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The link between fatigue and safety

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ABSTRACT

The objective of this review was to examine the evidence for the link between fatigue and safety, especially in transport and occupational settings. For the purposes of this review fatigue was defined as 'a biological drive for recuperative rest'. The review examined the relationship between three major causes of fatigue – sleep homeostasis factors, circadian influences and nature of task effects – and safety outcomes, first looking at accidents and injury and then at adverse effects on performance. The review demonstrated clear evidence for sleep homeostatic effects producing impaired performance and accidents. Nature of task effects, especially tasks requiring sustained attention and monotony, also produced significant performance decrements, but the effects on accidents and/or injury were unresolved because of a lack of studies. The evidence did not support a direct link between circadian-related fatigue influences and performance or safety outcomes and further research is needed to clarify the link. Undoubtedly, circadian variation plays some role in safety outcomes, but the evidence suggests that these effects reflect a combination of time of day and sleep-related factors. Similarly, although some measures of performance show a direct circadian component, others would appear to only do so in combination with sleep-related factors. The review highlighted gaps in the literature and opportunities for further research.

1. Introduction

Fatigue has been identified as a contributing factor for accidents, injuries and death in a wide range of settings, with the implications that tired people are less likely to produce safe performance and actions. These settings include transport operations such as road, aviation, rail and maritime, as well as other occupational settings (e.g., hospitals, emergency operations, law enforcement), particularly when irregular hours of work are involved. Almost everyone becomes fatigued at some time, either in their work or during their leisure time, and so may be at increased risk of accident or injury. Fatigue effects such as response slowing, failures in attention or failure to suppress inappropriate strategies have been identified in many high profile accidents (Mitler et al., 1988).

In many countries, fatigue is identified as a contributing factor in a significant proportion of road transport accidents (Horne and Reyner, 1995a; Lyznicki et al., 1998; Pierce, 1999; Philip et al., 2001; Dobbie, 2002). Estimates of the role of fatigue in crashes can vary considerably, depending upon the severity and circumstances of the crashes examined. Typical ranges cited are from 1 to 3% of all crashes (Lyznicki et al., 1998) to up to 20% of crashes occurring on major roads and motorways (Horne and Reyner, 1995b). There is general agreement that any percentages based on crash data underestimate the true magnitude of the problem, since the evidence for fatigue involvement in crashes is often questionable, being based on criteria that exclude other factors rather than identifying definite involvement of fatigue.

The objective of this paper is to review the scientific evidence for the link between fatigue, safety and performance outcomes. It will examine such questions as: what do we really know about the link between fatigue and safety? Is there evidence that we should be concerned about the effects of fatigue? Where are the gaps in our knowledge?

In any consideration of fatigue and its effects, the issue often passed over is the lack of a clearly defined and agreed upon definition of fatigue. Fatigue is a hypothetical construct which is inferred

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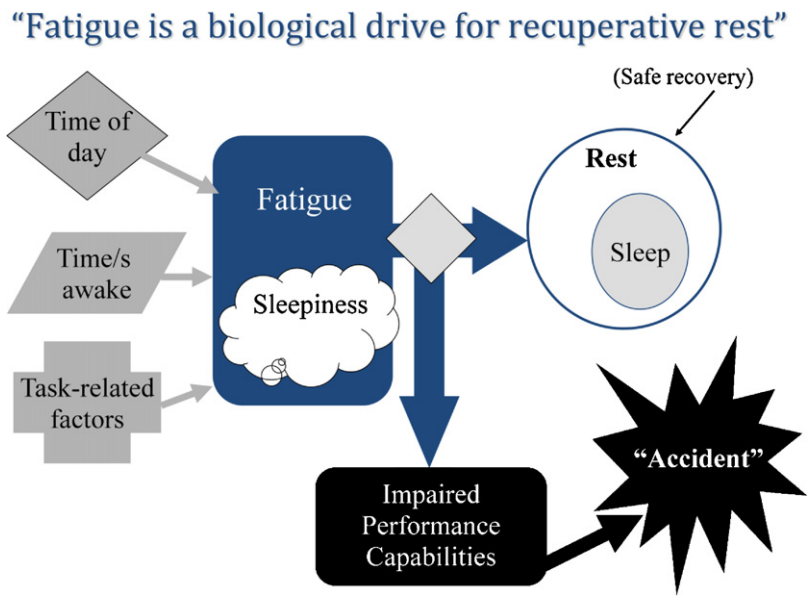

