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Predicting pilot's sleep during layovers using their own behaviour or data from colleagues: Implications for biomathematical models

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ABSTRACT

Biomathematical models are used in industry to estimate how much sleep people are likely to get on different work patterns, and how efficient and safe people are likely to be at work. Since there is evidence to suggest that individuals respond differently to sleep loss, there has been a recent focus on trying to account for individual differences. One possible approach could use past behaviour to predict future responses to similar working conditions. This study investigated the predictive value of sleep timing and duration data for a particular individual on a break between shifts relative to data from their colleagues. Sleep diaries and wrist actigraphy were collected from 306 international long-haul pilots for at least 2-weeks. Fifty layovers, equivalent in origin and destination, length and timing, were completed twice by individual pilots. Matched layovers done by other pilots ($n = 2311$) were also identified. Layover periods were analysed for minute-by-minute correspondence of sleep or wake (yes/no), and total sleep time (TST). Using an individual's own data improved concordance by approximately 5% relative to using a large sample of different pilots, and by 10% relative to using a random sample of 50 different pilots. Using an individual's own TST to predict their TST on an equivalent layover yielded an r value of 0.83, compared to $r = 0.78$ when data from a colleague was used, and $r = 0.73$ using different pilots in a random sample of equivalent size. The mean difference in TST using pilots' own data was <20 min, compared to <40 min using data from colleagues. However, the confidence limits on these differences were large (up to 8 h). Results suggest that for international pilots on specific layover patterns, knowing the past behaviour of an individual may only represent a modest improvement over knowing the length and timing of a colleague's sleep, when it comes to predicting their sleep behaviour.

1. Introduction

1.1. Overview

Biomathematical models are increasingly used in industry to predict a level of fatigue, alertness, performance or risk associated with a particular roster, and can therefore be used as part of safety-related decision making in a fatigue-management context (reviewed in Dawson et al., 2011). Given the current focus on individual differences in response to sleep loss (Van Dongen et al., 2003a,b) as well as differences in sleep patterns and strategies (Kandelaars et al., 2006; Roach et al., 2002), it has been suggested that biomathematical models should be developed that can capture, or take into account individual differences (Van Dongen et al., 2003a; Van Dongen and Balkin, 2004). Many available biomathematical models estimate sleep/wake patterns given different rosters, and then use these estimates to make inferences about fatigue, alertness or performance (Dawson et al., 2011). Therefore, a possible starting point for the inclusion of individual differences could involve capturing individual sleep/wake data in order to develop individualised sleep/wake predictions. However, in the workplace, there are many factors that may impact on sleep, including social and family factors, and in the case of transmeridian airline pilots, time zone changes (Kandelaars et al., 2006; Roach et al., 2002). As an initial step in investigating this, the aim of the current study was to examine whether information on the sleep/wake behaviour of a pilot during a single layover period would be more predictive of their subsequent behaviour during a similar layover, than information from their colleagues.

1.2. Biomathematical models and sleep neurobiology

There are two major approaches to biomathematical models, referred to as one- or two-step models (Darwent et al., 2010). For

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