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A review of definitions of fatigue – And a step towards a whole definition

Ross O. Phillips *

Institute of Transport Economics (TØI), Gaustadalléen 21, NO-0349 Oslo, Norway

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ABSTRACT

Despite its importance to health and safety, there is a long history of disagreement about how to operationalize fatigue when studying exertion in human transport operators. The current article reviews existing definitions, and consequently proposes a new definition as a step forward. A consideration of everyday use of the term finds that people often seem to use fatigue to describe a sensation related to exertion. Formal definitions of fatigue can be divided into a few broad definitions, capturing experiential, physiological and performance aspects of the construct, and many narrow definitions, focusing only on one or two of these aspects. Most existing definitions do not account explicitly for the role of sleep drives and sleepiness. They also fail to account for a wide range of factors associated with transport operator exertion, such as motivation and individual, organizational and environmental factors. Each of these points is assimilated in the derivation of a new "whole definition" of fatigue, in which the experience of human operator fatigue is a central aspect of the fatigue process. Although multidimensional and diffuse, the evolved definition does not detract from the measurement and study of limited aspects of fatigue. Rather, by describing the dynamic complexity of fatigue, it may help make explicit what different studies do or do not measure or account for in terms of the different aspects of fatigue. It is claimed that the proposed definition could be used to help harmonise attempts to study and tackle fatigue in transport health and safety contexts.

1. Introduction

The need for transport managers to understand and tackle fatigue for the purposes of safety is greater than ever as more demands are placed on operators in a 24-h society increasing in complexity and efficiency (Dinges, 2011; Ho et al., 2013; Lützhöft, Thorslund, Kircher, & Gillberg, 2007; Ricci, Chee, Lorandeau, & Berger, 2007; Strober & Deluca, 2013; Åkersted, 2000). Progress is hindered, however, by a long-term, unresolved lack of consensus about what fatigue is or how it should be measured (Bartley & Chute, 1947). Divergent attempts to operationalize safety-relevant fatigue mean that it is often difficult to generalize about its prevalence and risks for different types of operator. Failure by many applied transport studies to address how fatigue has been thought about and measured in relation to other studies does not help the situation. While some researchers create custom definitions for specific studies, others employ one of many validated measures originally developed for use with either clinical samples, the general population, or occupational or transport operator samples (Smith, Allen, & Wadsworth, 2006; Åhsberg, 2000; Matthews, Desmond, Neubauer, & Hancock, 2012). Other researchers

* Tel.: +47 47 68 33 81.
E-mail address: rph@toi.no

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let operators define fatigue for themselves (Hanowski, Hickman, Blanco, & Fitch, 2011; Williamson & Friswell, 2013), even though people seem to have trouble distinguishing fatigue from other subjective concepts with which it co-occurs, such as stress (Tepas & Price, 2000), anxiety (Lal & Craig, 2001), burnout (Huibers et al., 2003) or boredom (Scerbo, 2000).

Greater explicitness and convergence on operationalization of fatigue would lead to greater consistency of measurement, improve our ability to compare different findings, and help increase the priority of fatigue as a causal factor in relation to those causes that are more easily measured (Brown, 1995). It would also lead to more effective attempts at fatigue management, and consolidate the concept as one that is meaningful and useful (Phillips & Sagberg, 2010; Åhsberg, 1998; Stokes & Kite, 2000). The current article argues that the numerous attempts at definition in the relevant literature each have something to contribute to fatigue as an overarching, diffuse and multidimensional concept. However, due to the particular interests of researchers and the need to operationalize fatigue for specific types of study, most definitions to date may have been narrow, each effectively defining and measuring a different part of the same fatigue "elephant" (Hancock, Desmond, & Matthews, 2012). The article goes on to claim that by delimiting the origins, state and consequences of fatigue, a "whole" definition would help make explicit for different transport researchers, aspects of fatigue that different studies *do not* measure, as well as those that they do measure. As a starting point for debate, the article then goes on to propose such a definition.

2. Definitions of fatigue

2.1. Fatigue in everyday use

When researchers survey or talk to people about a concept in order to measure it, they often aim to optimise the face validity of their research by using an operational definition that reflects everyday usage (Gravetter & Forzano, 2012). According to English dictionaries, fatigue in humans is "extreme tiredness arising from mental or physical effort" (Oxford Dictionaries, 2013). A comparison with definitions for tiredness ("a need for sleep or rest") and sleepiness ("the state of being sleepy") shows that fatigue is unique in the way it is ascribed a cause, namely exertion (Oxford Dictionaries, 2013). Furthermore, while sleep is presumably the main way to recover from sleepiness (temporary circadian effects notwithstanding), it is not clear from the dictionary definition whether sleep or rest is required to recover from fatigue. We might also add that according to dictionary definitions, sleepiness may or may not occur in association with fatigue (Apostolopoulos, Sõnmez, Shattell, & Belzer, 2010).

It is important to question the assumption that dictionary definitions actually reflect everyday usage, which often sees unclear use of terms like sleepiness, tiredness and fatigue. However, popular use of the word in everyday language in phrases like "metal fatigue", "adrenal fatigue" or "battle fatigue" do seem to reflect dictionary definitions in that someone or something is "tired" to the extreme specifically because of some overuse, overexposure or exertion. Capturing this would thus seem to be important for the face validity of a whole definition of fatigue.

2.2. Fatigue as an experience

Several definitions in the research literature are closely related to dictionary definitions in that fatigue is described as a subjective feeling, experience, sense or awareness that is akin to tiredness (Table 1).

However, there are limitations to definitions of fatigue that are exclusively experiential. Firstly, they may fail to capture important fatigue effects, since feeling tired may be a late stage in a process in which unwanted effects have already invaded performance (Hockey, 2013, p. 13). A second problem is that they do not meet Soames-Job and Dalziel (2000)'s criteria for a robust definition of fatigue i.e. one that describes the origins, state and consequences of fatigue. People experiencing fatigue are adept at compensating in order to conserve performance if they are motivated to do so, even though this may come at a cost to themselves in terms of increased effort and exhaustion (Hockey, 2010). If we measure the subjective experience of fatigue, we may find that motivated people experience more fatigue than non-motivated people do, but we will not fully understand why unless we also measure their respective performance. This implies that it is necessary to expand the concept of fatigue beyond mere experience in order to understand the dynamic role of *exertion* in fatigue. A third limitation with existing experiential definitions, arising from our discussion of face validity, is that they often do not actually relate human fatigue directly to exertion, but rather to perceived or actual resource deficiency (e.g. Brown's and Shen et al.'s definitions).

A further point about experiential definitions is that they are associated with attempts to reserve the term "fatigue" for extreme tiredness caused by mental activity, and "impairment" for that caused by physical activity (Brown, 2000). One may question the usefulness of this distinction given that (i) many jobs in the transport sector and elsewhere include a mixture of physical and mental tasks that together result in a merged, general feeling of fatigue, and (ii) mental tiredness often has a somatic basis (Domasio, 1994). In addition, authors have recently pointed to the possibility of a common physiological basis for mental and physical fatigue: "as the muscle is the organ of physical action, so the brain is the organ of cognitive action and each [depends on limited energy stores and] similar response strategies" (Hancock et al., 2012).

It was pointed out long ago that the experience of fatigue is central to everyone's understanding of the concept (Bartley & Chute, 1947), and while the links to performance are far from straightforward, few would argue that the experience of fatigue is a useful indicator of health and safety performance in the short or long term. On the other hand there is no clear