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Factors contributing to the risk of airline pilot fatigue

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ABSTRACT

Fatigue is important in the aviation field because it affects many people's safety. The purpose of this study is to identify factors that affect airline pilot fatigue. This study proposes a fatigue model for airline pilots. Fatigue is classified into physical decline, mental decline, and rest defects. Based on 929 responses from pilots, this study verifies that pilot fatigue is affected by seven independent variables – flight direction, crew scheduling, partnership, aircraft environment, job assignment, ethnic difference, and hotel environment. Results show these factors affect physical fatigue, mental decline, and rest defects. These findings can contribute to reducing pilot fatigue, which is important in aviation in terms of physical fatigue, mental decline, and rest defects.

1. Introduction

Fatigue is a common sensation that is caused by a variety of activities associated with daily life (Curnow, 2002). Reports suggest that some 20% of the total working population is fatigued (Pawlikowska et al., 1994), and about 10% of men and 15% of women claim to be very tired or exhausted (Blackwell, 2010). When a driver is fatigued and/or stressed, the potential for a fatal accident increases because the driver fails to gather essential traffic environment information, which leads to poor decisions in traffic, a reduction in driving skill, and poor vehicle positioning on the road (I. D. Brown, 1993). The aviation industry is likewise affected by fatigue. One of the most frequently cited performance impairments is fatigue, and this has been a primary concern for the National Transportation Safety Board (NTSB) for over 40 years (FAA, 2012). More than 70% of aviation accidents can be attributed to human factors, which are recognized as one of the key determinants for managing and improving flight safety (Rudari et al., 2016; Yen et al., 2009).

In aviation workplaces, there are many factors that may result in fatigue, including social and family factors, and, in the case of transmeridian airline pilots, time zone changes (Caldwell, 2004). In view of the fact that sleep and circadian processes interact to influence sleep propensity, waking alertness, and performance, it is essential to accurately quantify the impact of these factors (Dongen and Dinges, 2000). Prolonged periods of working and displaced work schedules result in both subjective and physiological fatigue, cognitive performance decrements and errors, and safety risks (Mallis et al., 2004).

Pilots who flied regularly into their discretion hours had lower physical and psychological health, overall fatigue scores, and poorer self-rated general health. Seventy-five percent of 162 pilots reported severe fatigue (Jackson and Earl, 2006). A current study shows that the prevalence of sleep complaints was 34.9%, daytime sleepiness 59.3% and fatigue 90.6% (Reis et al., 2016).

Sleep is a major factor that determines fatigue. However, current technological advancements and the global economy require optimal human functioning 24 h a day, seven days a week. Throughout industrialized countries, a growing number of sectors (e.g. businesses, transportation, energy, public health, safety, and maintenance) now operate 24/7. For the millions of people working in these environments, the timing of sleep often deviates from its biologically natural nocturnal placement (Mallis et al., 2004). Most scientists believe that pilots should have the opportunity for 8 h of sleep in a rest period (NASA, 1999). However in many places, the current regulations do not ensure the opportunity for this amount of sleep. Pilots have filed reports with the National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System that also document the effects that work patterns have on pilot fatigue and performance (NASA, 1999). There is a frequent demand for airline pilots to maintain appropriate levels of alertness and performance when sleep is either reduced or misaligned relative to the endogenous circadian nadir for alertness (Sallinen et al., 2017).

There are active movements to manage the fatigue of airline pilots worldwide. The International Civil Aviation Organization (ICAO) published the second edition of its fatigue risk management manual, entitled *The Manual for the Oversight of Fatigue Management Approaches* (ICAO, 2016), and the American government published its rules in

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Flight and Duty Limitations and Rest Requirements: Flight Crew Members (FAR 117) (FAA, 2014). The EU 83/2014 Law was addressed pilot and cabin crew fatigue-related regulations; it was published in 2014 and implemented from February 18, 2016 (European_Commission, 2014). There are many task forces working to reduce pilot fatigue in many countries and organizations, including ICAO, the International Air Transport Association (IATA), and the International Federation of Air Line Pilots' Associations (IFALPA).

Analyses on fatigue causal factors have focused on medical and health factors rather than on cultural, humanities, and social systematic factors. Accordingly, this research focuses on determining fatigue causal factors from all perspectives.

2. Literature review

2.1. General theories on fatigue

Fatigue, its causes, mechanisms, and consequences have long been the topic of discourse and study. In lay terms, fatigue is readily understood as an outcome state in which one feels tired or sleepy. There is much debate between and within the many involved disciplines, but no definition has yet been agreed upon (Noy et al., 2011). Despite its importance to health and safety, there is a long history of disagreement on how to operationalize fatigue when studying exertion in human transport operators (Phillips, 2015).