Fig. 1. Framework for examining the relationship between fatigue and safety.

because it produces measurable phenomena even though it may not be directly observable or objectively measurable. Fatigue, as a construct, links a range of factors that presumably cause fatigue with a number of safety-related outcomes. The link between experiences like a long period without sleep and crashes or accidents is through the projected effect of fatigue. Fatigue is the mechanism by which the link exists.

There is little agreement on a definition of fatigue (Desmond and Hancock, 2001; Noy et al., 2011). However, for the purposes of this review fatigue is simply defined as *"a biological drive for recuperative rest"*. This rest may or may not involve a period of sleep depending on the nature of the fatigue. We consider that fatigue may take several forms including sleepiness as well as mental, physical and/or muscular fatigue depending on the nature of its cause. In the context of modern transportation systems it seems probable that sleepiness and mental fatigue are the most important forms of fatigue. In this paper we look at the evidence that all forms of fatigue can result in reduced performance capabilities and safety due to slowed or incorrect responses and/or total failures to respond.

This review examines evidence for the link between factors that are purported to cause fatigue and adverse safety outcomes. It first looks at evidence for effects on clear safety outcomes including adverse incidents and accidents and second at the evidence for adverse effects on performance that may be precursors of safety outcomes. Fig. 1 describes the overall framework for this review. The result of the development of fatigue and sleepiness may be either a safe recovery or a decrease in performance capability which may lead to an adverse safety outcome. The review examines the effects of the main influences noted to increase fatigue which include circadian influences, sleep homeostasis factors of sleep loss and time since last sleep, and specific types of task characteristics. These are shown on the left-hand side of the model depicted in Fig. 1. The model conceptualizes the experience of fatigue and sleepiness as providing the drive for restorative rest and sleep (or safe recovery, as shown on the right-hand side of the model). To the extent that this drive remains unsatisfied, the capacity to perform is impaired and this in turn increases the risk of adverse safety outcomes. Increasing levels of fatigue and sleepiness decrease performance capacity with, of course, falling asleep having the most extreme effects on performance capacity.

This review examines safety outcomes such as accidents and injury and also attempts to summarize concisely the relevant literature on fatigue effects on performance including errors and slowed responding. It could be argued that the most definitive evidence for the effect of fatigue on safety will come from establishing temporal relationships between fatigue and outcomes like crashes, injuries and accidents. At the heart of this contention is the argument that evidence of changes in performance and behavior alone do not necessarily imply increased risk of adverse safety outcomes. Further, evidence from laboratory or even simulation studies has been critiqued as inadequately reflecting operational or real-world performance. Nevertheless, there is a large body of peer-reviewed and position papers on the link between fatigue, or the factors that cause it, and performance, which is based on the often implied rationale that decreases in performance functions are of importance as they signify increased risk of adverse safety outcomes.

Dinges and Kribbs (1991) formally stated the argument for this body of research and put forward the notion that performance is a critical probe of central nervous system capacity, primarily that performance changes are the functional consequences of the physiological effects of fatigue. Further, they argued that performance changes are a way of linking direct evidence of fatigue effects of sleep loss from laboratory studies with field studies where performance decrements are potentially more readily observable than infrequent adverse safety outcomes. Thus, the review includes performance effects as well as overt safety outcomes of fatigue. The review will focus mainly on the effects of fatigue on transport safety, especially motor vehicle safety, as well as on safety in occupational settings.

The review follows the framework shown in Fig. 1. It first covers the evidence for the effects of circadian, sleep homeostasis and task-related factors on fatigue and safety outcomes. It then examines the evidence for each of these influences on performance capacity. Finally, it summarizes the evidence for the link between performance and safety outcomes. In addition to reviewing the available evidence, the review identifies needs for further research.

2. Link between fatigue and safety outcomes

This section describes the evidence for the relationship between the causes of fatigue, including circadian, sleep homeostasis and