

Mine Worker Fatigue and Circadian Rhythms

How biological clocks respond to light and darkness

By Max Martell



The mining industry often uses shift work schedules with the intention to have a productive working mine around the clock. However, one potential side effect of operating on a 24/7 basis can be the disruption of circadian rhythms, which results in worker fatigue — the mental state between wake and sleep.

Fatigue from shift work has the potential to decrease productivity and increase accidents in organizations where workers are overly fatigued (Dawson et al., 2000). In open pit mines fatigue-related accidents account for up to 65% of truck driving accidents alone (Schmidt, 2015).

The detrimental effects of severe fatigue include more than loss of productivity and accidents. Several potential health effects are directly associated with fatigue, including trouble sleeping, decreased alertness, slower reaction time, and a weakened immune system. Workers suffering from fatigue also show a general decline in cognitive abilities, such as problem solving and working memory. More serious health consequences of long-term chronic fatigue may include diabetes, obe-

sity, heart disease, and an increased risk of cancer (Kecklund and Axelsson, 2016).

Although one cause of fatigue is lack of adequate sleep, fatigue is not the same as sleepiness. Additionally, fatigue can result from the disruption of circadian rhythms, also known as the body's "biological clock." Circadian rhythms are highly affected by the natural cycle of daylight, and varying exposure to light causes a disruption. Hence, shift workers are inherently at risk of circadian disruption, with their working hours extending into the night or early morning. This disruption can cause us to have problems with getting enough sleep. Even one night of poor sleep — defined as either less than seven consecutive hours or frequent waking — can have negative effects on our health (Watson et al., 2015).

Light and Circadian Rhythms

Short wavelengths of light, which are mostly blue, are abundant in daylight. The human eye's responsiveness to these short wavelengths is what causes the sensitivity of circadian rhythms to daylight

(Figueiro et al., 2016). During the day, the plentiful bright, blue light creates alertness. At night, the lack of blue light signals the brain that it is time to sleep.

However, for night shift workers, working at night and sleeping during the day disrupts the normal day/night progression. Furthermore, artificial light sources such as shop lights and computer screens disrupt the natural cycle of light and dark after sunset. These light sources are often high in short wavelengths and attempt to mimic daylight, since that spectrum of light improves both visibility and alertness. This leads to a disruption in circadian rhythms by confusing the body into thinking it is still daytime. As a consequence, workers on the night shift can experience difficulty sleeping after their shift.

We also face a risk of circadian disruption during the day. When we do not get enough blue light exposure throughout the day, our body does not fully wake up. Just as with the previous scenario, when our biological clocks do not align with the natural light cycle, the misalignment can delay our normal period of sleep and cause us to have trouble sleeping.

Underground miners are one group at high risk for circadian disruption. Not only do they often work shift schedules and long hours, they may spend the majority of the day underground, where artificial sources supply all of the light. Even with bright white lights, like LEDs and fluorescents, it is very difficult to get light exposure equivalent to that of daylight while underground. On some underground mining equipment, amber colored lights filter out much of the blue light. The problems are made worse by the low reflectivity of the environment, making the ambient light darker as it reflects back very little of the available light. Consequently, much less light reaches the eye than normal. Making the problem worse still is the aging population of the mining workforce. As we age, our ability to see shorter wavelengths of light decreases, adding to the

challenge of getting enough light exposure while underground (Boyce, 2014).

Measuring Fatigue

People experience fatigue to varying degrees, and fatigue-causing factors affect some more than others. A person's age or general health might affect their sensitivity to fatigue. However, there are ways to measure fatigue, which can be a positive first step in addressing it.

Subjective Methods—Subjective methods for measuring an individual's fatigue include surveys and self-questionnaires, such as the Fatigue Severity Scale (FSS). Although this scale does not exactly measure "severity," it does help to evaluate the impact that fatigue has on a person's daily life. In the same way, the Psychomotor Vigilance Test (PVT) determines the impact of fatigue by measuring reaction time and alertness, and the Karolinska Sleepiness Scale (KSS) assesses subjectively how sleepy a person feels. Thus, these methods give us a way to understand the problem on an individual level.

Objective Methods—More direct methods, such as measuring a person's core



body temperature or taking blood samples to measure hormone levels, can determine if there is a disruption of circadian rhythms. However, these procedures are highly invasive and cannot easily be done in real time, making them impractical for measuring fatigue in a working mine. Saliva tests to measure the hormone melatonin, a common indicator for circadian rhythms, are somewhat more practical. Other methods seek to identify fatigue as it happens. These include facial recognition and eye-tracking technology, which monitor

a worker's apparent fatigue level. This approach can make workers uncomfortable, however, as they might consider it an invasion of privacy or disruptive to their work.

Dealing with Fatigue

A more active way of addressing worker fatigue is to use a preventative method. To control worker schedules and help limit shift work and excessive overtime, mine operators can implement a fatigue management system. These types of systems may help to manage fatigue resulting from shift work by first detecting and tracking it, and then making changes to either avoid or manage fatigue over time.

Yet for underground miners, even with a fatigue management system in place there is still the problem with lack of sufficient light. In this case, a lighting intervention may help to prevent the disruption of circadian rhythms. Other workers facing a similar issue are those working in Antarctica, who spend the sunless winter months in dark, isolated areas where the only light is from artificial sources. Similarly, the crew aboard U.S. Navy submarines may spend months at sea without natural light while

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utilizing strict shift work schedules. Both were able to successfully adopt a lighting solution using highly blue-enriched light sources to provide enough illumination and short-wavelength light throughout the day to reduce the misalignment of circadian rhythms (Najjar et al., 2014; Young et al., 2015), which also led to an increase in alertness and quality of sleep.

Using these lights during the night shift, however, would contribute to the disruption of circadian rhythms. Yet workers still need light to do their jobs. One potential solution is to use light sources

with longer wavelengths of light falling in the red spectrum. Research has shown that red light can increase alertness and performance without impacting circadian rhythms (Figueiro et al., 2016).

Such a lighting solution would be challenging to implement in a mine environment, and the exact nature of an intervention remains a subject for future research. However, improving the lighting conditions has the benefit of making hazards more visible to miners, and NIOSH researchers are hopeful that it can also serve as an effective fatigue intervention in underground mines.

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Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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