Fatigue is defined as a suboptimal psychophysiological condition caused by exertion. The degree and dimension of the condition depend on the form and context of exertion. The fatigue changes strategies or resource use (Phillips, 2015). The Oxford dictionary defines fatigue as extreme tiredness resulting from mental or physical exertion or illness (Oxford, 2013). NASA defines it as feeling tired, sleepy, or exhausted (NASA, 1999).

In addition to the definitions listed in Table 1, there are two other important definitions of fatigue in the aviation field. First, ICAO defines fatigue as a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties (ICAO, 2010). Second, fatigue involves psychological and physical tiredness with a range of symptoms such as tired eyes, yawning and increased blink rate. Fatigue has major implications for workplace and transportation safety, and it is a negative symptom of many acute and chronic illnesses (Tran et al., 2010) (see Table 2).

2.2. Fatigue types

2.2.1. Physical fatigue

Fatigue is generally classified as either physical or mental. Sufficient rest is the only remedy for fatigue (Dinges et al., 1996) and an insufficient rest period does not enable a fatigued individual to recover from that fatigue (Dawson and McCulloch, 2005). From the viewpoint of airline pilots, fatigue is related to crew schedules and rest periods.

Physical fatigue is caused by more than just one muscle being unable to perform. During physical activity, the onset of muscle fatigue is gradual and depends upon an individual's level of physical fitness, and other factors, including sleep deprivation and overall level of healthiness. Proper rest can reverse this process. A lack of energy in the muscles causes the physical fatigue by reducing the drive originating from the central nervous system or by decreasing the efficiency of the neuromuscular junction (Wesensten et al., 2004).

2.2.2. Mental fatigue

Mental fatigue is a psychobiological state caused by prolonged periods of demanding cognitive activity and characterized by subjective feelings of tiredness and lack of energy (Marcora et al., 2008). It is measured as a reduction in the ability to perform mental tasks. Sleep disruptions, which may induce mental fatigue, decrease cognitive functioning and psychomotor vigilance task (PVT) performance. It is remarkably difficult to understand mental fatigue and the cognitive processes underlying its behavioral manifestations (Curnow, 2002).

Mental fatigue is also defined as a temporary inability to maintain optimal cognitive performance. During any cognitive activity, the symptom of mental fatigue is gradual and depends on an individual's cognitive ability, and also upon other factors, including sleep deprivation and overall health. Decreased physical performance has also been

Table 1
Definitions of fatigue.

Category	Definition	Source
Subjective	subjectively experienced disinclination to continue performing the task because of perceived reductions in efficiency	(Brown, 1995; Soames-Job and Dalziel, 2000)
	an overwhelming sense of tiredness, lack of energy and a feeling of exhaustion, associated with impaired physical and/or cognitive functioning	(Shen et al., 2006)
	Awareness of a decreased capacity for physical and/or mental activity due to imbalance in the availability, use and/or restoration of resources needed to perform an activity	(Strober and Deluca, 2013)
Physiological	the state of an organism's muscles, viscera, or CNS, in which prior physical activity and/or mental processing, in the absence of sufficient rest, results in insufficient cellular capacity or system-wide energy to maintain the original level of activity and/or processing by using normal resources	(Soames-Job and Dalziel, 2000)
	weakness … from repeated exertion or a decreased response of cells, tissues, or organs after excessive stimulation, stress or activity	(Hirshkowitz, 2013)
	a change in psychophysiological state due to sustained performance [of one or more tasks at work]	(Linden et al., 2003)
physiological/performance	reduced force production, loss of exercise capacity, increased sense of effort or perception of force	(Strober and Deluca, 2013)
	the inability to function at the desired level due to incomplete recovery from demands of prior work and other waking activities	(Gander et al., 2011)
Performance	measurable decrements in performance of an activity caused by extended time performing it	(Bartlett, 1953)
	a diminished capacity for work and possibly decrements in attention, perception, decision making and skill performance	(Cercarelli and Ryan, 1996)
	decrements in performance on tasks requiring alertness and the manipulation and retrieval of information stored in the memory	(Gawron et al., 2000)
Multiple	three aspects to fatigue: physiological, objective (work decrement), and subjective fatigue	(Bills, 1934)
	an individual's multi-dimensional physiological-cognitive state associated with stimulus repetition which results in a prolonged residence beyond a zone of performance comfort	(Hancock and Verwey, 1997)
	a psychophysiological state that occurs when a person is driving and feeling tired or drowsy, to the extent that they have reduced capacity to function, resulting in performance decrements and negative emotions and boredom as they attempt to stay awake during the task	(Craig et al., 2011)