Summary:

An assessment of studies of human fatigue in land and sea transport

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Field and survey studies measuring operator fatigue in land and sea transport are assessed against an argument that a broad operationalization of fatigue is required in order to fully understand it. Our assessment finds that the progress towards an understanding of fatigue in transport is restricted by a range of different but narrow conceptualisations of the construct. One result is that we know little about the relative prevalence of fatigue in different transport operators, a situation which could be improved using a standardised measurement battery for the assessment of operator fatigue. Further implications are that important contributors to fatigue, such as recovery from work during non-work life, have been neglected, as have some important outcomes such as the longer term safety impacts of operator burnout. Better management of the risks of fatigue in transport requires that future studies address important knowledge gaps by attending to the broader concept of fatigue.

Despite technological developments, human operator fatigue continues to threaten safe transport by road, sea, rail or air. One way to improve matters is to encourage understanding and application of research into transport operator fatigue. The current report hopes to help do this by reviewing and assessing research on fatigue in operators working in different transport contexts.

Assessment in terms of how fatigue is thought about

Fatigue is an abstract, diffuse and complex construct, with intractable psychological, physiological and performance aspects. The effect of fatigue on performance may be of ultimate interest to transport managers and regulators, but a conceptualization of fatigue solely in terms of performance will be problematic, not least because fatigue often does not clearly manifest itself in performance. Because of the risks involved, most transport operators are highly motivated to maintain performance in the face of experienced fatigue, and evidence suggests that they do this successfully, at least across the hours of a normal shift. Researchers increasingly accept that there are costs involved in maintaining performance, e.g. the operating strategy may be simplified or there may be longer-term health decrements because of the increased effort involved. These hidden or "latent" decrements may be detrimental to safety in ways that are not immediately obvious to either the operators or their organizations. In order to fully understand the effects of fatigue, there is a need to measure and account for fatigue in terms of how it is experienced, how it affects operator physiology, and how it can affect performance in both obvious and subtle ways. Reflecting this, the following definition of fatigue is employed as a basis for assessing how fatigue studies to date have operationalized the construct:

Fatigue is a suboptimal psychophysiological condition caused by exertion. The degree and dimensional character of the condition depends on the form, dynamics and context of exertion. The *context of exertion is described by the value and meaning of performance to the individual; rest and sleep history; circadian effects; psychosocial factors spanning work and home life; individual traits; diet; health, fitness and other individual states; and environmental conditions. The fatigue condition results in changes in strategies or resource use such that original levels of mental processing or physical activity are maintained or reduced.*

This definition implies that psychological and physiological aspects need to be measured in order to fully understand the state of fatigue. In order to understand the fatigue process, we need to characterize the form, dynamics and context of exertion, in addition to actual and latent performance. Studies can thus be assessed according to their relative treatment of the fatigue state and process. The above definition also accounts for sleepiness as an integral component of the experience and process of fatigue, in terms of the role of "rest and sleep history" and "circadian effects" in exertion. An interesting question is whether and how different studies account for sleepiness in their treatment of fatigue.

Assessment of knowledge using the fatigue risk trajectory

The implicit aim of many studies of human operator fatigue is to inform practice. One way to assess the extent to which they do this is to structure the knowledge collected from these studies according to different levels of fatigue risk management, using a version of Dawson & Fletcher's (2001) fatigue-risk trajectory modified to account for our broad conceptualization of fatigue. The modified trajectory is aimed at managers and regulators, and presents five levels at which they should monitor and provide countermeasures for fatigue in human transport operators:

1. Work time, work quality, non-work life quality.
2. Actual recovery from work.
3. Reports of fatigue and behavioural symptoms.
4. Fatigue-related errors.
5. Fatigue-related incidents and accidents.

86 studies on operators working in road, rail and maritime sectors

Our assessment was carried out on field or survey studies from the last 40 years that attempted to measure fatigue in human transport operators working in the road, rail or sea sectors. We retrieved 86 studies: 24 from shipping, 39 from the road sector and 23 from the rail sector.

Most of the road studies focus on poor sleep, working time and occupational and framework conditions as contributors to fatigue. Most involve long-haul truck drivers, though there are several studies of bus driver fatigue. In the road studies fatigue is often operationalized as generalized sleepiness, although several consider acute sleepiness or acute broader fatigue.

