.

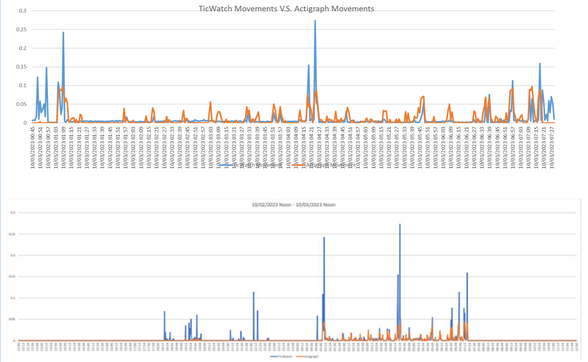

Figure 3. Two representative demonstrations of the accelerometers in the smartwatch (blue) compared to those in the actigraph watch.

The results of comparing subjective fatigue scores throughout the day with those of the fatigue estimate from the watch app are shown in Figure 5.

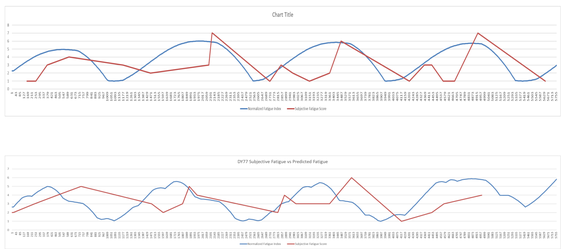

Figure 4. Comparison of subjective fatigue from the COTS watch with the app's model for predicted fatigue.

DISCUSSION

The actigraph compares favorably with the polysomnographic measures of sleep so it is approved for use in sleep labs. It costs over $3000 and requires an expert to program and analyze the information. The COTS watch costs under $200 and all the features of a smart watch in addition to sleep analysis.

Both determine sleep quality. The watch estimates the level of awake fatigue impairment based on sleep history and quality. The watch data are presented in real time and also available for research purposes.

There are many smart watches that purport to measure sleep but none to date have been rigorously tested against clinical sleep lab standards and none report on sleep quality in ways that are easily and quickly calculated for FMS. Biomathematical models that estimate fatigue for FMS are often based on simple response time measures and require expert analysis. Our model is based on a complex, cognitive task popular in human performance literature (Divided Attention task); like the multi-tasking in real world operations.

For these reasons, the watch app is a better choice for a FMS. Real time data are available to the wearer and to the safety monitor of organizations that use an FMS.

CONCLUSIONS

We are still in the data analysis process but preliminary data indicates the COTS app is as accurate as the actigraph in assessing sleep quality. Also, the application seems very good at predicting subjective fatigue levels

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