Rail studies are more concerned than road studies with assessing acute sleepiness due to recent schedules worked. There is also a greater focus on the longer-term effects of fatigue, and health-related factors arising because of shiftwork appears to be a particular concern. Despite this, chronic fatigue or burnout are rarely considered explicitly.

Many studies on the causes of seafarer fatigue have tended to focus on the link between different watch patterns and sleep, especially for watch officers. Studies may survey a large number of crew, or there may be more intensive measurement of a few crew on a single vessel. Generalized fatigue has been operationalized using a range of standard measures. Self-reports on momentary fatigue or sleepiness are also common. Attempts to generalize about prevalence rates are complicated by the heterogeneous nature of shipping and the wide range of fatigue measures employed, although one study finds that seafarers generally report fewer fatigue symptoms than do truck drivers.

Need for a standardized measurement battery

As a result of our assessment we found that an understanding of fatigued states in transport operators is limited by studies using unique customized measures or one or two of a range of different standardized measures. Few studies assess the different dimensions of experiential fatigue. Understanding would therefore be improved if applied studies were to use a standard measure battery that captures not only acute and generalised broader fatigue and sleepiness, but the various important dimensions of experiential fatigue. Such a battery should include instructions on when fatigue and sleepiness should be measured in operators in relation to their work periods.

We identify four candidate measures for such a battery: the Epworth Sleepiness Scale, the Karolinska Sleepiness Scale, the Swedish Occupational Fatigue Index, and the Samn-Perelli measure of fatigue. Tables of average scores and shares of samples scoring above threshold scores on each constituent battery measure would improve understanding and help managers and regulators assess the severity of fatigue in different operator populations. Difficulties associated with the measurement of physiological aspects of fatigue might also be improved by standardization, together with a focus on naturalistic observations of operators in real world settings. Regarding operationalization of the fatigue state, we also find that there is a need for authors to be more explicit about their treatment of sleepiness in relation to fatigue.

A need to address both quantity and quality in work and non-work life

There is increasing recognition that the quality of work may be just as important as the quantity of work (i.e. work time) in terms of the effects on sleep and resulting fatigue. Given this, we find that there is a need to study how the psychosocial and physical quality of work interacts with working time to cause fatigue. We also find that the quality of life outside work has been overlooked as an important contributor to fatigue at work. While several studies in different sectors address the influence of framework conditions on fatigue, comparative studies of the different conditions faced by operators in different subsectors would illustrate more clearly to regulators and organizations, the effects of various business drives on operator fatigue.

Better ways to study performance effects

Improved reporting of near misses and accidents in all sectors would help in the study of the role of fatigue. Self-reports of performance levels could be improved by standardizing the periods for which operators are asked to report on incidents of severe sleep (or falling asleep) while operating. Increased observation of fatigue preceding incidents in naturalistic settings would assist understanding, and increased use of operational parameters, such as brake and accelerator use patterns, may be preferable to invasive psychomotor performance tests. The way in which fatigue influences more complex aspects of performance (e.g. increased reliance on default mental schemas) has yet to be considered, but requires that such performance effects can be operationalized for study.

What else do we need to know to improve how we manage fatigue risks?

A consideration of the findings of the studies retrieved for this report in relation to our modified fatigue-risk trajectory confirms that while work time has been well studied, there is a need to consider how work time, work quality and non-work life quality interact to influence operator fatigue. It has been established for many operators that restricted sleep and perceived fatigue results from work time demands, and that restricted sleep impedes recovery, but there is much less consideration of recovery during non-work wake time. Such recovery could be assessed by supplementing standard sleep measures with a standard measure of the need for recovery, taken just after and just before work. In addition, the fatigue assessment battery described above could be supplemented by the identification of critical fatigued operator symptoms and behaviours, and used as part of a safety risk management system to trigger countermeasures that prevent operator fatigue affecting performance. It is already possible for schedulers to predict fatigue risks from software parameters based on sleep history, time on task and time of day. However, there is little understanding of the dynamic mutual interactions between poor sleep, health and psychosocial pressures, which will lead to fatigue risks that are poorly predicted by existing software.